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journal or publication title	IIiX '14 Proceedings of the 5th Information Interaction in Context Symposium
page range	68-75
year	2014-08
URL	http://hdl.handle.net/2241/00123666

doi: 10.1145/2637002.2637012

How Concept Maps Change if a User Does Search or Not?

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ABSTRACT

Previous studies have shown that a concept map can capture changes in the user knowledge structure during a search. However, these studies could not exclude the possibility of the influence of instructions or time-dependent changes. In this study, we have compared differences between concept maps created before and after a search condition and a non-search condition to reveal whether these changes are due to searching.

In the experiment, participants were required to gather information on the Web in preparation for a group discussion. The participants were divided into two groups representing two tasks, convergent and divergent tasks. The convergent task required gathering web pages for a specific and detailed discussion, and the divergent task required gathering web pages for a wide-ranging discussion. Participants performed each task under search and filler conditions. In the search condition, they searched the Web. In the filler condition, they played a typing game on a PC.

We compared pre- and post-task concept maps. Analysis of the number of nodes in the concept maps indicated that changes in the search condition are significant, whereas changes in the filler condition are insignificant. The analysis of the number of nodes at each distance from the center nodes in the concept maps showed that tasks had a greater effect in the search condition than in the filler condition. Finally, we consider whether the experimental results support our hypotheses.

Categories and Subject Descriptors

H.3.3 [**Information Storage and Retrieval**]: Information Search and Retrieval—*Measurement, Performance*

Keywords

concept map, exploratory search, task models, user experiments, user studies

IIiX '14 August 26 - 29 2014, Regensburg, Germany

ACM 978-1-4503-2976-7/14/08 $15.00.
http://dx.doi.org/10.1145/2637002.2637012

1. INTRODUCTION

Searching on the World Wide Web (Web) is more than just a simple tool for information retrieval (IR). Web searches are also used for investigating, learning, and decision-making. For example, when people buy a new digital camera, they often search and browse many digital camera websites or customer reviews. During these activities, they acquire knowledge about digital cameras (i.e., functions, structure, price, design, and size). Marchionini [4] defined such searches as exploratory, and suggested that better search systems to support exploratory searching are needed. White and Roth [12] also said that there is a need to support search behavior beyond simple lookups.

In this study, we examine a method for evaluating an exploratory search system. Traditional evaluations of IR systems have centered on evaluating documents found during searches based on certain metrics, such as recall and precision. However, interest in user-centered evaluations has increased in the IR community.

Previous studies of user-centered evaluations and evaluations of exploratory search systems analyzed whether users could effectively seek information and conduct an exploratory search through interaction with the systems. Some studies have focused on what users could acquire from the information sources they found [11]. However, methods for detecting changes in user knowledge have not been established. Our focus is on evaluating the cognitive changes in the user knowledge during exploratory searches. We use a concept map to evaluate the knowledge users acquire and investigate how their knowledge structure changes as a result of searching for information on the Web.

A concept map is a graphical representation that allows people to represent their knowledge explicitly [6]. Figure 1 shows an example of a concept map about plants. The concept map consists of concept words, arrows that connect the concept words, and linking words on the arrows.

- Concept words (nodes): Nouns that represent objects or concepts, such as a car, cleaning, a dog, learning, a chair, and a birthday party. Concept words are enclosed in circles.

- Linking words (link labels): Verbs, adjectives, and conjunctions that represent the relationships among the concept words in the concept map, such as have, like, and is. Linking words are written on the arrows as labels.

- Arrows (links): Relationships among the concept words. Connected concept words and linking words make up sentences such as "Plants have flowers." In this case, the arrow is drawn from "plants" to "flowers" and labeled "have."

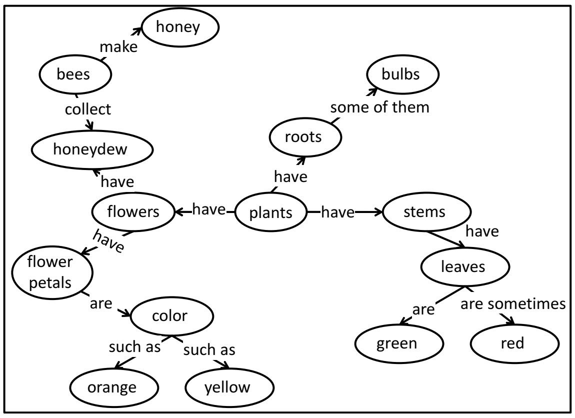


Figure 1: Example concept map about plants, (Source: Egusa et al. [3], p.176)

Concept maps have been used as measures to assess learner knowledge and understanding. Meagher [5] reported that the graph structures of concept maps become more complex from the first class in a course to the final exam. Rebich and Gautier [8] also showed that the total number of useful items on post-course concept maps increased, whereas the total number of weak items and misconceptions decreased.

In the IR community, several studies have used concept maps as a means of measuring change in an actor's knowledge. Belkin et al. [1] proposed a research design to use structural representations of data collection and users' knowledge. Pennanen and Vakkari [7] explored how a student's conceptual structure is related to search tactics and successful searching. They reported that, between the beginning and end of an overall task, different features of the student's conceptual structures were connected to a successful search in terms of the useful documents they found. Cole et al. [2] focused on how students' mental model diagrams for a topic were represented in an early exploration stage of an information-seeking process. They suggested a 12-category classification schema for the mental models. Zhang [13, 14] focused on how users' mental models for IR systems affect their information seeking behaviors. Zhang measured mental models by asking users to draw diagrams on images of IR systems.

Egusa et al. [3] investigated how a user's concept map differs before and after a search and how the differences between the topics, scenarios, and browser types influence the user's concept map. A comparative analysis of concept maps between pre-search and post-search maps indicated that users significantly changed their knowledge structures for a topic through an exploratory search. Saito et al. [9, 10] also confirmed the effects of scenarios on their search activities and knowledge structures. In their experiment, participants were required to gather information on the Web in preparation for a regular magazine feature. Participants were divided into two scenario groups, divergent and convergent. The results showed the differences between the two scenarios. In the divergent scenario, the nodes that were near the center node increased, whereas the nodes that were far from the center node decreased before and after search. Conversely, the opposite pattern was found in the convergent scenario. These results indicate that the participants in the divergent scenario changed their knowledge widely, whereas the participants in the convergent scenario changed their knowledge deeply.

Previous studies show that the concept map can capture changes in the user knowledge structure during a search. However, previous studies [3, 9, 10] have only analyzed the changes of concept maps before and after searching. Therefore, these studies could not exclude the possibility of the influence of instructions or time-dependent changes. To reveal whether these changes are due to searching, we have compared the differences between concept maps created before and after a task for two conditions, search and non-search.

2. METHODS

2.1 Experimental Design

In the experiment, we focused on the influences of search (performing search or not) and tasks (convergent and divergent). The participants were assigned to a factorial experiment that included two conditions and two topics with within-subjects factors and two tasks with between-subjects factors. The two within-subject factors were counter-balanced.

2.2 Participants

Thirty-five undergraduate students aged 19-24 participated in this study (18 male and 17 female). The participants were recruited from various departments at universities in the Tokyo area. They were divided into two task groups. Their ages, genders, and majors of participants in each group were balanced.

2.3 Tasks

The participants were instructed to assume the role of a university student and gather information on the Web in preparation for a class discussion on two topics, i.e., environmental and educational issues.

There were two tasks: convergent and divergent tasks. In the convergent task, participants were required to gather pages for a specific and detailed discussion. In the divergent task, participants were required to gather web pages for a wide-ranging discussion.

2.4 Conditions

There were two conditions, a search condition and a filler condition. In the search condition, the participants searched the Web, whereas in the filler condition, they were instructed to play a typing game on a PC.

We prepared instructions for each task for the two topics and two conditions. The instruction sets for the environmental issues topic using the convergent task with the search condition and the educational issues topic using the divergent task with the filler condition are shown in Appendices A and B, respectively.

2.5 Procedures

The participants answered a questionnaire about their experience using web search engines and the Internet. They were given instructions on creating concept maps and were given time for practice. They then received their task instructions and drew a concept map for the assigned topic (10-minute time limit). A blank sheet of paper with a single center node for the topic, i.e., either environmental or educational issues, was provided.

After drawing the concept map, the participants conducted a task in the search condition or the filler condition for 15 minutes. After completing each task, the participants were required to draw another concept map about the assigned topic and to answer questions about their prior knowledge of the topic, their interest in the topic, and the difficulty of the topic. In addition, they were asked to provide comments regarding the task. Only the participants who performed the task in the search condition were required to answer questions about the difficulty of gathering information and satisfaction with the information gathering results. They then performed the other task for the other topic from the instruction stage to answering the questionnaire.

Then, the participants answered questions comparing the two tasks and the changes in their knowledge after completing the task.

In the final session, the participants were asked to check whether the same concept could be found on both concept maps. If such corresponding concepts were found, they were assigned the same number. The participants were then asked to comment on how they felt about the changes between the two concept maps, i.e., before and after the task.

2.6 Equipment

The participants used a laptop PC with Windows 7, Internet Explorer, and "Typing of Haniwa," which is a typing practice game. Google, Yahoo! Japan, Bing, Infoseek, and the Japanese search engine "goo" were bookmarked on the browser as the general search engines. The participants' search behaviors while using the browser were recorded as screen capture videos using *HyperCam*.

3. ANALYSIS METHODS

We compared two concept maps for each task, a pre-task concept map drawn by a participant before conducting a task and the corresponding post-task concept map, to examine whether the participant's knowledge representations of the topic changed.

Figure 2 shows an example of the pre- and post-task concept maps. The participants drew the concept maps manually during the experiments.

We counted the elements of a graph of a concept map and analyzed the change in the elements between pre- and post-task concept maps, i.e., how the participants changed their internal concepts for each topic.

3.1 Numbers of Common, Lost, and New Nodes

Figure 2 shows concept maps drawn by a participant for the educational issues topic in the convergent task. The gray node is the center node. The nodes enclosed in dotted lines with the same number indicate that the participant marked these nodes as having the same meaning in the final session.

We defined three types of changes between participant's pre- and post-task concept maps [9]. The nodes that participants identified as having the same meaning in the pre- and post-task maps and the center nodes were defined as common nodes. Nodes existing only in the pre-task map were defined as lost nodes, whereas nodes first appearing in the post-task map were defined as new nodes. We then analyzed the number of common, new, and lost nodes.

3.2 Number of Nodes at Each Distance from the Center Node

We examined the differences in the position of each node in the map between tasks and conditions.

To analyze differences in the position of each node, we defined the distance of each node from the center node [9]. The distance of each node is measured by the number of arrows from the center. Nodes that were linked to more than two nodes and had more than two distances were counted at each distance. We counted the number of nodes at each distance from the center node. Nodes at distance 5 or greater were considered to be in the same category. Moreover, to clarify the differences between tasks and conditions, we calculated the amount of change for each distance from the pre- to post-task maps by subtracting the number of nodes at each distance in the pre-task map from those in the post-task map. If the number of nodes in the post-task map at distance n was greater than that in the pre-task map, the amount of change at distance n would be positive.

3.3 Hypotheses

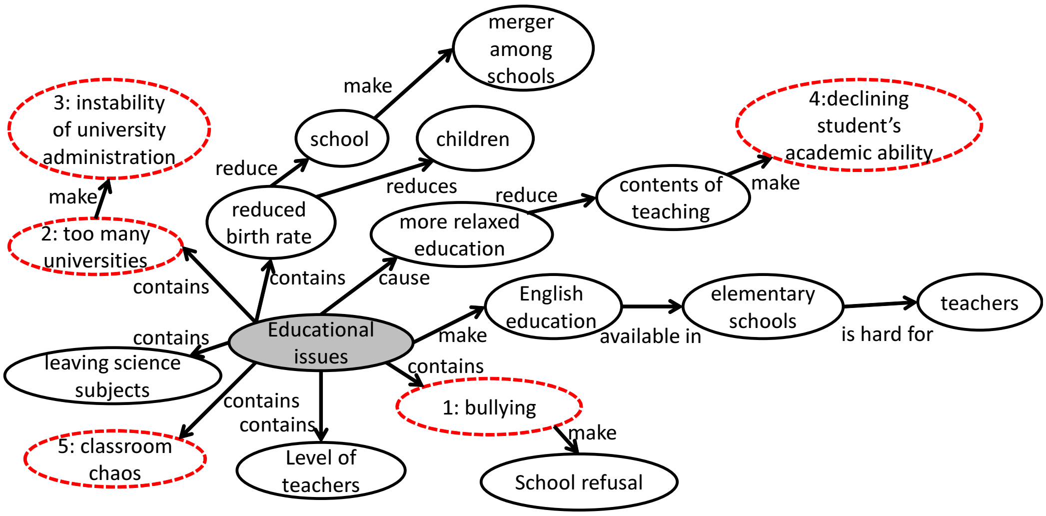
We considered the following hypotheses at the beginning of the experiment. These are based on the results of previous studies [3, 10, 9]

- Hypothesis 1: A participant conducting the search condition task browses various web pages and acquires new information; thus, the concept maps drawn by the participants in the search condition task would change dynamically between pre- and post-tasks. Therefore, the number of lost and new nodes in the search condition task would be greater than that of lost and new nodes in the filler condition task.

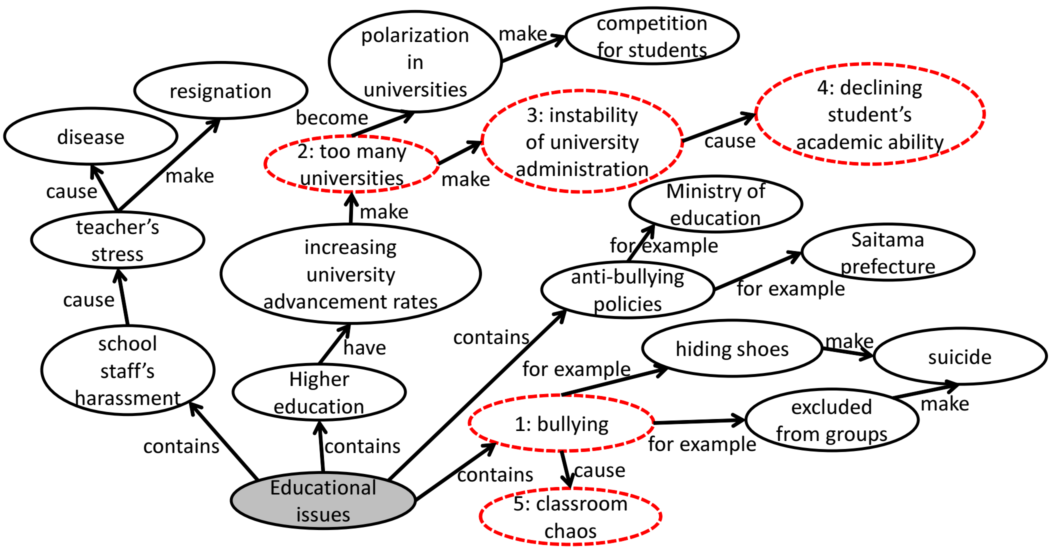
- Hypothesis 2: A participant conducting the filler task does not browse any web pages or acquire any information; thus, the concept maps drawn by participants in the filler task would not change between pre- and post-tasks. Therefore, the number of common nodes in the filler condition task would be greater than in the search condition task.

- Hypothesis 3: For the same reason as Hypothesis 1, the concept maps drawn by participants performing the convergent task would differ from those performing the divergent task. More concretely, in the divergent task, nodes placed near the center would increase and those placed far from the center would decrease from pre-task to post-task concept maps. Conversely, in the convergent task, nodes placed near the center would decrease and those placed far from the center would increase from pre-task to post-task concept maps.

- Hypothesis 4: For the same reason as Hypothesis 2, we predict that there will be no significant differences between the concept maps drawn by participants performing the convergent task in the filler condition and those performing the divergent task in the filler condition.



(a) Pre-task concept map



(b) Post-task concept map

Figure 2: Concept maps drawn by a participant for the educational issues topic in the divergent task. (The authors have translated the original descriptions from Japanese.) The original maps were drawn in pencil on paper (257 mm × 364 mm)

4. ANALYSIS RESULTS

In the following analysis, we excluded one participant's data because most nodes in the concept maps did not have links; thus, we could not obtain a structure from the concept maps.

4.1 Number of Common, Lost, and New Nodes

Table 1 lists the mean, median, standard deviation, minimum, first quartile, third quartile, and maximum of the numbers of common, lost, and new nodes in each task for the two conditions. Figure 3 shows the mean number of these nodes.

We conducted a 2-way mixed analysis of variance (ANOVA) with the condition as a within-subject factor and the task as a between-subjects factor for each type of change.

The number of lost and new nodes in the search condition were slightly greater than in the filler condition (lost: $F(1,32)=3.86$, $p<.10$; new: $F(1,32)=3.80$, $p<.10$). The number of common nodes in the search condition was less than in the filler condition ($F(1,32)=5.22$, $p<.05$).

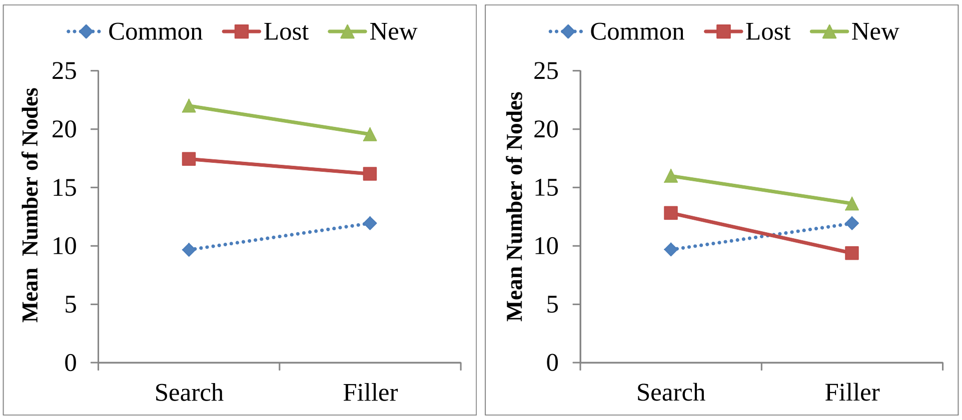
In total, in the search task, there were few common nodes and a relatively large number of lost and new nodes. These results suggest that the concept maps changed significantly after the web searches were performed by the participants.

4.2 Number of Nodes at Each Distance from the Center Node

Table 2 lists the mean, median, standard deviation, minimum, first quartile, third quartile, and maximum of the amount of change at distances 1, 2, 3, 4, and 5 or greater for

Table 1: Number of common, lost, and new nodes in each task for the two conditions

Task	Type of change	N	Mean.	Median	SD	Min.	1st Qu.	3rd Qu.	Max.
Convergent:									
Search	Common	18	9.7	10.0	5.2	1	6.3	12.8	18
	Lost	18	17.4	12.5	15.1	1	11.0	15.8	51
	New	18	22.0	16.0	19.9	3	9.8	21.8	67
Filler	Common	18	11.9	11.5	5.9	4	8.0	14.0	27
	Lost	18	16.2	12.0	16.1	0	8.0	18.0	55
	New	18	19.6	14.0	17.4	1	10.8	21.8	70
Divergent:									
Search	Common	16	9.7	10.0	4.0	3	6.8	11.5	17
	Lost	16	12.8	11.5	8.8	1	6.8	14.3	30
	New	16	16.0	14.0	7.1	7	11.0	19.0	31
Filler	Common	16	11.9	11.5	6.1	2	7.8	16.3	24
	Lost	16	9.4	9.5	7.0	1	3.8	12.8	24
	New	16	13.6	14.0	6.7	2	8.8	18.0	27



(a) Convergent (b) Divergent

Figure 3: Mean number of common, lost, and new nodes in each task for two conditions

the two conditions for each task. Figure 4 shows the mean amount of these changes.

We conducted a 2-way mixed ANOVA with the condition as a within-subject factor and the task as a between-subjects factor for each amount of change at a particular distance.

For the amount of change at distance 1, the task showed significant effects of the task ($F(1,67)=6.96$, $p<.05$) and there was a significant interaction between the task and condition ($F(1,67)=6.36$, $p<.05$). In the search condition, the amount of change at distance 1 for the divergent task was more than that in the convergent condition ($F(1,32)=15.9$, $p<.01$). The amount of change at distance 1 for the convergent task in the search condition was slightly less than in the filler condition ($F(1,32)=3.74$, $p<.10$).

The amount of change at distance 2 in the divergent task was more than those that in the convergent task ($F(1,67)=6.77$, $p<.05$).

For the amount of change at distance 4, there was also a significant interaction between the task and condition ($F(1,67) = 4.22, p < .05$). In the search condition, the amount of change at distance 4 for the divergent task was less than that in the convergent task ($F(1,32)=6.73$, $p<.05$). The amount of change at distance 4 for the convergent task in the search condition was greater than that in the filler condition ($F(1,32) = 4.57, p < .05$).

5. DISCUSSION

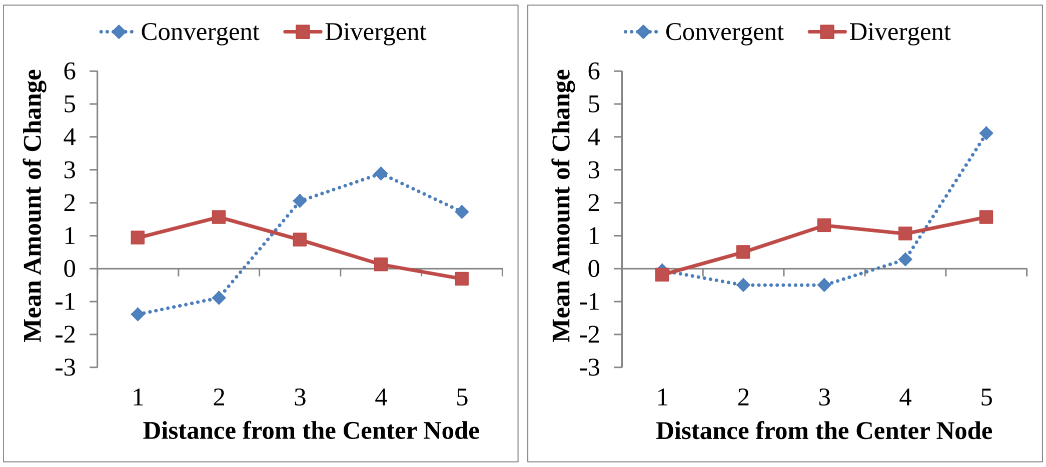
The authors examined and compared differences between concept maps created before and after conducting a search or a filler condition for two tasks.

Analysis shows that the number of new and lost nodes in the search condition was greater than the number of new and lost nodes in the filler condition, and the number of common nodes in the filler condition was greater than in the search condition. These results indicate that the changes in the search task are significant, whereas changes in the filler task are insignificant. This clearly supports Hypotheses 1 and 2.

The analysis of the number of nodes at each distance from the center nodes in the concept maps shows that the amount of change at distances 1 and 2 in the search condition for the divergent task was greater than that for the convergent task, and the amount of change at distance 4 for the convergent task was greater than that for the divergent task. In the filler condition, the amount of change only at distance 2 for the divergent task was greater than that for the convergent task. These results indicate that the tasks had a greater effect in the search condition than in the filler condition. In the search condition, the changes in the concept maps were dependent on each task. The number of nodes in the concept maps from the post-task divergent task increased at distances near the center node, whereas the number of

Table 2: Amount of change: differences from pre- to post-task in the number of nodes at each distance

Task	Distance	N	Mean.	Median	SD	Min.	1st Qu.	3rd Qu.	Max.
Convergent:									
Search	1	18	-1.4	-1.5	1.9	-5	-2.0	0.0	1
	2	18	-0.9	-1.0	2.9	-6	-3.0	1.8	5
	3	18	2.1	1.5	4.3	-5	-1.0	5.5	10
	4	18	2.9	2.0	3.8	-2	1.0	3.8	12
	5-	18	1.7	0.5	3.6	-2	0.0	2.0	13
Filler	1	18	-0.1	0.0	2.2	-3	-1.8	1.0	6
	2	18	-0.5	-1.0	4.4	-9	-1.8	1.0	12
	3	18	-0.5	1.0	5.9	-20	-1.8	2.8	7
	4	18	0.3	0.0	2.7	-6	-0.8	1.0	6
	5-	18	4.1	0.0	11.9	-10	0.0	5.8	48
Divergent:									
Search	1	16	0.9	1.0	1.6	-3	0.0	2.0	4
	2	16	1.6	1.0	2.7	-2	-1.0	4.0	6
	3	16	0.9	1.0	3.3	-6	-1.0	2.5	6
	4	16	0.1	0.0	2.1	-5	-1.0	1.3	3
	5-	16	-0.3	0.0	1.7	-4	-0.5	0.0	3
Filler	1	16	-0.2	0.0	1.6	-4	-1.0	1.0	2
	2	16	0.5	0.0	2.1	-2	-1.0	2.3	5
	3	16	1.3	1.0	2.5	-2	0.0	2.5	6
	4	16	1.1	0.5	2.7	-6	0.0	2.3	6
	5-	16	1.6	0.0	2.4	0	0.0	3.0	8



(a) Search (b) Filler

Figure 4: Mean amount of change: difference from pre- to post-task in the number of nodes at each distance

nodes for the convergent task increased at distances further from the center node. These results show similar trends as previous research [9]. These results support Hypothesis 3. In addition, Hypothesis 4 is weakly supported, with the exception of distance 2 for the divergent task.

In Hypotheses 2 and 4, we initially predicted that the concept maps created before and after the filler condition would be very similar. Hypothesis 2 is supported. However, the experimental results show that Hypothesis 4 is only weakly supported.

Here, we discuss this gap between the hypotheses and the experimental results. Some participants added the following comments to the final questionnaires.

> *I remember some additional knowledge on the topic by taking some time during the task. (Participant 01, task: divergent, and topic: educational issues)*

> *My focus on the topic moved between pre- and post-task. (Participant 05, task: divergent, and topic: educational issues)*

> *As I drew a concept in the order where I had reminded the things on that topic, I wrote a particular part of the topic that I had been interested in at that moment. (Participant 06, task: divergent, and topic: environmental issues)*

> *The associations in my mind on the topic were improved after the [filler] task. (Participant 19, task: divergent, and topic: educational issues)*

I remembered very different images on the topic and drew them. (Participant 25, task: convergent, and topic: educational issues)

According to these comments, participants thought about a topic from different viewpoints during or after a filler condition task. The participants drew a concept map based on these different viewpoints. Specific reasons for such differences are unclear. In general, such differences in knowledge seem exist in a participant's mind a priori. Subsequently, even a filler condition task may stimulate some of the different aspects. However, the changes in the concept maps after the filler condition task are less than the changes in the case of the search task. The concept maps in the filler condition task changed; however, the amount of change for the filler condition task was less than that for the search condition task. These results indicate that concept maps could be used to measure such changes, which may reflect knowledge changes incurred as a result of a search.

6. CONCLUSION

In this paper, we have analyzed the differences between search and non-search conditions for different tasks. Analysis of the changes in the concept maps showed different patterns for the two conditions and two tasks. However, several issues remain, including how a retrieval system contributes to such changes of concept maps and searcher knowledge from the viewpoint of user-centered evaluation. In future, we will investigate the effects of a retrieval system and perform an algorithm-based analysis of the use of concept maps.

7. ACKNOWLEDGMENTS

This work was supported by the Japan Society for the Promotion of Science, KAKENHI Grant Numbers 25730193 and 23700283.

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APPENDIX

A. Topic on Environmental Issues for the Search Condition in the Convergent Task

Please carry out this task as if you were in the following situation:

You are a student at the university. You take a liberal arts course in "Society of the Day." In last week's class, you were assigned homework to gather information using the Internet about environmental issues for discussion with other students in the next class.

The teacher asked students to gather detailed information for a specific environmental issue rather than information for various environmental issues.

You have this class today; however, you have completely forgotten the homework until now.

The class will start in fifteen minutes. You decide to search the Web to find information and add bookmarks for the assigned topic.

Procedure:

(1) When you start a web browser, you will see a blank page. Please choose your favorite search engine from the list of search engines and perform the task.

(2) If you find a useful web page, add it to the bookmarks.

B. Topic on Educational Issues for the Filler Condition in the Divergent Task

Please carry out this task as if you were in the following situation:

You are a student at the university. You take a liberal arts course in "Education of the Day." In last week's class, you were assigned homework to gather information using the Internet about educational issues for discussion with other students in the next class.

The teacher asked the students to gather information for various educational issues rather than detailed information for a specific educational issue.

You have this class today; however, you have completely forgotten the homework until now.

The class will start in fifteen minutes. You give up trying to do the homework and choose to play a typing game instead for fifteen minutes.

Procedure:

(1) Please click the shortcut for the typing game "Typing of Haniwa" on your desktop.

(2) Please play the typing game for fifteen minutes.