Using a Concept Map to Evaluate Exploratory Search

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Background

• Previous studies on user-centered evaluations and exploratory search systems:
  – Can users *effectively seek information*?
  – Can they conduct Exploratory Search by *interaction with the systems*?

• Previous studies: What can users acquire from information sources found?

• Our focus: *users’ cognitive changes* during exploratory search
Objective

• User’s cognitive changes by search:
  How can we measure changes in the user’s knowledge structure, before/after Exploratory Search?

• Concept map
  – used in learning & education to describe learners’ knowledge representations
Concept Map (Cmap)

Example of concept map about plants

Concept map: **concept words**, arrows to connect concept words, and **linking words** on the arrows
Related Works – Concept Map

• Concept maps: introduced in educational fields
• In IR & IS context:
  – Cole et al., 2007; Halttunen and Järverin, 2005; Pennane and Vakkari, 2003
  – Used Concept maps to represent user’s knowledge structures and their changes
• In our context:
  – A basic tool to analyze effectiveness of Exploratory Search supporting systems
    • Grater the effectiveness, grater the change in cmaps
  – Examine affects of topics for searching and affects of search task scenarios
Research Questions

• RQ1: What differences can be observed between pre- and post-search concept maps?

• RQ2: How do differences between topics, scenarios and browser types influence changes in user’s concept maps?

➢ User Experiment
Experimental Design
Participants

• 35 undergraduate students
  – Ages: 18 – 28
  – Males: 17, Females: 18
  – Majors:
    literature, nursing science, pedagogics, engineering, political economics, jurisprudence, commercial science, science & engineering, etc.
  – No experience drawing concept maps
Search Task

• Information-gathering task
• Participants gather information on Web as preparation for writing a term paper on a topic
• Participants conducted two search tasks for different topics
  – *Topic* is an experimental factor
Factors in Experiment

1. Topics (within-subject factor)
   - Media topic
   - Politics topic

2. Scenarios (between-subjects factor)
   - Selective
   - As-Many-As

3. Browser types (within-subject factor)
   - Tab Browser
   - Non-tab Browser
1. Topics (within-subjects factor)

- Participants gather info on the Web for writing a term paper on Media or Politics topic
- Media:
  “The media’s impact on the young adult population”
- Politics:
  “The influence of a change in government administrations”
- Not fact-finding topics
- Diverse discussions and opinions on the Web

Participants must investigate discussions not only by looking for multiple opinions but also by comparing viewpoints.
2. Scenarios (between-subjects factor)

• Selective scenario
  – Carefully select 10 or fewer Web pages

• As-Many-as scenario
  – Gather as many Web page as possible
3. Browser type (within-subjects factor)

• Web browser allowed:
  – Use of tabs (Tab Browser)
    – or –
  – Non-use of tabs (non-Tab Browser)

• Purpose: effect of interface
  – Why: experienced users used tabs lots
## Procedure

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<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Time</th>
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<tr>
<td>Preparation</td>
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*Cmap: Concept Map*
Procedures

1. Quizzes about Web, IR, and Writing: 10 min.
2. Search Experience Questionnaire: 10 min.
3. Instruction of Cmap: 5 min.
4. Practice of Cmap: 5 min.
5. Instruction of Task: 5 min.
6. Pre-Search Cmap for Topic: 10 min.
7. Search: 15 min.
8. Post-Search Cmap for Topic: 10 min.
9. Questionnaire for Task: 10 min.
10. Instruction of Task: 5 min.
11. Pre-Search Cmap for Topic: 10 min.
12. Search: 15 min.
13. Post-Search Cmap for Topic: 10 min.
14. Questionnaire for Task: 10 min.
15. Closing Questionnaire: 10 min.
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**2nd task**
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1st task

2nd task
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- Post-Search Cmap for Topic: 10 min.
- Questionnaire for Task: 10 min.
- Closing Questionnaire: 10 min.

The second task followed the same sequence as the first task.
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- Post-Search Cmap for Topic: 10 min.
- Questionnaire for Task: 10 min.

1st task

- Instruction of Task: 5 min.
- Pre-Search Cmap for Topic: 10 min.
- Search: 15 min.
- Post-Search Cmap for Topic: 10 min.
- Questionnaire for Task: 10 min.
- Closing Questionnaire: 10 min.

2nd task
Procedure

Quizzes about Web, IR, and Writing 10 min.
Search Experience Questionnaire 10 min.
Instruction of Cmap 5 min.
Practice of Cmap 5 min.
Instruction of Task 5 min.
Pre-Search Cmap for Topic 10 min.

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1st task

2nd task
Procedure

- Quizzes about Web, IR, and Writing: 10 min.
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- Questionnaire for Task: 10 min.
- Closing Questionnaire: 10 min.
Procedure

**Quizzes about Web, IR, and Writing**
- 10 min.

**Search Experience Questionnaire**
- 10 min.

**Instruction of Cmap**
- 5 min.

**Practice of Cmap**
- 5 min.

**Instruction of Task**
- 5 min.

**Pre-Search Cmap for Topic**
- 10 min.

**Search**
- 15 min.

**Post-Search Cmap for Topic**
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- 10 min.

**Instruction of Task**
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**Search**
- 15 min.

**Post-Search Cmap for Topic**
- 10 min.

**Questionnaire for Task**
- 10 min.

**Closing Questionnaire**
- 10 min.
Counter-balanced

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*Cmap: Concept Map*
Results
Analysis Method: Overview (1) concept map → directed graph

- Using graph components:
  - Node
  - Link
  - Link label

Graph:

- Voters desire change in government makes Democratic Party with Hatoyama with Mrs. Sachi Hatoyama
- Effect of change in government
- Consists of Yamba Dam with anxiety
- Is cased by bureaucrats initiative
- Consist of politicians initiative
- Drops the plan of Hall of Fame in Animation
- Aso, former PM supports planned
- Otaku attracts electric city
- Akihabara
Analysis Method: Overview (2)
Comparing pre- and post-search cmaps

Pre-search cmap: drawn up before search task

Post-search cmap: made after search task

What changed?
Data preparation

Each concept map transcribed into GraphViz format

digraph G {
  id0 [label="Effect of change in government"]
  id0 -> "change in government" [label="is caused by"]
  "change in government" -> "Democratic Party" [label="makes"]
  "Democratic Party" -> Hatoyama [label="with"]
  Hatoyama -> "Mrs. Sachi Hatoyama" [label="with"]
  voters -> "change in government" [label="desire"]
  voters -> "rights to vote" [label="have"]
  id0 -> "Hall of Fame in Animation" [label="drops the plan of"]
  Akihabara -> "electric city" [label="is"]
  Akihabara -> Otaku [label="attracts"]
  Otaku -> "Aso, former PM" [label="supports"]
  "Aso, former PM" -> "Hall of Fame in Animation" [label="planned"]
  id0 -> "politicians initiative" [label="consists-of"]
  "politicians initiative" -> "bureaucratic initiative" [label="is counterpart of"]
  id0 -> "Yamba Dam" [label="consists-of"]
  "Yamba Dam" -> anxiety [label="with"]}

Participants manually draw concept maps with a pencil
Example of concept map generated using GraphViz dot command
Numbers of nodes, links, and link labels

Analysis Results:
Number of nodes = 16
Number of links = 15
Number of link labels = 15
Summary: number of graph components in concept maps (n=70)

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<th>Min.</th>
<th>Max.</th>
<th>Mean.</th>
<th>Median</th>
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- Average number of nodes (22-23) and links (23 – 24)
- Numbers of nodes and links show similar tendencies
- Reason: nodes usually only have a single link
Summary: number of graph components in concept maps (n=70)

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Numbers of pre- and post-search graph components show similar tendencies.
Metrics of Difference between Pre- and Post-search Concept Maps

• Metrics of difference between pre- and post-search concept maps:
  – Common, New, and Lost graph components

• Analysis:
  – Numbers of common, new, and lost graph components
Common nodes

Pre-search cmap

voters desire change in government makes Democratic Party with Hatoyama with Mrs. Sachi Hatoyama

has rights to vote

is caused by Effect of change in government

expressway

Common nodes: those having the same label

Post-search cmap

Democratic Party makes Hatoyama led by with Mrs. Sachi Hatoyama attracts attention in mass-media

Effect of change in government

led by with claims friendships

makes expressway

→ Number of common nodes: 4

By the same participant
Common links

Pre-search cmap

voters → desire change in government → makes Democratic Party → with Hatoyama → with Mrs. Sachi Hatoyama
is cased by Effect of change in government

data

Common links: Source node and target node are common

Post-search cmap

Democratic Party → makes Hatoyama → led by 1 Mrs. Sachi Hatoyama → with 2 attracts attention in mass-media

Effect of change in government

→ Number of common links: 2

friends → makes express way
Common link labels

Pre-search cmap
- voters → desire
- change in government
- Democratic Party
- Hatoyama
- Mrs. Sachi Hatoyama

Effect of change in government

Common link labels: common links with the same labels

Post-search cmap
- Democratic Party
- Hatoyama
- Mrs. Sachi Hatoyama

Effect of change in government

→ Number of common link labels: 1
Lost nodes and new nodes

Pre-search cmap

Lost nodes: only in pre-search cmaps
New nodes: only in post-search cmaps

Number of lost nodes: 4
Number of new nodes: 3
Lost links and New links

Lost links: only in pre-search cmaps
New links: only in post-search cmaps

Number of lost links: 5
Number of new links: 4
Lost link labels and New link labels

Pre-search cmap

- voters have rights to vote
- desire change in government
- makes change in government
- with Democratic Party
- with Mrs. Sachi Hatoyama
- is cased by Effect of change in government
- expressway

Number of lost link labels: 5

Lost link labels: only in pre-search cmaps

New link labels: only in post-search cmaps

Post-search cmap

- Democratic Party makes Hatoyama
- led by Mrs. Sachi Hatoyama
- attracts attention in mass-media
- makes friendships
- makes express way

Number of new link labels: 5
Combined concept map of pre- and post- search concept map with common, new, lost graph components.

- : Common
- dashed circle: Lost
- circle: New
Summary: common, new, and lost graph components (n=70)

<table>
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- Numbers of common components smaller than numbers of new & lost components
- Post-search cmaps are greatly modified from pre-search cmaps
Common
Lost
New

Pre-concept map

- voters desire change in government makes Democratic Party with Hatoyama with Mrs. Sachi Hatoyama
- change in government is cased by Effect of change in government
-Effect of change in government consists of Yamba Dam and politicians initiative with Hall of Fame in Animation
- Yamba Dam is counterpart of anxiety
- politicians initiative consists of bureaucrat initiative with Akihabara Otaku
- Akihabara Otaku attracts electric city

Aso, former PM supports electric city

Hall of Fame in Animation planned

Concept maps greatly changed After web searching

Democratic Party makes Hatoyama claims friendships

Democratic Party makes Hatoyama

Effect of change in government makes Hatoyama

- voters have rights to vote
- change in government makes desire
- Democratic Party makes Hatoyama with Mrs. Sachi Hatoyama
- Mrs. Sachi Hatoyama attracts attention in mass-media

Democratic Party makes Hatoyama

- voters have rights to vote
- change in government makes desire
- Democratic Party makes Hatoyama with Mrs. Sachi Hatoyama
- Mrs. Sachi Hatoyama attracts attention in mass-media
Influences of experimental factors: Topics, scenarios, and browser types

- ANOVA analysis: number of common, new, lost graph components and three experimental factors
  - Significant differences in only common nodes and common link labels between scenario factors

**Common nodes and common link labels:**

- Selective > As-Many-As
- \( p < .10 \)

- **\( p < .01 \)**
Summary of Results (1)

• RQ1: What differences observed between pre- and post-search cmaps?
  – Analysis: Major changes between concept maps before and after exploratory search tasks
  – Many graph components in pre-search concept maps were lost
  – Many new components appeared in post-search concept maps
Summary of Results (2)

• RQ2: How do differences between topics, scenarios and browser types influence changes in user’s concept map?
  – No differences: Topic and Browser type
  – Scenario factor: Numbers of both common nodes and link labels in As-Many-As scenario smaller than in Selective scenario
Conclusions

• Concept maps: evaluated how users change knowledge structure after exploratory search

• User experiment:
  – Task: Information-gathering
  – Factors: topic, scenario, browser type

• Analysis: concept maps as directed graphs
  – Metrics: Common, new, and lost graph components

• Results:
  – Concept maps greatly changed after web search
  – Fewer common nodes and link labels in As-Many-As scenario than in Selective scenario
Thank you!

For more details, please visit our Web site: http://cres.jpn.org