An Analysis of Eye Movements during Browsing Multiple Search Results Pages

Yuko Matsuda [1], Hidetake Uwano [1], Masao Ohira [1], Ken-ichi Matsumoto [1]
[1] Graduate School of Information Science, Nara Institute of Science and Technology
8916-5,Takayama, Ikoma, Nara, JAPAN
{ yuko-m, hideta-u, masao, matumoto }@is.nasit.jp

Abstract. In general, most search engines display a certain number of search results on a search results page at one time, separating the entire search results into multiple search results pages. Therefore, lower ranked results (e.g., 11th-ranked result) may be displayed on the top area of the next (second) page and might be more likely to be browsed by users, rather than results displayed on the bottom of the previous (first) results page. To better understand users' activities in web search, it is necessary to analyze the effect of display positions of search results while browsing multiple search results pages. In this paper, we present the results of our analysis of users' eye movements. We have conducted an experiment to measure eye movements during web search and analyzed how long users spend to view each search result. From the analysis results, we have found that search results displayed on the top of the latter page were viewed for a longer time than those displayed on the bottom of the former page.

Keywords: Eye tracking, Web search, User activity, Search results page

1 Introduction

Web search engines are designed to search for useful information on the World Wide Web. Each search engine uses different algorithms to rank web pages, but their interfaces are similar to each other; that is, users type some words into a query box and receive a rank-ordered list of web pages that is relevant to the words. Better understanding user activities would provide us insights into improvements of interactions during web search and the usefulness of the interfaces for search engines.

Up to now, many studies have reported analysis results of users' web search activities based on eye tracking, which is well-known as an effective means to understand what users are looking for during web search. One of the studies [2] showed that users tend to spend most time browsing a few, top results on a search results page while they spend less time browsing the bottom of the page. The study concluded users strongly rely on the correctness of a ranked order presented by a search engine.

As with the above study, most previous studies also have focused on user interactions on the first page of the entire search results. However, many users browse multiple results pages in using a search engine [3]. Neglecting this fact might lead to an incomplete understanding of user activities in web search. When a number of

search results exist, most search engines separate the entire results into multiple search results pages and display one results page at a time (e.g., 10 search results on a page. The numbers of results displayed on one page depends on user preference.) In this case, lower ranked results (e.g., 11th result) may be displayed on the top area of the next page and might be more likely to be browsed by users, rather than results displayed on the bottom of the previous (first) results page.

Therefore, it is important to analyze and understand user activities in searching multiple search results pages in order to provide users with a means or new interface that enables them to more naturally browse search results in a ranked order recommended by a search engine.

In this paper, we have conducted an experiment to observe effects of search result positions on user activities in web search. We measured eye movements during web search tasks and analyzed them to understand how long users spend to browse each result.

2 Related Work

There have been many studies on user activities in web search. A popular approach to analyzing user activities in web search is to use data of browsing histories or access logs [6][7][8]. Although using history data helps us understand a user's access paths or interests in a specific web page, it cannot be used for analyzing a user's attention to search results during web search and influences of displayed positions of search results on web search activities.

Another approach is to use eye tracking instruments to capture user activities based on eye movements. Cutrell, et al. [1] used eye tracking to analyze the influence of the length of a site summary (a snippet text) presented in web search results on a user's search activities. The results of their experiments indicated that a long site summary has an effect of decreasing search time and increasing a user's search correctness in informational search tasks where users are trying to find a specific web site or homepage. In contrast to informational search tasks, in navigational search tasks where users are trying to find web pages that include some kind of information, it has an effect on the increase of search time and the decrease of user's search correctness.

Guan et al. [2] also measured eye movements and then analyzed the influence of positions of target results that users are looking for. They found that users took longer to search the target results and were less successful in finding the targets when the search targets were placed in low positions on a search results page. Although the study provides useful insights into the design of a new interface for web search engines, it only focused on the first search results page. So it still fails to capture user activities in browsing multiple search results pages. Lorigo et al. [9] analyzed differences of task types in web search. They reported that users performing informational search tasks took longer to complete those tasks than navigational ones and spent more time to stay at pages linked by search results. However, the study also did not focus on time consumption for each search result and user interactions with multiple search results pages.

In this paper, using multiple search results pages and two types of tasks (i.e., informational and navigational tasks), we measure and analyze users' eye movements

for each set of search results to provide a new understanding of user activities in web search.

3 Experiment

3.1 Overview

To observe how users look at each set of search results during browsing multiple search results pages, we analyzed total time of eye movements on each search result.

In the experiment, participants were asked to search for appropriate web pages (target results) from the search results pages of Google to find particular information with predetermined words. The information and words were specified by experimenters. The experimenters measured eye movements of the participants during the tasks. To analyze user's eye movements helps us understand how users browse search results. In the experiment, WebTracer [10] was used as an eye tracking system. WebTracer allows us to collect and analyze data of a user's eye movements and operations (e.g., mouse and keyboard operations) during web search. After the tasks, participants answered a questionnaire about their usual search activities and were interviewed about observed interactions in the tasks. Participants of the experiment were 21 undergraduate students studying information science. All participants used web search in daily life and used Google as their main search engine.

3.2 Apparatus

In the experiment, the following equipment was used.

- Display: 21-inch LCD monitor (Viewable screen size: H30 x W40cm, Resolution 1,024 x 768 pixels)
- Distance from subject's face to display: approx. 50cm
- Device for measurement of sight-line: NAC, EMR-NC (View angle: 0.28 degrees, resolution on the screen: approx. 2.4mm)
- Recording and playing of sight-line data: WebTracer

3.3 Task

The tasks performed by participants were (1) to search for appropriate web pages linked by search results from search results pages, (2) to find particular information specified by the experimenters and (3) to bookmark the target pages.

The time limit of each task was ten minutes whether participants could complete the task or not. In the experiment, participants needed to use predetermined words and they were prohibited from changing search words during the tasks. Since the purpose of this experiment was to observe user's activities in using multiple web search results pages, participants were only permitted to move to web pages linked by Google's search results. The order of the tasks was counterbalanced to consider the learning effect.

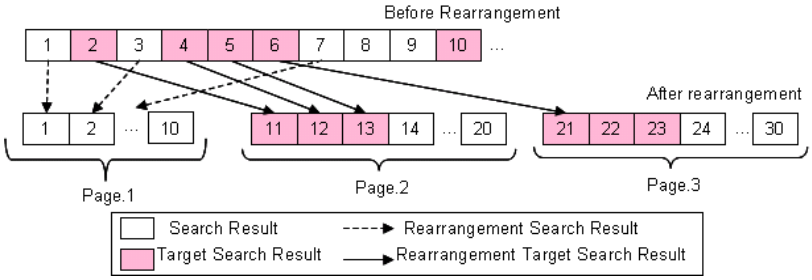

Fig. 1. Example of Rearrangement Search Results.

The tasks themselves were based on the test collection provided by NTCIR (NTCIR-4 WEB) [11][12]. In this experiment, the two types of tasks were selected as follows.

- Informational Task: required participants to find specific information (e.g., web pages including information on university entrance exams). The task was completed by finding three web pages linked by target results and bookmarking them.
- Navigational Task: required participants to find specific web pages (e.g., official web page of the university). The task was completed by finding a web page linked by a target result and bookmarking it.

  Each participant performed ten tasks (five tasks for each task type).

3.5 Design of Web Search Results Pages

To prevent the bias effect of the numbers of target results and their positions, we modified the results pages that were saved in a local computer when we searched with Google. The participants performed the search tasks with the modified search results pages.

The previous study showed users search about 2.35 pages [3]. Therefore, we prepared three search results pages and allocated target results randomly on the search results pages. Advertisements and information irrelevant for web search were removed. We used Google's default setting in which 10 search results are displayed at a time. In addition, Google's original (unmodified) search results pages were used for fourth or later search results pages. Note that each search result and display position of search results followed Google's page rank.

To prevent participants from finishing their search only on the first page, we allocated target results on the second or third page. Figure 1 is an example of a way of inserting target search results.

For the design of search results pages, we prepared four rearrangement patterns of search results (Figure 2). In the Informational Task, we displayed target results in top (I-1), middle (I-2), bottom (I-3) and even (I-4) in second and third search results page. In Navigational Tasks, we displayed target results in the top (N-1, N-3) and bottom (N-2, N-4) on the second and third search results pages. Since participants may notice the experimenters' intention (i.e., target results were displayed only after the second page), we insert a dummy task (original search results of Google) into each task.

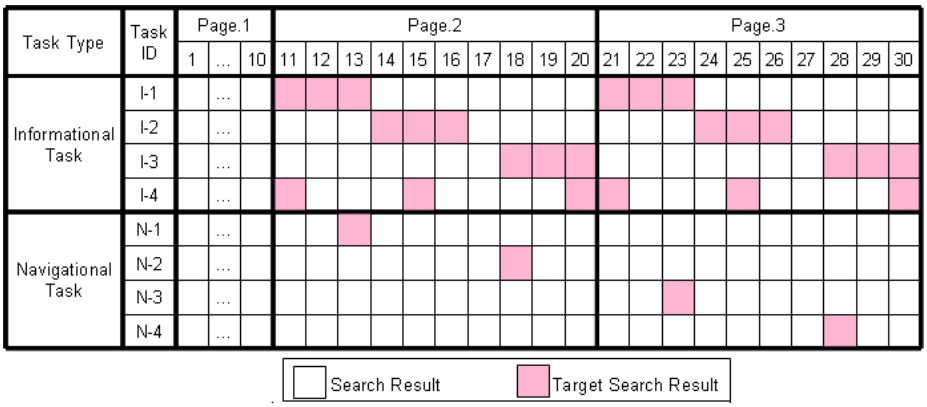

Fig. 2. Inserted Positions of Target Search Results.

3.6 Experimental Procedure

1. Explanation of the experiment and preparation: Experimenters explained the experiment and the eye tracking system to participants.
2. Configuration of the eye tracking system: We configured devices for measurement of sight line and checked sight line (calibration).
3. Task for practice: To understand the flow of the experiment, participants practiced a task. The task was an Informational Task. Original search results pages of Google were used.
4. Performing tasks: Experimenters explained each search task and participants started to search. This was repeated until all the tasks were finished.
5. Questionnaire: At the end of the experiment, participants were asked to answer a questionnaire about their daily use of web search engines.
6. Interview: Participants were also asked to answer an interview about observed characteristic activities during the tasks.

4 Results

4.1 Eye Movement

Figure 3 shows the example of eye movements gathered in the experiment. The vertical axis shows the position of search results and the horizontal axis shows the time of appeared sight line. In the Figure, horizontal line describes eye movements on search results and the circle shows user click to the search result.

The figure showed this user searched the results from top to bottom. The total time of eye movements on the clicked result was longer than other results.

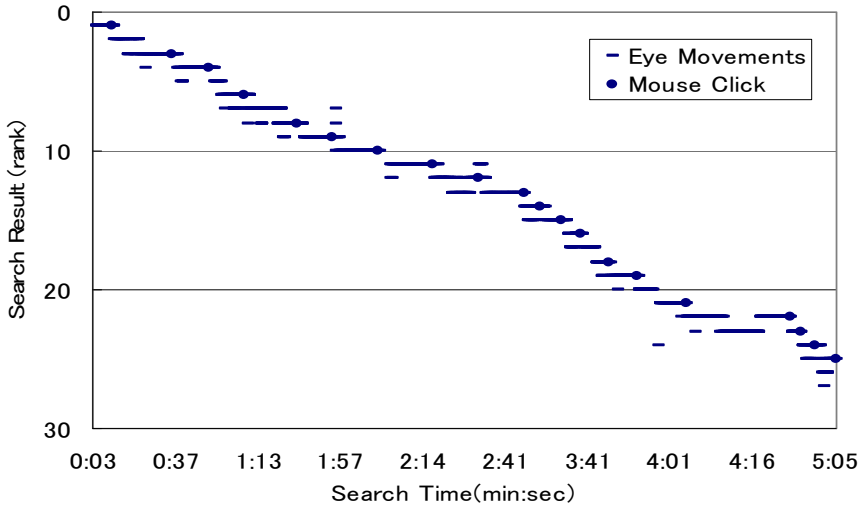

Fig. 3. Eye Movements and Clicked Search Result during the task.

Table 1. Classification of Search Completion Pages.

Group	Last Search Result	Last Search Results Page	Number of Task	
			Informational	Navigational
G0	~5	Less than 1	6	5
G1	6~15	1	18	21
G2	16~25	2	33	38
G3	26~	Over 3	27	20

4.2 Analytic Procedure

To calculate the total time of eye movements, we separated the tasks by search completion pages. The search completion page is calculated from the position of the lowest search result looked at by each subject. Table 1 shows the classification of search completion pages by group. In this paper, we would like to analyze users' activities searching multiple search results pages. Hence, we analyze the tasks which finish at the second page (G2) and after the third page (G3).

We use the length of time to analyze the eye movements. Even if a users' gaze appears at a certain search result, it does not necessarily mean that the reviewer has interest that line. Hence, we have to distinguish a focus (i.e., interest) from users' eye movements. In this paper, we defined focus as the eye remaining on a certain search result more than 100ms.

To increase correctness of the analysis, we also remove eye movements that stay a long time on a particular position. When the user reads a search result intensively, the time of eye movements to the results greatly increases. However, this increase is not the effect of display position but the effect of the content of the result itself, that is, title of the web page, snippet (description of the web page), and URL. To distinguish a user's intensive reading, the average reading time of clicked search results was adopted. Basically, users read the results before the clicking, to decide to move to the web page. Hence, it is reasonable to remove the eye movements to search results that stay more than the average time of clicked search results. In this experiment, the average time in the Informational Task was 3.18 seconds, and 2.44 seconds for the Navigational Task.

4.3 Analysis Result

Figures 4 and 5 describe the mean time of eye movements on each search results classified as G2 and G3, respectively. The vertical axis shows the mean time of eye movements and the horizontal axis shows the rank of results. In both groups, users tend to view search results longer in informational tasks than navigational tasks.

To evaluate effects of search result positions on user activities in web search, we calculated the total time of eye movements on top search results and bottom search results. Table 2 shows the average time of eye movements for the three results that were ranked high and displayed at bottom of the page (HB), and for the three results that were ranked low and displayed at top of the page (LT) in G2. Table 3 shows the average time of eye movements for the three HB results and that for the three LT results in G3. The table describes that the mean time of eye movements to LT is

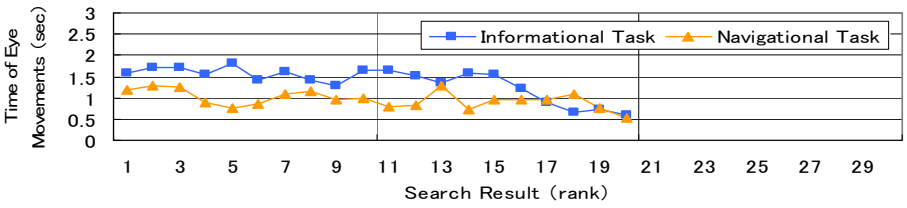

Fig. 5. Mean Time of Eye Movements on each Search Result in Informational Task (square) and Navigational Task (triangle) of G2.

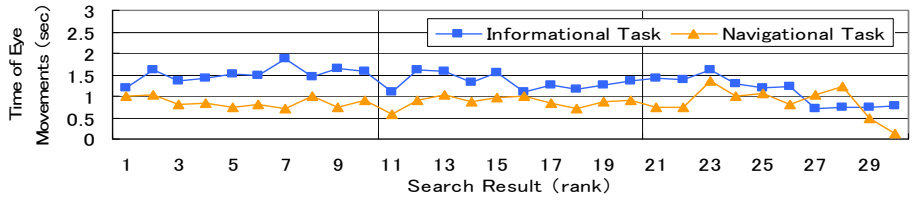

Fig. 5. Mean Time of Eye Movements on each Search Result in Informational Task (square) and Navigational Task (triangle) of G3.

Table 2. Mean Time of Eye Movements for High-Rank Results Displayed in Bottom Area 3 and Lower-Rank Results Displayed in Top Area 3 in G2.

Group	Search Results	Mean Time of Eye Movements (sec)	
		Informational	Navigational
LT_1	1~3	1.67	1.24
HB_1	8~10	1.46	1.04
LT_2	11~13	1.51	0.96
HB_2	18~20	0.66	0.79

Table 3. Mean Time of Eye Movements for High-Rank Results Displayed in Bottom Area 3 and Lower-Rank Results Displayed in Top Area 3 in G3.

Group	Search Results	Mean Time of Eye Movements (sec)	
		Informational	Navigational
LT_1	1~3	1.38	0.95
HB_1	8~10	1.56	0.88
LT_2	11~13	1.43	0.84
HB_2	18~20	1.25	0.83
LT_3	21~23	1.48	0.95
HB_3	28~30	0.75	0.61

almost the same as HB, or longer than HB in some cases (e.g. between HB_2 and LT_3 at G3). This result indicated users did not view the search results in proportion with page rank.

In particular, we focused on the top-three search results (LT) of each page (see Figures 4 and 5). In Figure 4 (eye movements of G2), the mean time of eye movements to the first result of each page (ranks 1 and 11) was shorter than the second and third results (ranks 2, 3, 12, and 13) at both task types. Also at G3 (Figure 5), eye movements to the first result of the page were shorter than the second and third search results.

5 Discussion

5.1 Effect of Task Differences

The result of the experiment describes that users tend to view search results longer in informational tasks than navigational tasks. In the Navigational task, users read the snippet of the search result, then decide to click the search result or not. On the other hand, in the Navigational Task, users read the title and URL of the result instead of the snippet to decide to click the result. Reading the title and URL of the result requires less time than reading the snippet, therefore the length of the eye movements in Informational Tasks is longer than Navigational Tasks. The result suggests that when users browse multiple web search results pages, they adopt different reading patterns for each task.

5.2 Effect of Position within a result page/screen

The result of the experiment describes that time of eye movements on LT is longer than HB. The result shows that users are impressed not only by the rank but also the position of the search results within the results page. That is, the time length of eye movements on the search results is influenced by *the position within a results page*.

The detailed analysis showed the time of eye movements on second and third results in each page are longer than the first result. This result suggests users' eye movements are attracted by the position on the screen. In the experiment, users viewed the middle area of the screen more than the top area. The second and third results are displayed on the middle of the screen when the user went to the search results page. On the other hand, the first result is displayed on the top of the screen. The first result is turned out by the scroll, hence, the user interest moved to the second/third results. This assumption was verified from interviews of the subjects.

5.3 Design Implications

Using the results of the experiment, we propose a design encouraging users to browse the search results based on the rank. To increase the time of the eye movements of the users, the results displayed on the bottom of the page should be emphasized to get more attention from the users.

In the Navigational Task, users concentrated their eye movements on the title of the web page or URL since the result page was a goal of the task. Hence, a thumbnail and/or attribute (e.g. the official page or blog) of the Web page are useful information for the users searching a specific web site.

6 Conclusion

In this paper, we experimentally analyzed the effect of the result position on the results pages. In the experiment, we measured users' eye movements during web search tasks to analyze how long users spend on each result of the results pages. As a result, we found the results displayed on the bottom of the page were viewed for a shorter time than the results displayed on the top of the next page. Also, we found the tendency that the second/third results of each page were viewed longer than the first result of the results page. As a future work, we will analyze the effect of the display position on the screen.

Acknowledgments. We would like to thank all the participants. In this paper, we used a part of the data of the NTCIR-4 WEB task that is sponsored by the National Institute of Informatics, as organizers of the NTCIR-4 WEB task project.

References

1. Cutrell, E., Guan, Z.: What Are You Looking For?: An Eye-tracking Study of Information Usage in Web Search, CHI '07: Proceedings of the SIGCHI conference on Human factors in computing systems, pp.407-416 (2007)
2. Guan, Z., Cutrell, E.: An Eye Tracking Study of the Effect of Target Rank on Web Search, CHI '07: Proceedings of the SIGCHI conference on Human factors in computing systems, pp.417-420 (2007)
3. Jansen, B.J., Spink, A., Saracevic, T.: Real life, real users, and real needs: a study and analysis of user queries on the web, Inf. Process. Manage., Vol.36, No.2, pp.207-227 (2000)
4. Broder, A.: A taxonomy of web search, SIGIR Forum, Vol.36, No.2, pp.3-10 (2002)
5. Rose, D.E., Levinson, D.: Understanding User Goals in Web Search, WWW '04: Proceedings of the 13th international conference on World Wide Web, pp.13-19 (2004)
6. Murata, T., Saito, K.: Extraction and Visualization of Web Users' Interests Using Site-Keyword Graphs, journal of Japan Society for Fuzzy Theory and Intelligent Informatics (in Japanese), Vol. 18, No.5, pp.701-715 (2006)
7. Clarke, C.L.A., Pan, B., Agichtein, E., Dumais, S., White, R.W.: The Influence of Caption Features on Clickthrough Patterns in Web Search, SIGIR '07: Proceedings of the 30th annual international ACM SIGIR conference on Research and development in information retrieval, pp.135-142 (2007)
8. Otsuka, S., Toyoda, M., Kitsuregawa, M.: A Study for Analysis of Web Access Logs with Web Communities (in Japanese), Transactions of Information Processing Society of Japan, Vol.44, No.18, pp.32-44 (2003)
9. Lorigo, L., Pan, B., Hembrooke, H., Joachims, T., Granka, L., Gay, G.: The influence of task and gender on search and evaluation behavior using Google, Inf. Process. Manage., Vol.42, No.4, pp.1123-1131 (2006)
10. Sakai, M., Nakamichi, N., Shima, K., Nakamura, M., Matsumoto, K.: WebTracer: A New Web Usability Evaluation Environment Using Gazing Point Information (in Japanese), Transactions of Information Processing Society of Japan, Vol.44, No.11, pp.2575-2586 (2003)
11. Eguchi, K., Oyama, K., Aizawa, A., Ishikawa, H.: Overview of the Informational Retrieval Task at NTCIR-4 WEB, Proceedings of the Fourth NTCIR Workshop on Research in Information Access Technologies Information Retrieval, Question Answering and Summarization (2004)
12. Oyama, K., Eguchi, K., Ishikawa, H., Aizawa, A.: Overview of the NTCIR-4 WEB Navigational Retrieval Task 1, Proceedings of the Fourth NTCIR Workshop on Research in Information Access Technologies Information Retrieval, Question Answering and Summarization (2004)