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# RAPID AND ACCURATE IDEA TRANSFER: EVALUATING CONCEPT MAPS AGAINST OTHER FORMATS FOR THE TRANSFER OF COMPLEX INFORMATION

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**Abstract**. Concept Maps (Cmaps) have proven useful for capturing and organizing knowledge, particularly of those who create the Cmaps. Their usefulness for transferring knowledge has not been as extensively researched. In business, government and military settings, slideshows (e.g., Microsoft PowerPoint) are a preferred format for presenting "complex" ideas, while the journal article remains the preferred format in academic circles. This empirical investigation compared Cmaps with other common formats of information presentation. Complex information expressed in a report about a humanitarian crisis was presented to military graduate students in four formats: journal article in traditional text, a hypertext version of the journal article, a Microsoft PowerPoint presentation, and a set of hyperlinked and resourced Cmaps. After reviewing the material, participants recreated the information and answered a set of questions to test comprehension of the material. Additionally, a preference survey was conducted with 34 professionals across military and industry domains to consider attitudes toward Cmaps for presentation. Cmaps were empirically demonstrated to be more effective than PowerPoint on key measures of knowledge transfer and rapidity in creation. They were also shown to be the preferred format for complex information presentation, when compared to PowerPoint.

## 1 Introduction

Concept Maps (Cmaps) have proven useful for capturing, organizing, and assessing knowledge (Cañas 2004b, Cañas 2006). Benefits have primarily been demonstrated for the creators of Cmaps. The benefits for *transferring* knowledge have not been as extensively examined, and empirical findings on the matter have mostly been limited to educational applications. Where Cmaps have been compared to other strategies for knowledge transfer, they have shown promise. Puntambekar, et al. (2007) demonstrated the advantages of Cmaps relative to hyperlinked text pieces, forming what he called a "Concept Mapped Project-based Activity Scaffolding System" for increasing the understanding of the interconnected nature of the concepts and principles in middle-school science. Kinchen and Cabot (2007), in looking at dental education, showed that Cmap presentations led to better performance than sequential PowerPoint presentations when the aim of knowledge transfer was a deep understanding of the subject – i.e., comprehension as opposed to a memorization of facts.

Outside of the classroom, the goals of knowledge transfer may not only be learning but also strategizing, argumentation, planning, decision making, policy making, and other practical applications. It has been claimed that Cmaps lead to improvement in the effectiveness and efficiency of knowledge transfer of complex ideas. Hoffman and Shattuck (2004), using a study design biased *against* Cmaps, found that military officers, both junior and senior, performed as well using a Concept Map-based version of their traditional "Operations Orders" as they did with the traditional structured paragraph format, on measures of comprehension and recall. Wagoner (2004) presented data from the same experiment showing a search efficiency improvement of up to 40% for experienced users of the Cmaps. Despite the potential gains, Wagoner also found a general reluctance to change from the traditional, linear, text-only format of Operations Orders. The finding was not unexpected, given that Cmaps are novel to many people, and that most people are more accustomed to and more comfortable with traditional text forms and formats.

This latter finding is of particular interest for the present investigation. One reason for the paucity of clear evidence regarding the usefulness of Cmaps for knowledge transfer is the general reluctance some people may have to depart from customary and ubiquitous formats of information presentation. Globally, in business, government and military settings, slideshows of the type created with Microsoft PowerPoint are a preferred format for presenting "complex" ideas,[1] while the journal article or proceedings paper remains the preferred format in academic circles.[2]

[1] We place the word 'complex' in scare quotes because the slide format often results in a simplification of the complex information.
[2] The irony of the latter situation is not lost on the authors as they draft this paper!

Tufte (2006) has been among the chief critics of the slavish and sometimes dangerous use of slideshows, pointing to *inter alia* their tendency to "reduce the analytic quality of serious presentations of evidence" (p. 3). The U.S. government's recognition of the pervasive use of PowerPoint presentations has led it to consider whether the conventions that such software supports – indeed encourages – may be serving as a contributing cause of systemic underperformance in organizations that depend heavily on the rapid and accurate communication of complex ideas. This consideration gave rise to the present empirical investigation.

## 2 An Empirical Investigation: Rapid and Accurate Idea Transfer

We conducted an empirical investigation to compare the impact of four different presentation formats on comprehension as a form of knowledge transfer, specifically tested by incidental recall of complex information. We hypothesized that the presentation of complex information in Concept Map-based formats would enable more rapid and accurate knowledge transfer than each of the other three formats: traditional text, hyperlinked text pieces (hyper-text), and PowerPoint slides. The study was conducted from February through June, 2008, with data collection occurring from April through June. In a related study, we conducted a survey of preferences for Cmap and PowerPoint formats in May 2008. This paper reports findings from both studies. References to the survey participants and methods are explicit – all other references are to the empirical study.

### *2.1 Method*

#### 2.1.1 Participants

The participants were 61 graduate students at Naval Postgraduate School, Monterey, California. The students were officers of varying ranks in the United States Military. Participants were recruited and selected for the study with no regard for age or gender, and they were not compensated or awarded for their participation.

#### 2.1.2 Hypotheses

Three hypotheses were tested in the study.

H1: The presentation of information in Concept Map-based format will result in better comprehension of information, as compared to presentations of information in traditional text- (i.e., journal article), hypertext- (i.e., hyperlinked text pieces of the journal article), and PowerPoint-based formats (i.e., slideshows).

H2: The presentation of information in Concept Map-based format will result in greater efficiency of information transfer, as compared to presentations of information in traditional text-, hypertext- and PowerPoint-formats.

H3: The presentation of information in Concept Map-based format will not be preferred to the presentation of information in PowerPoint-based format. Following Wagoner (2004), we suspected that most people would prefer a customary format – PowerPoint – to Cmaps.

#### 2.1.3 Design

The study employed a between groups design. Participants were randomly assigned to one of four groups each with N=15 (the hypertext group was assigned an additional participant after one participant was determined to be quite disengaged in the procedure, for a total N=61). All participants were presented with the same complex information. However, participants in each of the four groups were presented the information in one of four formats: traditional text, hypertext pieces, a PowerPoint presentation, and a set of Cmaps with hyperlinked resources (e.g., pictures, statistical graphs, text) taken from the source article. Thus, the main independent variable was format.

#### 2.1.4 Materials

The learning materials and the test questions were developed independently so that those who worked through the source document to prepare the test questions would not be biased by having played a hand in preparing the learning materials (i.e., any inclination to have information that is salient in one or another of the formats be more likely to be queried in the recall test questions). Some members of our team developed the questionnaires, based on the traditional text journal article. Another member developed the Cmaps without seeing the questionnaire. And the PowerPoint version was prepared by a third-party (i.e., not the authors) graphics design

company with no knowledge of the nature and purposes of the study. The company was chosen for its experience in creating professional PowerPoint presentations, and compensated via a 'flat-fee' arrangement that encouraged efficiency.

The complex information sets, in each of their formats, are illustrated in samples in Figures 1-4. These were derived from an article (Farzana, 2008), which described a complex set of historical economic, and political circumstances of the Bihari refugee community of Bangladesh.

The traditional text version was an abridged version of the journal article as it originally appeared, and was presented to participants as a 17-page Microsoft Word document, with a word-count of 4,523. The hyper-text version was created by the authors. It used the same text as the linear text version, carved into short text pieces that were hyperlinked together at appropriate relevant places within the document. The material was presented to participants as 25 hyperlinked PowerPoint slides, which followed the structure of the traditional text.

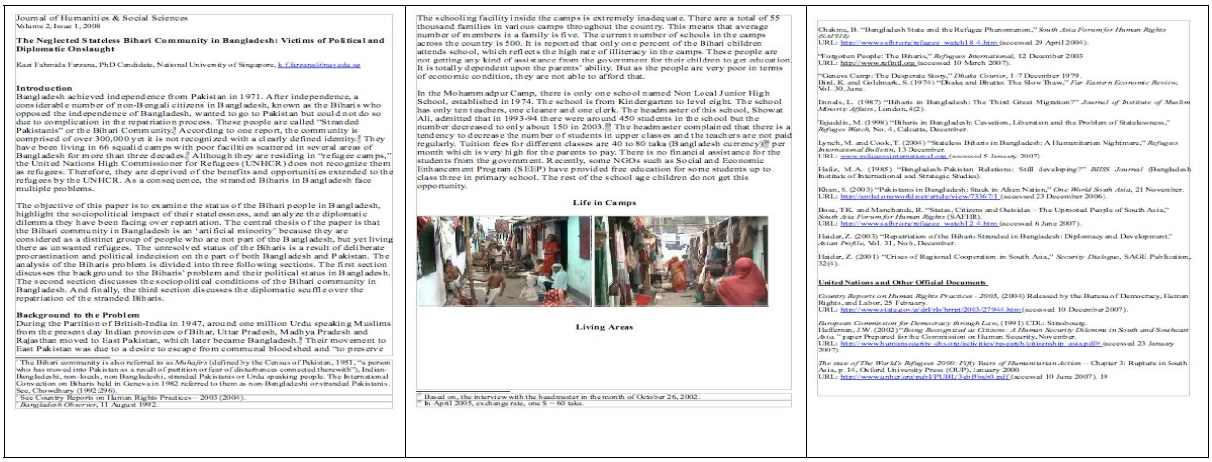

**Figure 1**. Traditional text samples.

**Figure 2**. Hypertext samples.

The PowerPoint designer was provided with the traditional text version and was instructed to prepare a professional-looking presentation using his own design intuitions and discretion. Certain additional constraints were provided, and we based these explicitly on Tufte's (2006) critique of PowerPoint, which was a driving factor in our sponsor's interest in studying alternative methodologies for briefing. The constraints were:

- Assume a presentation of approximately 20 minutes in duration,
- Allow the length of the presentation to principally be dictated by the content (not the time),
- Represent all of the source document material (some of the material became the "Notes" that appeared under some of the slides),
- Attempt to use no more than 40 words per slide, and
- Use multiple features of PowerPoint (which Tufte criticizes), as deemed appropriate, including bullet lists, templates, background graphics, photos, animations, sounds, summaries of statistical data, and AutoConent Wizard.

In total, the PowerPoint presentation was created in approximately 52 hours. The PowerPoint version was presented to Participants as a 56-slide presentation, with an approximate word-count of 1420, not including the

text included in the Notes. Participants viewed the presentation in slideshow mode, but were not constrained to remain in that mode. Participants had access to the Notes in hardcopy.

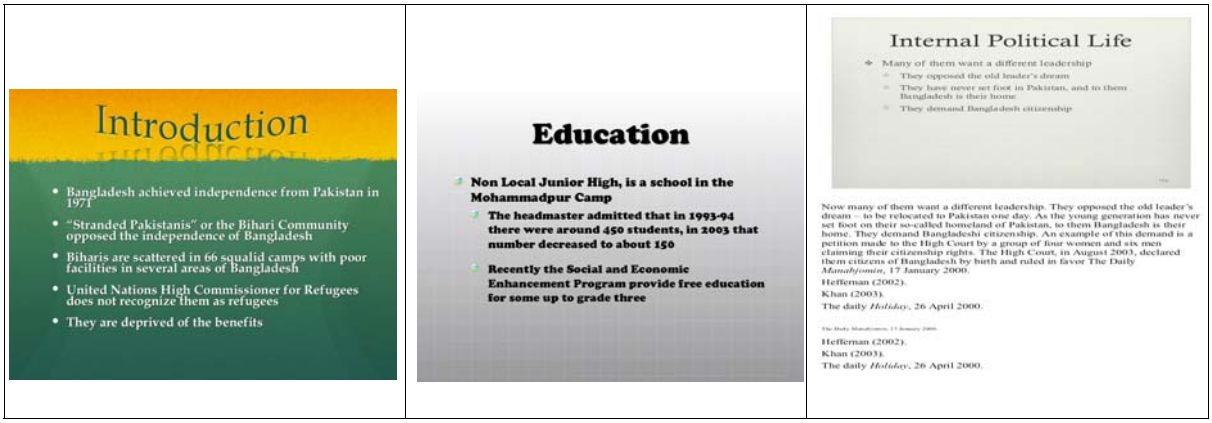


**Figure 3**. PowerPoint presentation samples.

The Concept Map version was prepared by the authors using CmapTools (Cañas, et al. 2004a). The traditional text version was transformed into 16 "propositionally coherent" and hyperlinked Cmaps. Hoffman (Crandal, Klein, Hoffman 2006) explains: "Using the link labels to express relations between two concepts, the node-link-node triples in Concept Maps form propositions, that is, they can be read as 'stand alone' simple and meaningful expressions" (p. 51). When all of the triples in a Concept Map are well-formed propositions, the Concept Map is said to be 'propositionally coherent.' In total, the Cmaps included 301 separate concepts, 344 propositions, and 3,345 words (not including the brief text pieces attached as resources). As each Cmap was made, propositions in the original text were marked off (understanding that a single sentence typically contains more than one proposition). An independent check assured that the Cmaps (with the text pieces included in the Notes) included all of the material in the original document. Notably, the bulk of the Cmap creation was undertaken by one author who was purposefully unaware of the content of the questionnaires. Hyperlinked to the Concepts were 22 Resources (e.g., text documents, photos) taken from the source article. In general, the material selected for inclusion in brief text pieces was material that conveyed a detailed example. Where Resources were added, the color of the concept nodes was changed to yellow in order to encourage participants (who would be generally unfamiliar with Cmaps) to follow the hyperlinks (shown in bold in Figures 5 and 6). In total, the Cmaps were created in approximately 18 hours. The Cmaps and resources were presented in an .html browser to enable all Cmaps and resources to be presented in the same application. Thus, Cmaps were presented in whole, not piecemeal, as each Cmap was selected. The icon and hyperlink for CmapTools that is standard for .html exported Cmaps was removed.

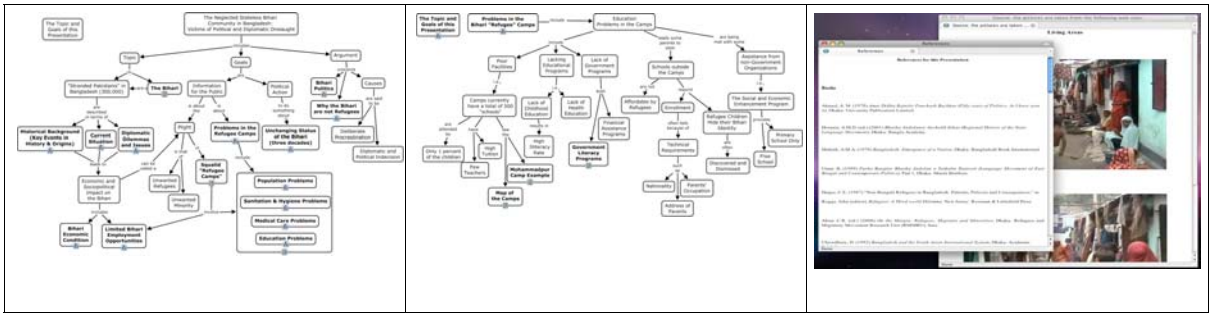

**Figure 4**. Concept Map samples.

Figures 5 and 6 present the Cmaps at viewable scale.

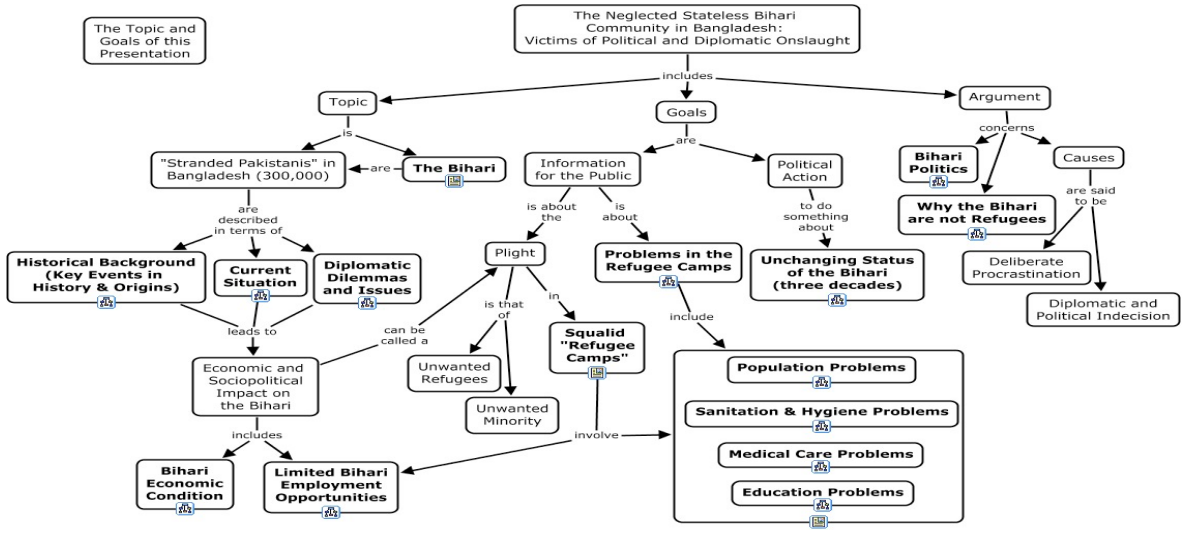


**Figure 5**. Concept Map sample #1 at viewable scale.

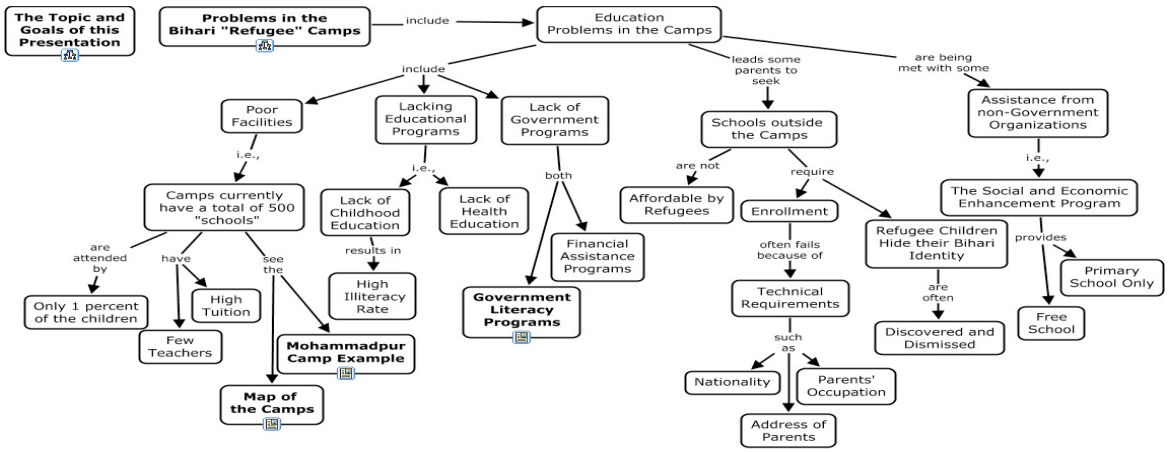


**Figure 6**. Concept Map sample #2 at viewable scale.

### 2.1.5 Procedure

We adopted the incidental learning paradigm since incidental recall can be a strong test of memory, and hence comprehension. The incidental learning paradigm is an experimental paradigm used to investigate learning without intent. "At the beginning of the experiment, participants think that their only task is to rate the acquisition stimuli...they do not know that they will later be asked to recall the acquisition [matter]. The purpose of this incidental procedure is not to trick the [participants], but to investigate how particular types of acquisition activities affect learning and subsequent recall" (Bransford, 1979). The incidental learning paradigm presumes that information processed at deeper – i.e., more conceptually connected – levels will result in superior recall – not recognition – of information.

Participants were presented a 10-question, short-answer Pre-test questionnaire (to measure content familiarity). Next, the participants were instructed to review the information sets (i.e., the acquisition task) in order to prepare to participate in a study in which they would be presented with a current challenge for the US military. They were led to believe that after reviewing the focus material they would engage in a group problem solving session about the humanitarian challenges now facing the US military. It was suggested the review should take about 20 minutes, but they were encouraged to not feel constrained by time. Following the acquisition task, the Participants were presented with a recreation task: they were asked to recreate the material in a format of their choosing. (We suspected that the hypertext and the Cmaps would result in recall of some form of net-like diagrams because we had seen this in Hoffman and Shattuck, 2004, and therefore it might be argued that Cmaps work because they are diagrams, as opposed to being Cmaps per se. If both the hypertext and Cmap groups recreated net-like diagrams, and the Cmap group outperformed on the incidental recall task, we would submit that gains in performance were due to the diagrams being Cmaps, not just diagrams.) Participants

were then presented with a surprise 20-question short-answer Post-test questionnaire. All questions on both questionnaires were fill-in-the-blank, requiring numeric and text answers. Three of the questions were repeated on both tests.

We tested hypothesis H2 via analysis of the time each group took to review the same information in each of the four formats. Expanding on Wagoner's finding (2004), H2 postulated that Cmaps would also introduce efficiency gains into overall performance. We also examined the amount of time required to create the PowerPoint and Concept Map-based formats, since rapidity of idea transfer is relevant not only to the speed of transfer but also the speed of preparation for transfer.

All Participants were then briefed on the purpose and design of the study. Since the study's cover story was a form of deception, after the study was completed participants were given the opportunity to request that their data be discarded. None asked to have their data discarded.

In our related study, all participants were invited to review the PowerPoint and Cmap formats, and asked to complete an anonymous survey ("survey") regarding their preferences for and experience with either format, and their willingness to use Cmaps for presentation. Additionally, a sample of professionals drawn from one of the authors' social network (N=75) was invited to participate in the survey. All aspects of the survey were conducted online, to include the invitation, review of the formats, answering preference questions, and providing demographic data, which was optional. In total, 34 invited respondents completed the survey, with 25 providing demographic data. The sample included professionals, mostly age 26-45, with more than 16 years of education, drawn from government, military and industry occupations, including military officers, research scientists, and marketers.

### *2.2 Results*

To test H1, we conducted an analysis of the Pre- and Post-test questionnaires, and the recreation created by each participant during the incidental recall phase of the experiment. Each Pre- and Post-test questionnaires were scored by two members of our team using a scoring key. Given the complexity of the information set, questions requiring descriptive answers or names of entities were marked conservatively, with allowances for spelling and semantic similarity. For example, a question requiring "Bay of Bengal" was credited for answers such as "Sea of Bengal" and "Bengali Sea." Numeric answers were strictly marked. The recreation artifact was scored by wordcount, and two of our team created proposition lists enabling a proposition count. The lists were deemed accurate representations of the recreations via two waves of inter-scorer reliability checks. The method of recreation was also noted (i.e., whether a participant recreated text, a bulleted-list, or some form of net-like-format.

Summary statistics are shown in Table 1 (STD = standard deviation).

| **Statistic** | **Traditional text** | | **Hypertext** | | **Cmap** | | **PowerPoint** | |
|---|---|---|---|---|---|---|---|---|
| | Mean | STD | Mean | STD | Mean | STD | Mean | STD |
| Preparation time (in mins) | N/A | N/A | N/A | N/A | 1080 | N/A | 3120 | N/A |
| Review time (in mins) | 22.13 | 5.51 | 21.38 | 5.89 | 27.25 | 8.32 | 26.36 | 12.16 |
| Pre-test score (% correct, 10 questions) | 16.67 | 13.84 | 15.63 | 14.71 | 13.46 | 16.51 | 25 | 16.29 |
| Post-test score (% correct, 20 questions) | 56.58 | 21.22 | 52.81 | 23.07 | 47.49 | 11.94 | 58.75 | 12.44 |
| Pre- and Post-test score difference | **39.92** | N/A | **37.19** | N/A | **34.03** | N/A | **33.75** | N/A |
| Recreation wordcount | 168.67 | 69.00 | 153.38 | 68.24 | 126.46 | 105.48 | 184.57 | 73.02 |
| Recreation proposition count | 38 | 14.66 | 35.69 | 9.56 | 33.77 | 19.46 | 43 | 19.21 |
| Recreation format (net-like only) | 0 | N/A | 1 | N/A | 3[3] | N/A | 0 | N/A |

**Table 1:** Summary Statistics.

As a measure of each individual's overall effort on all the tasks, we simply summed the time they spent reviewing the material, their Post-test scores, and the word and proposition counts. The mean score for effort

[3] In addition to these three, two discounted Cmap participants created net-like formats.

was 263.78, with a standard deviation of 113.53. The fourth lowest score, 93.5, belonged to the hypertext group participant whose observed minimal effort warranted the exclusion. The three lowest participant scores, 38 (Cmap group), 46.42 (PowerPoint group), and 63 (Cmap group), were thus discounted from the analysis. The score for one of the Cmap group participants was adjusted by a method of proportions to account for accidental noncompletion of the final six questions on page two of the Post-test questionnaire. The mean score for all other participants on the final six questions (44.72%) was averaged with the participant's score (75%) for the first 14 questions (on page one of the questionnaire), for a conservatively adjusted score of 59.86%. (The Pre- and Post-test score difference for the Cmap group actually increases to 35.19 with the participant's page one score of 75%.)

Our survey data revealed that 55.88% of the respondents preferred the Cmap format, while 44.12% preferred the PowerPoint format. While 100% of the respondents had prior experience creating PowerPoint slides, on 52.94% had created Cmaps. And 70.59% of the respondents expressed a willingness to consider creating Cmaps for presentation.

### *2.3 Discussion*

#### 2.3.1 H1: The presentation of information in Concept Map-based format resulted in better comprehension of information as compared to presentations of information in PowerPoint-based format but not in traditional text- and hypertext-based formats.

On the primary score of interest – Pre-and Post-test score difference – the Cmap group outperformed the PowerPoint group, but underperformed relative to the traditional text and hypertext groups. We were not surprised by the underperformance, since the memory text questions were drawn directly from traditional text, and participants were very familiar with the text and hyperlinked text formats. We were, however, surprised by the comparison with PowerPoint. Possibly, the PowerPoint group was comprised of superior performers, despite randomized group assignment. The PowerPoint group as a whole scored considerably higher on the Pre-test score than all three of the other groups, strongly suggesting greater initial content familiarity, and scored higher on the Post-test. But the PowerPoint group's review time was higher than that for the traditional-text and hyper-text groups. This finding may help explain the performance differences among the groups. The wordcount and proposition count results for the PowerPoint group may be explainable by the abundance of information they had to review – i.e., the slideshow and comprehensive notes. In other words, the PowerPoint group effectively received the information twice by reviewing the slideshow and reading the notes. In hindsight, this study might have utilized a PowerPoint mode more closely resembling general use – i.e., the notes would be presented as an audio voice-over. Nevertheless, in terms of knowledge transfer, the PowerPoint group appears to have been advantaged by the performers and/or an abundance of information presented in the customary PowerPoint format.

The Cmap group, in comparison, scored the lowest on all three performance measures – i.e., Post-test score, recreation wordcount and recreation proposition count. However, the Cmap group included the most net-like-recreations, with only one participant in the hypertext group recreating a net-like diagram. And most importantly, the Cmap group's Pre- and Post-test score difference was higher than the PowerPoint group.

Echoing Kinchen and Cabot (2007), we view these findings, when taken in total, as persuasive evidence of the *comprehension* improvement strength of Cmaps, at least with regard to the PowerPoint-based format. The Cmap group did not necessarily recall more *facts* accurately, as tested by the Post-test. Nor did they recall more *information*, as tested by the counts. But compared to the PowerPoint group, they demonstrated greater overall improvement in their knowledge *between the Pre- and Post-tests* and were more likely to recreate their knowledge in map-based formats. Thus, we believe that the Cmap group outperformed the PowerPoint group because the information was presented *as* Cmaps. Future investigations could examine comprehension even more closely by considering the semantic accuracy of the recreated propositions.

#### 2.3.2 H2: The presentation of information in Concept Map-based format partially resulted in greater efficiency of information transfer, as compared to presentations of information in PowerPoint-based formats but not with regard to traditional text-, hypertext-formats.

The Cmap group took longer than all other groups in material review time. We were not surprised by this finding, given both the low level of familiarity of most people with Cmaps (in particular, .html versions of CmapTools Concept Map files) and the navigation requirement put on the participants in order to review all of the material. We were intrigued by the performance of the hypertext group, as it may suggest that hyperlinking

itself may indeed create efficiencies in the review of complex information. And we suspect that the navigation confound may all but disappear when Cmaps are presented by their creator, or if additional navigation aids were introduced. Future investigations could follow these lines. We were very surprised by the considerable difference in preparation time. Even when potential confounds such as the skill of the creators, the introduction of "Tufte constraints," and the incentives for efficiency, we believe that the dramatic difference provides the most compelling evidence to date of the efficiency of creating presentations of complex information sets in Cmaps, specifically in CmapTools. Future investigations could focus directly on this issue.

#### 2.3.3 H3: The presentation of information in Concept Map-based format was preferred to the presentation of information in PowerPoint-based format.

Contrary to our expectations, the Survey yielded compelling evidence of a broader-based preference for Concept Map-based formats over Power-Point-based formats. Of particular interest to us were the familiarity of the respondents with Cmaps. Apparently, more people are becoming more familiar with them. When exposed to their potential value for presentation, we see a willingness to present information as Cmaps in the future. We consider this finding encouraging for the continued exploration of Concept Maps as tools for complex information transfer.

## 3 Acknowledgements

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