The Influence of Multimedia on Improving the Comprehension of Organizational Information

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ABSTRACT: Text is the predominant form of organizational information. Comprehending text-based information requires intensive cognitive processing effort on the part of readers. Drawing on multimedia literature, this study identified a characteristic of multimedia presentations, namely complementary cues, which have the potential to improve the comprehensibility of organizational information. A set of hypotheses about the benefits of multimedia over text-based presentations was generated based on the theoretical perspective that we developed. These predictions were tested through a laboratory experiment using a simulated multimedia intranet. Results show that multimedia facilitates the retention and subsequent recall of *explanative information* but not of *descriptive information.* Explanative information is organized facts connected by their underlying *functional relationships.* Descriptive information consists of *isolated facts* without an explanation of the relationships between these facts. The ability to retain and recall explanative information, in turn, leads to a greater ability to make correct inferences about new organizational situations.

KEY WORDS AND PHRASES: human information processing, information comprehension, information presentation, information recall, learning and inference, multimedia.

Journal of Management Information Systems / Summer 2002, Vol. 19, No. 1, pp. 99–127.

0742–1222 / 2002 $9.50 + 0.00.

THE COGNITIVE TECHNOLOGY GROUP AT Vanderbilt University defines multimedia as the "linkage of text, sound, video, graphics, and the computer in such a way that the user's access to these media becomes nonlinear and virtually instantaneous" [11, p. 118]. The objective of this study is to investigate whether or not multimedia as compared with text-based information improves the comprehensibility of organizational information and the inference ability of decision-makers.

The predominant information representation format for organizational decision-making is text and numbers. This includes formal documents, computer outputs, letters, memos, reports, and meeting summaries or transcripts. As illustrated later, reading text-based information is frequently cognitively intensive and often leads to comprehension failure. Multimedia technology presents an opportunity to enhance the comprehensibility of text-based information. Multimedia has experienced phenomenal growth in the recent years. Today, most consumer software products use multimedia. Personal computers have all been made multimedia-capable in recent years. The Internet is replete with Web pages that contain graphics, animations, sound, or video. Multimedia-related books and magazines occupy a significant amount of shelf space in the computer section of bookstores. These trends, together with the popular and academic press, give the impression that multimedia is a dominant mode of information dissemination.

Although this might be the case, multimedia production is still costly and time-consuming. As many have experienced, downloading multimedia images from the Internet still causes delays unless one has a high bandwidth capacity link. Rather than accepting the superiority of multimedia as an *article of faith,* it is important to examine whether or not its advantages exist and under what conditions. In this study, our objectives are to identify the theories that allow us to predict the benefits of different media and then test these predictions empirically.

Most of the research in multimedia has been conducted within the domain of education. With the exception of Rao and Goldman-Segall [33], little effort has been devoted to exploring its potential contributions in organizational settings, although several researchers have suggested using multimedia to capture organizational memory [33, 39]. On the organizational front, the capability of an organization to store historical information and create a knowledge management system has become more common and efficient with advances in hardware and software technologies. Such information can be made accessible to internal and external parties through intranets, extranets, and the Internet. Yet it is still the case that multimedia formats require more storage space, take longer to transmit and download, and are more difficult to develop compared with text files. Adopting a new technology often entails a cost-benefit trade-off [41]. Therefore, from the practical standpoint, the purpose of this study is to demonstrate the possible benefits of using multimedia so practitioners can decide if these benefits can justify the costs of its adoption.[1]

Although there exists a considerable body of literature examining the benefits of multimedia, most of the past studies were conducted in the context of how elementary or high school education could benefit from multimedia technology. Thus, it is

not clear whether or not the findings from this body of research can be generalized to organizational contexts. This paper describes the third in a series of experiments conducted to investigate media differences, mainly to compare text versus multimedia-based information. The first experiment [23] examined the advantages of multimedia over text-based information presentation in the context of a specific limitation of human information processing called *first impression bias.* The second experiment [22] investigated the effects of multimedia representation on the perceived ambiguity and the usefulness of the data provided. The third experiment (reported in this paper) focuses on measuring the impact of different media on an individual's ability to make inferences beyond the data provided. Together, these three experiments attempt to extend our understanding of the conditions under which multimedia would be beneficial in organizational contexts.

Theoretical Background

IN THIS PAPER, BASED ON THE COGNITIVE psychology literature, we examine why processing text-based information requires intense cognitive effort and is error prone. Then, based on the multimedia research literature, we identify the benefits of multimedia over text. From these differences, we predict how media differences will lead to the retention of different types of information and how this will influence the ability of an individual to make inferences.

We need to point out at the onset that the focus of our paper is on organizational information. Other aspects of multimedia, such as the aesthetic quality [5, 40] and the fun element [14, 43], associated with the use of multimedia in other contexts will not be addressed here. Our particular focus should be kept in mind when interpreting the theoretical perspectives discussed in the next section.

Despite the popularity of multimedia technology, empirical evidence establishing its benefits remains mixed. For example, Clark and Craig [10] surveyed the available multimedia research and concluded that empirical results in this area remain questionable. They went on to state that "Future research in this area should not be supported unless there is clear theoretical reason to expect learning gains due to any characteristics exclusive to a certain mix of media" [10, p. 29] (cf. [9, 19, 20, 34]). In this paper we argue that multimedia presentation can improve the comprehension of only certain types of information. That is, one of the reasons for the equivocal results observed in the literature may be that different research studies examined different types of information. (We will elaborate on our conjecture in detail in later sections.) To this end, we present a classification scheme for information types.

Information Types

Mayer [26] proposed that knowledge could be classified into two broad categories: *descriptive* knowledge and *explanative* knowledge. *Descriptive knowledge* refers to knowledge in which the key components or events are described but not explained,

such as a list of facts, a description of a series of events, or a set of procedural instructions. In contrast, *explanative knowledge* refers to knowledge in which the functional relationships among two or more variables are expressed and the underlying functional rules or mechanisms are explained. In this paper, descriptive information refers to information that contributes to the building of descriptive knowledge, whereas explanative information contributes to the building of explanative knowledge.[2]

Both descriptive and explanative information are the precursors of the ability to solve problems creatively. *Creative problem solving* refers to the ability to solve problems that are different from those the learner has previously learned. Mayer [26] argued that creative problem solving reflects the "true understanding" of the event or information. He suggested that true understanding is at a level higher than the recall of information and that true understanding means that, in addition to knowing the basic descriptive and explanative information presented, a learner must be able to put this information together in a new way and apply it to a new context. We label this ability as *inference ability.* This is based on the assumption that a certain threshold level in comprehending descriptive information has been reached. Without knowing some basic facts, it is impossible to make any inferences. However, once this threshold is reached, there is no further improvement by acquiring more descriptive information.

In the next section, we will discuss a theoretical model of text-based information processing and explain how multimedia presentation enhances the comprehension of explanative information but not descriptive information.

Processing Text-Based Information

There are many models of text-based information processing [1, 13, 17, 28, 36, 42]. Among these, the most widely adopted is the model proposed by Van Dijk and Kintsch [42]. In this model, text comprehension is assumed to consist of two levels of processing. At the surface level is the verbatim representation of text fragments or speech-like representation of text, called a *microstructure.* At the higher level is the hierarchical structure, which reflects the meaning of elements that are extracted from the microstructure. This is called a *macrostructure,* more commonly known as the "gist" or the "theme" of a text [42].

A person, such as a researcher reading a journal article, can work on only a small part of the text at a time. The reader carries along a small portion of the macrostructure in working memory. If the reader understands the information in the text and sees a *relationship* between this information and the macrostructure in their working memory, the new text being read is connected to the macrostructure. Therefore, in comprehending text-based materials, a reader has to build a macrostructure from a lower-level microstructure of the text. Subsequently, the developed macrostructure is then connected to the existing knowledge structure, either in working memory or long-term memory for retention. All of these processes are cognitively intensive and comprehension failure may occur at any one of the stages [4]. From the above, there are three important characteristics of text-based information processing to note. First,

macrostructures capture the essential ideas at the expense of omitting some specific details. Therefore, because of the limitation of cognitive resources, if a reader is focusing on memorizing the specific details they will "lose the big picture" and not be able to construct the macrostructures needed to comprehend the information. This is consistent with the research findings in mental model formation, namely that those learners who focus on learning the surface structure of an interface will not be able to generate a deeper understanding of the interface [24].

Second, a macrostructure is essentially the "glue" that holds the isolated text fragments together. The reader can integrate those fragments into their existing knowledge only if they can see a relationship between the fragments and the macrostructure in their working memory. Finally, regardless of whether the readers can find the functional relationships to link the ideas together, processing text-based information is an intensive cognitive effort. Comprehension may fail at any given stage.[3] We consider in the next section how multimedia presentation could improve the comprehension of organizational information.

Processing Multimedia-Based Information

A key characteristic of a multimedia presentation is that it presents information using multiple representations that complement each other. For example, an image (picture/figure, graphic, video scene, and so on) can be presented together with text or verbal descriptions. Representation of information in multiple formats has been argued to lead to better retention and retrieval. Paivio's [29] *dual coding theory* presents the central core of this argument. Briefly, the theory posits that there are at least two distinct modes of representation in memory, a *verbal* mode and a *visual* or imagery mode. The two systems are interconnected in that the information in each system can be cross-referenced.[4]

Every symbolic system has it strengths and limitations. For example, although conventional wisdom suggests that a picture is worth a thousand words [21], it is difficult to use pictures to convey the meaning of conditional events or causes, such as "if," "nevertheless," "because," or "no" [35]. On the other hand, as Hansen argues, "many human experiences are encoded in symbolic systems that resist logical descriptions, at least, they are not handy to communicate when translated into verbal (or text) descriptions" [16, p. 8].

In short, the theoretical advantage of the use of complementary cues is that although people can construct a mental representation (macrostructures, in the case of text-based information) of the information input from either audio or visual representation, the use of dual representations can complement the limitations of using one representation alone. Operating on this belief, researchers often present their results in text and figures in journal articles.

Our conjecture is that the use of complementary cues improves the comprehension of only explanative information (that is, explaining the functional relationships between two or more facts) but not of descriptive information (that is, isolated facts). Although descriptive information can be adequately conveyed using verbal

or text-based media, conveying explanative information in such media presents limitations. As illustrated earlier, processing verbal or text-based information entails building macrostructures based on read or heard text fragments, which demands a high level of cognitive effort. On other hand, with multimedia presentation, a graphic or picture can effectively summarize the gist (that is, macrostructures) of the text, thus reducing the cognitive effort required and, at the same time, improving the comprehension of the information conveyed.

As an example, when the verbal/text description that explains the structure of an organization is complemented by a hierarchical organizational chart, the readers are likely to create a better understanding of the functional relationships among individual departments and positions in that organization. Nonetheless, without the verbal description, the organization chart alone is probably inadequate to convey the complete information. This is because, as an abstraction, the organizational chart necessarily omits some details. In this case, each representation plays a unique role in helping comprehension. As another example, researches frequently apply this technique by summarizing and linking their hypotheses in the form of graphical research models.

Although complementary cues are of benefit to the understanding of explanative information, they are not as helpful for descriptive information. A statement such as "there are 250 people working in this department" effectively conveys the fact. Adding a picture, graphic, or even video of these employees working in their offices, for example, does not make the statement any easier to comprehend or remember, except for being more artistically pleasing.

In summary, given the same information content, we believe that the complementary effect of presenting information via multiple representations eases the processing of explanative information but not of descriptive information. Mayer [25] provided empirical evidence supporting this argument. He observed that the use of text illustrators enhanced the acquisition of explanative information but not of descriptive information. Text illustrators are figures, graphs, and animations, or the like, that are used to illustrate the concepts discussed in the text. Essentially, a text illustrator, when presented together with text or verbal information, is a form of multimedia presentation.

The advantage of using text illustrators is attributable to the complementing effect of the illustrators and the structure that they provide. That is, visual presentation, such as a text illustrator, that complements the verbal/text-based presentation can effectively summarize the key explanative information and can clearly show the connectedness of the explanative information. Therefore, instead of building the macrostructure as they read the text, the reader is provided with it. This not only reduces the cognitive load of the reader in terms of building the macrostructure, but also improves comprehension because important details are summarized in the visual presentation. However, presenting descriptive information in multiple forms does not improve the comprehensibility of such information, because these raw facts can be effectively conveyed by text or verbal representation. Multiple representations do not provide additional value.

The Research Model

Based on the theoretical arguments that we delineated above, the effect of multimedia presentation on descriptive information, explanative information, and inference ability can be summarized in the model depicted in Figure 1. The model indicates that the way information is being conveyed (via different types of media, such as, multimedia versus text-based) directly affects a decision-maker's ability to acquire and recall both explanative information (path "A" in Figure 1) and descriptive information (path "B" in Figure 1). In turn, a decision-maker's ability to acquire and recall explanative information affects their ability to apply the information to novel situations—that is, making inferences (path "C" in Figure 1). In this context, recall is defined as the ability to remember a specific piece of information that was presented. Inference, on the other hand, involves integrating and connecting with the information presented to deduce and figure out the appropriate answer to a particular question.

The model also suggests that media type does not directly affect the decision-maker's potential ability to make inferences (path "D" in Figure 1). Rather, it *indirectly* affects inference ability by organizing and presenting information in such a way that it becomes easier to encode and recall explanative information. Finally, the acquisition of descriptive information does not affect the ability to make inferences (path "E" in Figure 1).

Hypotheses

Through a summary of over a dozen studies, Mayer [25] concluded that with text descriptions, the use of a graphical illustration, which in essence is a mechanism that provides complementary cues to help one integrate information (a macrostructure), increases recall of explanative idea units (but not descriptive idea units), and improves one's ability to make inferences. Therefore, the positive relationship between the use of multimedia and the decision-maker's ability to retain and recall explanative information can be attributed to the role that multiple representations in multimedia play to make the relationships among events or various pieces of information explicit. Therefore, we hypothesize the following:

> *H1a: Subjects who use a multimedia system will recall more explanative information than those who use a text-based system (path "A" in Figure 1).*

Multimedia may have an adverse effect on the recall and retention of descriptive information. Multimedia provides decision-makers with the required macrostructure to integrate the functional relationships among the components or events involved, since it focuses the decision-maker's attention at a higher level. Accordingly, it may result in the decision-maker losing some of the detailed information such that the acquisition of descriptive information is negatively affected [25]. Therefore,

> *H1b: Subjects who use a text-based system will recall more descriptive information compared with those who use a multimedia system (path "B" in Figure 1).*

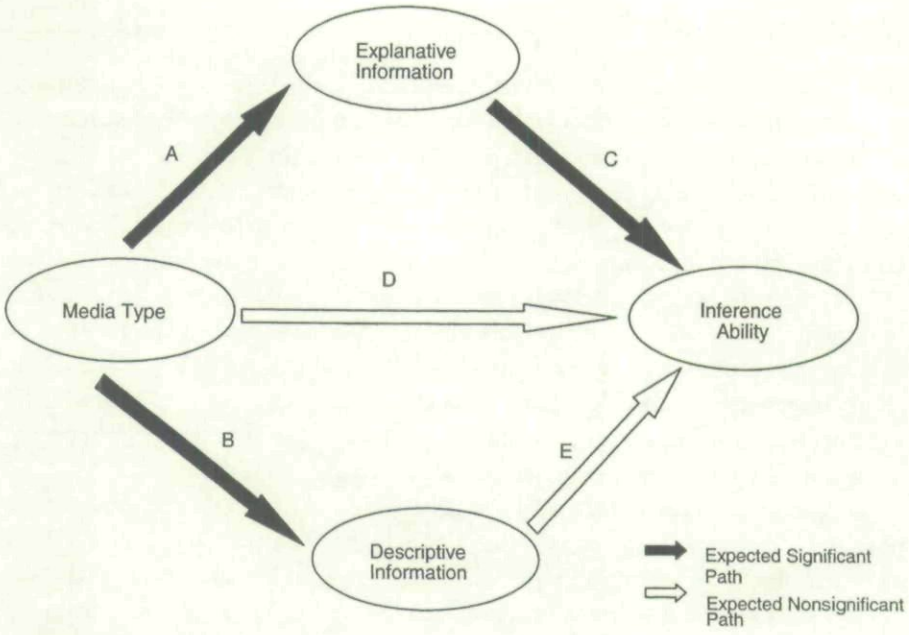

Figure 1. The Research Model

Mayer [26] suggested that the ability to make inferences depends on the presence of certain explanative information in memory. In other words, learners who retain the explanative information are more likely to build integrated learning outcomes and hence have high inference ability. Therefore, we expect that subjects who score highly on the explanative test (as a result of using the multimedia presentation) would perform well on the inference test, whereas subjects who recall more descriptive information would not perform well on the inference test. This also implies that the effect of media on inference ability is not a direct one. Rather, it is mediated by the amount of explanative information retained.

In studying how people learn to use a computer system, Lim et al. [24] observed similar outcomes. They found that subjects who focused on the surface-level activities, such as detailed physical actions concerning moving icons around, did not perform well when they were asked to make inferences about novel situations. On the other hand, subjects who focused on the higher-level goals, such as relating lower-level actions to higher-level actions, performed much better on the same inference test. Lim et al.'s [24] classification of surface-level versus higher-level focus is similar to descriptive versus explanative information. They argued that a higher-level focus (explanative information) causes learners to develop mental models that have higher inference potential. Based on the above, we suggest the following hypotheses:

H2a: The use of a multimedia system will not directly *lead to higher inference ability (path "D" in Figure 1).*

H2b: Subjects who recall more explanative information will have higher inference ability (path "C" in Figure 1).

H2c: Subjects' recall of descriptive information will not affect their inference ability (path "E" in Figure 1).

Research Method

Subject Population

ALL SUBJECTS WERE RECRUITED through campus advertisements from the student population of a large public university. The recruitment advertisements specified that participants must know how to operate a mouse input device. This was to avoid spending additional training time. Participants were not required to have experience with using the Web. Participation was entirely voluntary. Three incentives were provided for participation. First, C$20 was given for participation. Second, an additional C$30 was offered for each of the three best performers. Third, after their participation, all subjects were entitled to attend a free, one-hour World Wide Web tutorial.[5]

Prior to the actual experiment, 15 subjects were recruited to participate in the pilot study. They were also recruited by campus posting from the same sample pool. They were used to establish the time needed to finish the experimental task. Based on the feedback of these subjects, small modifications to the questionnaire and instructions were made (typographical errors and confusion in meanings were corrected).

Experimental System

The system used in the experiments was designed explicitly for this study. It was designed to run on an IBM-compatible PC with a NEC 15-inch Multisync 4FGe monitor. The system was implemented as a *simulated* intranet. Subjects used Netscape (version 1.1) to browse the experimental materials stored on an 850 MB hard drive. With this configuration, retrieval of information, including video clips, was almost instantaneous.

The video clips were digitized using Intel's Smart Video Recorder Pro [37] at a frame output rate of 20 frames per second. Since most of the clips were interviews, this frame rate provided a fairly smooth replay quality. Figures 2 and 3 show two examples of the user interface. Subjects could examine any piece of information at any time by clicking on the underlined and highlighted text (as shown in the figures), which simulates the hypertext link feature found on most Web browsers.

Experimental Materials

To ensure, at a minimum, mundane realism and the generalizability of the findings, information from a real organization was selected.[6] The British Columbia Cancer

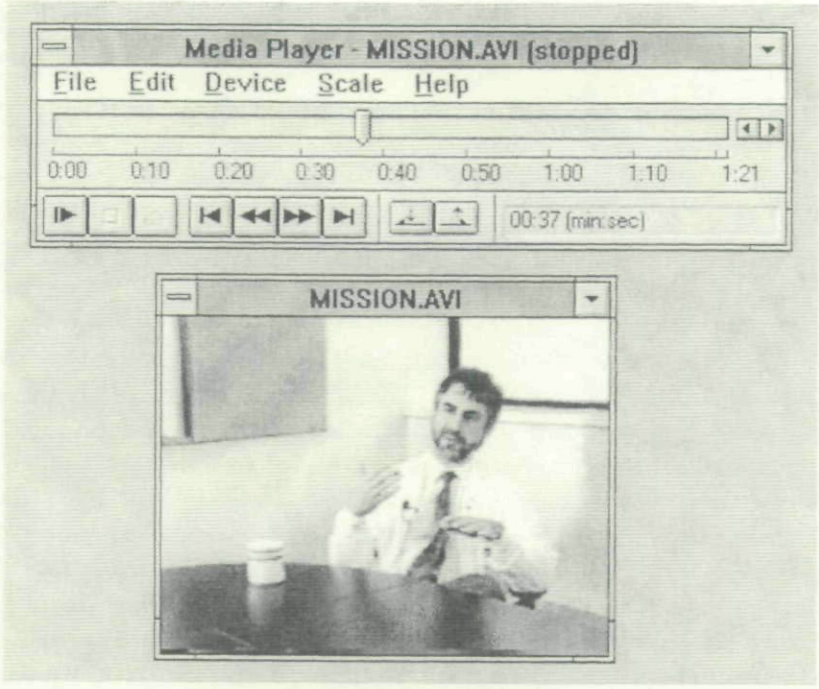

Figure 2. An Example of the User Interface of the Multimedia System.

Research Center (BCCRC) was used as the background case in this study. The materials used in this experiment included:

1. an interview with the director of the BCCRC on various aspects of the organization, such as its organizational structure and decision-making processes,
2. general introduction to the six departments of the BCCRC, and
3. interviews with several researchers and department heads of the BCCRC.

These interviews were divided into smaller segments based on the specific topic discussed. Transition text was developed to link these segments together to create Web pages.

Depending on the experimental condition assigned, subjects used one of the two versions of the system (text or multimedia). Subjects in the multimedia condition viewed information in real-time, full-motion video. For example, to learn about the mission of the BCCRC, subjects could simply click on a hypertext link that said "mission." A video clip, which showed the director of the BCCRC explaining the mission of the organization, was then presented. Subjects using the text-based system received the same verbal content in text form using the same hypertext link access method. Figure 2 is an example of the user interface in the multimedia system, showing a video clip playing after a hypertext link was selected in a previous screen. Figure 3 shows the corresponding user interface in the text-based system when the same

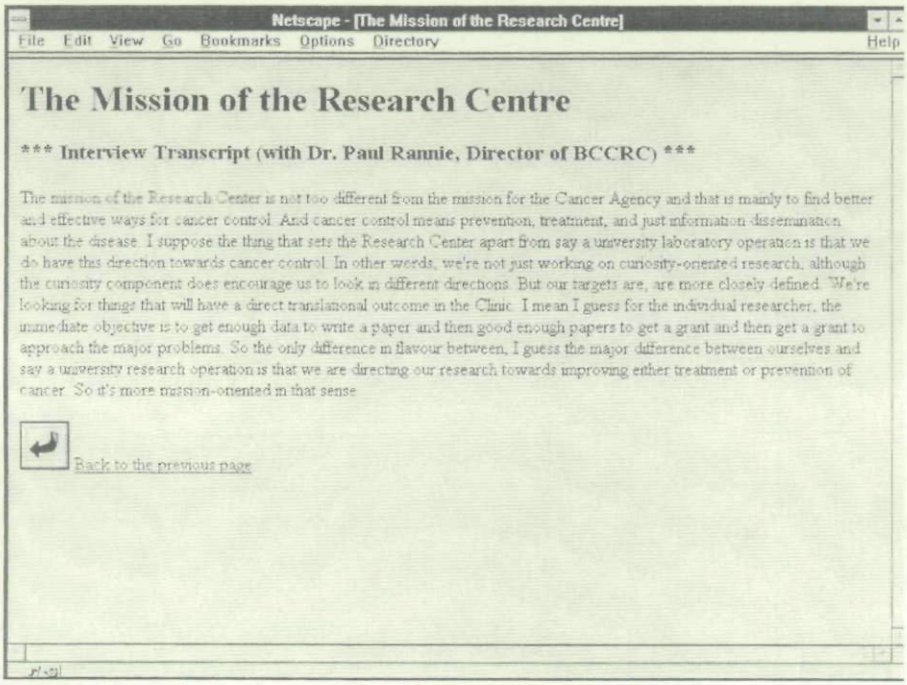

Figure 3. An Example of the User Interface of the Text-Based System.

selection was made. A professional transcriber prepared the written transcripts. These transcripts included only the spoken words, as would be the case for ordinary meeting transcripts. An independent research assistant proofread the transcripts with the aid of the actual video clips.

Experimental Task

At the beginning of the experimental session, subjects were instructed to play the role of a newly appointed board member of the BCCRC. Since they were new to the organization, their task was to become familiar with the BCCRC. Subjects used either the text-based or the multimedia system, depending on a random experimental assignment, to examine the information that provided an overview of the BCCRC. This included clarifying the relationship between BCCRC and its two sister organizations (British Columbia Cancer Agency and British Columbia Cancer Foundation), illustrating the BCCRC organizational structure, describing the mission of BCCRC, and explaining the functions of each of the six departments within the BCCRC. In both conditions, subjects were given 20 minutes, which, based on pilot testing, was concluded to be sufficient time to browse through the information. Using Netscape, subjects had the option to probe various aspects of the organization. For example, subjects could find out more about the mission of the BCCRC by "asking" the director of

BCCRC (via clicking the hypertext link that said "Mission of BCCRC"). Subjects could also "visit" a particular department of interest (by clicking on a hypertext link that has the name of that department).

At the end of the 20 minutes, subjects were instructed to stop. They were then given a comprehension test, which consisted of 15 questions, shown in Appendix C. Subjects were *not* allowed to refer back to information in the system when answering the questions.

Independent Variable

Media type was the only independent variable. Two systems, a text-based system and a multimedia system, were contrasted in the experiment. The two systems were equivalent in terms of verbal information content. The only difference was that the multimedia system presented some information in the form of video clips, whereas the text-based system presented the same information using text transcripts exclusively.

Dependent Variables

There were three dependent variables, *comprehension of explanative information, comprehension of descriptive information,* and *inference ability.* A reading comprehension test was used to measure these variables. The test consisted of three parts: an explanative test, a descriptive test, and an inference test. The validities of these tests are discussed in Appendix D.

1. *Comprehension of explanative information.* Three questions that directly asked about the functional relationships of presented ideas were used to measure the comprehension of explanative information. They are questions 1, 2, and 5 in the Comprehension Test (Appendix C).
2. *Comprehension of descriptive information.* Five *fact-based* questions were included as the descriptive test. These questions required subjects to recall facts that were explicitly mentioned in the information presented. These are questions 3, 4, 6, 7, and 8 in the Comprehension Test (Appendix C).
3. *Inference ability.* Seven inference questions were included in the Comprehension Test (questions 9–15 in Appendix C). These questions required subjects to infer information that was not previously learned. To answer these questions correctly, subjects had to make inferences based on the information they had examined.

In the experiment, the subjects were indeed given enough materials to answer all the questions in the three tests. The information needed to answer the descriptive and explanative questions was explicitly presented. On the other hand, the information for the inference questions was not made explicit. The subjects needed to connect the facts presented and make inferences to derive the correct answers.

A pretest was conducted to ensure that subjects would be able to answer all the questions in the tests with the information provided in the system. Two subjects, other

than those who participated in the actual experiment, were given the test and asked to search for the answers to the questions. One of them used the text-based system; the other used the multimedia system. No time limit was made, and they were allowed to revisit the information stored in the system while they were answering the questions. Both of them correctly answered all 15 questions. This indicated that both systems contained the necessary information to answer the questions and were equivalent in terms of information content.

Experimental Procedures

The experiments were conducted with one subject at a time in an isolated room. All experimental sessions, with the exception of the pilot study, were conducted by two research assistants (one research assistant at a time), trained together by the first author. The research assistants were asked to strictly follow the experimental protocols given. The research assistants were not told the objectives and the hypotheses of the study until the data collection phase was completed.

Preexperimental Session

Upon arrival, subjects were greeted and thanked for their participation and interest. They were then shown to the seat in front of the computer. After the subject signed a consent form, the research assistant handed the subject an instruction sheet labeled General Description (see Appendix A). Next, a 10-minute tutorial on the Web and Netscape was introduced. This tutorial was self-paced, but the research assistant stood next to subjects to answer any questions. The entire preexperimental session took about 15 minutes.

Experimental Session

Subjects were given the first instruction sheet (labeled as Task Description Ia in Appendix B). They were told to press an "OK" button whenever they were ready to start. They were given 20 minutes to examine the information in the system. The allotted time was determined through a pilot study. Through the pilot study, it was established that with 20 minutes subjects could comfortably go through the information once and still have time left to review part of the information if they wished. The research assistant moved to a corner of the room while subjects were performing the tasks. The subject was asked to note any irregularities during the experiment.

After subjects had examined the information in the system, they were given the comprehension test (Appendix C). To discourage random guessing, for the descriptive and explanative parts of the comprehension test, subjects were told beforehand that a quarter of a point would be deducted from their score for each wrong answer. They were asked to leave the response blank if they could not remember the correct answer. Also, for each question, the answer choices were made similar enough that it was difficult to guess without knowing the answer. Most subjects finished the test within five to eight minutes.

Statistical Analyses

A PARTIAL LEAST SQUARES (PLS) ANALYSIS, which is a second-generation statistical analysis method, was used to analyze the collected data. The key advantage of the second-generation techniques, such as PLS and LISREL, over first-generation techniques is the greater flexibility that they give to researchers to examine the interplay of theory and data. Specifically, second-generation techniques allow the observation of:

- model relationships among multiple criterion variables;
- unobservable (latent) construct variables;
- model errors in measurements for observed variables; and
- a priori substantive or theoretical and measurement assumptions against empirical data [8].

Most important, second-generation statistical methods allow simultaneous assessment of the measurement and theoretical (structural) model [6, 7].

Subjects' Profiles

Of the 80 subjects, 54 percent were males. Their average age was 25. One-half were business students; the others majored in the sciences (27 percent) and the arts (23 percent). Forty-seven percent were undergraduate students; the rest were graduate students.

Criterion (b), identified by Chin [7], allows us to identify three independent latent variables affecting inference ability and one independent latent variable affecting descriptive information and one affecting explanative information. Based on Chin's criterion (a), descriptive information has five indicators and explanative information has three indicators, whereas inference ability has six indicators. Therefore, the minimum sample size required is 60 (6×10). With 80 subjects, we believe that our PLS analysis has sufficient power.

Evaluation of Random Assignments and Possible Outliers

First, to ensure that the random assignment was successful, the experimental treatments were compared based on five variables: age, gender, year of study, major field of study, and language background. No statistically significant differences were found across the experimental conditions on these five variables. The descriptive statistics for these five variables across the treatment conditions are reported in Table 1.

There were no univariate or multivariate within-cell outliers at an alpha level of 0.001. However, it was noticed that very few subjects (only 10 out of 80) were able to correctly answer question 9 (one of the inference test questions). Although it was not intended, this question assumes some background knowledge on the part of the subjects. To correctly answer the question, the subject needs to understand the difference between a journal that publishes theory-based research and one that publishes ap-

Table 1. Descriptive Statistics on the Subjects' Demographics Across Treatments

	Text-based system	Multimedia system
Number	40	40
Age	25.2	24.4
Gender	21 males	22 males
	19 females	18 females
Year of study at university	5.5 (1st year graduate study)	5.1 (1st year graduate study)
Major	8 — Arts	10 — Arts
	11 — Sciences	10 — Sciences
	21 — Business	20 — Business
Language	29 — English as 1st language	27 — English as 1st language
	11 — English as 2d language	13 — English as 2d language

plied research. This question was dropped from further analysis. As a result, only six out of the original seven inference questions were included in the final analyses.

Results

Table 2 shows the means and standard deviations for the three dependent variables.

We hypothesized that comprehension of explanative information was mediating the relationship between media type and the ability to make inferences. A structural equation modeling software package, PLS-Graph [32], was used to test this expected relationship. The results of the PLS analysis are presented in Figure 4. In Figure 4, the number on top of each path represents the weight (similar to a standardized beta weight in a regression analysis). The R^2 value for each endogenous construct (that is, descriptive information) represents the proportion of variance in the construct accounted for by the antecedent constructs [5].[7]

First, Figure 4 shows that the path from the media type to explanative information (beta = 0.31) was significant at $p = 0.05$, but the path from media type to descriptive information (beta = –0.16) was not. This indicates that media type significantly affected the acquisition of explanative information, but not of descriptive information. Therefore, H1a is supported but H1b is not.

Second, Figure 4 also shows that the direct path from media type to inference ability (beta = 0.177) was not significant, that is, the use of a text-based or multimedia system did not *directly* affect the ability to make inferences as predicted in H2a. Third, the path between explanative information and inference ability (beta = 0.32) was significant at the 0.05 level. This supports H2b, which states that subjects who score high on the explanative test will also score high on the inference test. Finally, the path between descriptive information and inference ability (beta = 0.13) was not significant. This supports H2c, which states that subjects' recall of descriptive information will not affect their inference ability.

Table 2. Means (Standard Deviations) of Explanative and Descriptive Test Scores

Variable	Text-based system	Multimedia system
Explanative test score	2.10 (0.74)	2.70 (1.07)
Descriptive test score	3.03 (1.03)	2.70 (1.07)
Inference test score	2.55 (1.32)	3.23 (1.23)

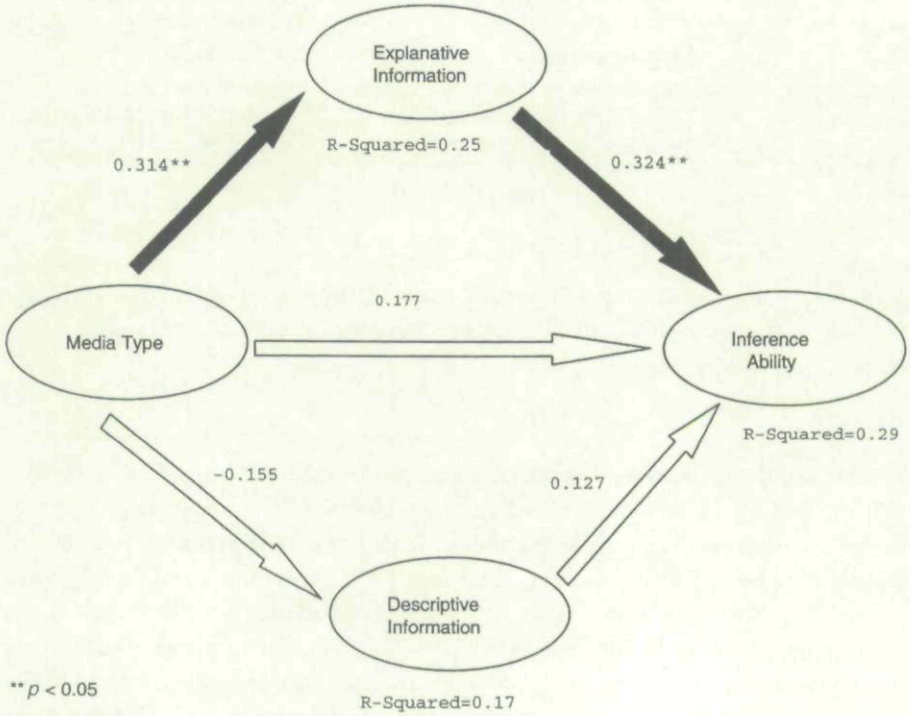

Figure 4. The Results of the PLS Analysis.

Taken together, the results of the PLS analysis demonstrate that the media type did not *directly* affect inference ability. Instead, the media type affected the acquisition of explanative information, which in turn affected the ability to make inferences. Overall, this is consistent with our prediction that comprehension of explanative information mediates the relationship between media type and inference ability.

Discussion and Conclusions

THE FOCUS OF THIS STUDY WAS THE INVESTIGATION of how multimedia can be utilized to enhance the capability of conventional text-based systems with the purpose of improving information comprehension. In the results reported in the previous section, the use of multimedia was found to facilitate the retention and subsequent recall

of *explanative information* but not of *descriptive information.* Explanative information is organized facts connected by their underlying *functional relationships.* Descriptive information consists of *isolated facts* without an explanation of the relationships between these facts. The advantage of multimedia systems in facilitating the retention and recall of explanative information is attributable to the inherent features of multimedia. Specifically, multiple representations of information compensate for the limitations of each type of representation when used alone [18]. Further, better retention and recall of explanative information leads to a greater ability to apply it to new situations. Taken together, results indicate that multimedia systems present information in such a way that they facilitate the acquisition of explanative information, and this in turn leads to a greater ability to make correct inferences.

Regardless of the type of information the system is intended to convey to its users, multimedia presentation clearly has the advantage of creating a deeper level of understanding, as indicated by supporting and enhancing inference ability. This finding has also been observed in other organizational research. Based on a meta-analysis of 21 experiments, Premack and Wanous [31] concluded that a new employee's future job performance might be affected by the method of presentation (reading from text-based documents versus audiovisual presentation) during their job orientation training. They speculated that audiovisual presentation increased job performance by showing subjects a successful "behavioral model" prior to commencing work. Together, our results show that multimedia presentation has the advantage of helping learners and decision-makers to create a better and deeper level of understanding of the information.

Limitations

Several limitations exist in this research and warrant some discussion. First, although the PLS analysis used in this study provided significant results that supported several hypotheses, the R^2 values obtained were lower than desired, ranging from 0.17 to 0.29. However, this is reasonable as learning is affected by a large number of factors other than the learning materials themselves. It is expected that individual abilities and motivation play key roles in learning outcomes. Further, an R^2 value of less than 0.1 is not uncommon in behavioral science studies, as well as in research employing structural equation modeling [12]. In light of this fact, the R^2 values obtained by this study should be considered acceptable.

The second limitation is the realism of the simulated system and task. Every effort was made to ensure the realism of the experiment. This includes the use of authentic experimental materials from a real organization. Nonetheless, several inherent weaknesses might have discounted the desire of realism. For example, to ensure that subjects were able to complete the tasks within a predetermined length of time, the information stored in the experimental system was reduced to a minimal level. In a more realistic organizational situation, the amount of information stored in a real system is more than that of the simulated system in the experiment, though decision-makers are unlikely to examine all of it.

Another limitation of this study is the type of questions used for measuring comprehension and inference ability. Multiple choice questions were used for the comprehension and inference tests. Open-ended questions would have provided a richer data set on how subjects make inferences and a deeper level of understanding of why and under what situations multimedia works better than text, though responses to open-ended questions are more open to interpretation.

Contributions

The major theoretical contribution of our study is that it provides a theory-based explanation of the benefit of multimedia presentation. Despite the popularity of multimedia technology, empirical evidence establishing its benefit has remained mixed [6, 10, 13, 14, 29]. This study provides a possible explanation for this mixed finding. In this study, we found that multimedia presentation can only improve the comprehension of explanative information, but not of descriptive information. This finding is consistent with several studies that show that multimedia only improves the recall of conceptual information and actual problem solving but not the retention of verbatim information [21, 29, 30]. Therefore, one of the possible reasons for the mixed results observed in the literature may be that different research studies were actually examining different types of information.

Another contribution of this study is that it draws from the education literature and tests the theory developed in an organizational context. Although there exists a considerable body of literature examining the benefits of multimedia, most of these studies were conducted in the context of how grade school children could benefit from multimedia technology. By developing and testing a multimedia theory in the organizational context, this study establishes how organizations might benefit from this new technology.

One practical implication of this study is that it provides some preliminary guidelines on how organizational information can be effectively stored and presented. One major domain of application is the design of intranets. Intranets have gained popularity during the past few years. However, little research has been conducted to guide their design. Although larger organizations might have long recognized the values of storing their organizational information in multimedia format, such practice could still be expensive for smaller organizations [38]. The advent of the intranet technology lowers the cost barrier for smaller organizations. However, the new challenge is to derive a set of guidelines on how and when to use this rich array of tools (text, graphics, audio, video, and animations) so that organization members can make better use of the information.

Our results suggest that capturing and presenting information on descriptive information requires only text-based representation. However, multimedia representation can be used to enhance the comprehension of explanative information. Not only should system designers take this into consideration when designing their organizational intranets, but users should also be aware of the consequences of media differ-

ences and be sensitized to matching the media type with their information processing needs.

From a larger perspective, the three studies we conducted to compare text versus multimedia-based information presentation extended our understanding of the conditions under which multimedia would be beneficial in organizational contexts. However, they also point to the potential dangers of misusing multimedia capabilities. We observed [23] that although multimedia could reduce the influence of a negative first impression bias, it might also be used to mislead managers to create a false positive first impression bias. Furthermore, although multimedia presentation could reduce the perceived ambiguity of provided equivocal information [22], it might create confusion when used to present less equivocal information. In the study reported in this paper, we found that multimedia is useful for improving the comprehension of explanative but not descriptive information. Considering the findings of our Study 2 [22] and the current study, it appears that multimedia is best suited to presenting equivocal explanative information.

Together, the findings from the three studies suggest that, to take full advantage of multimedia, systems designers and managers need to be aware of its strengths as well as its potential weaknesses. Although our studies provided some initial guidelines for multimedia usage, they also point to the need for more future studies to develop a comprehensive theory for organizational use of multimedia so as to understand better the conditions under which multimedia can be beneficial or harmful to organizations. The next section suggests some possible avenues for future research.

Future Research

Using multimedia to preserve organizational information is still a relatively new practice. Much research needs to be done before the benefits of multimedia systems can be fully tested. One immediate research direction is to compare other means of capturing and presenting organizational information. In our research, two very basic systems were chosen for the comparison. It would be prudent to examine whether the findings would hold for other systems. For example, synchronization of the multiple representations (that is, of the verbal description and image) can be varied (total synchronization for the two versus off-synchronization). Comparing the two systems would provide answers on whether the benefits of multimedia are indeed derived from the fact that multiple representations provide multiple information cues, or from the fact that multimedia simply presents information in a more "natural" and easy to understand form.

In this study, the benefits of multimedia were examined in a static context in which decision-makers attempt to comprehend and make inferences based on the information provided. One natural extension is to examine the use of multimedia information in a more dynamic context in which various people interact with each other, one that is similar to the situation encountered by virtual teams. The results of such a study would provide guidelines for the design of information systems that better support the needs of virtual teams.

Conclusions

The growing use of audio and video conferencing as well as the Internet demonstrate that these information technologies will likely become common to an organization's information processing activities in the future. Capturing video and audio information may not be as cumbersome as was once believed. Although it is still expensive to retain audio and video information, in terms of computer storage costs, this cost may be offset by the elimination of the labor cost of manually transcribing information to text. In addition, the cost of storage will probably continue to decrease rapidly as storage technologies improve. Still, we need to emphasize that making video and audio that are useful to others to see is extremely labor-intensive. The overall expense exceeds the equipment cost. Development of useful materials involves a large number of hours of outlining the scope and purpose of the shoot, writing and refining a script, practicing, shooting, reshooting, editing, and so on.

In conclusion, this study has demonstrated that multimedia can be used to improve the comprehensibility of organizational information. Although cost and technical difficulties may still prohibit the widespread adoption of multimedia technology for preserving and capturing organizational information, this will change as organizations realize the advantages of using the technology. We see this research effort as a step in that direction.

Acknowledgments: The authors thank Fan Chun and Sharon Hartung for their assistance in conducting this research, Gary Schwartz for providing audiovisual support, and Wynne Chin for his help with the PLS analyses. They also thank Ricki Goldman-Segall, Robert Goldstein, Bill Remus, Choon Ling Sia, Glen Taylor, and Lawrence Ward for their valuable comments. They especially thank the British Columbia Cancer Research Agency for providing the background information needed for this study. Financial support for this study was provided by the Social Sciences and Humanities Research Council of Canada and the Natural Sciences and Engineering Research Council of Canada.

Notes

1. We thank one of the anonymous reviewers for pointing this out to us.
2. Note that the concepts of descriptive versus explanative knowledge map closely to the concepts of near versus far transfer and rote versus meaningful learning [3, 27].
3. Note that although it is true that readers can go through several rounds of reading to make sure that the information is fully comprehended, it remains true that such processes are cognitive effort intensive.
4. It should be added that there has been considerable debate on Paivio's notion of two memory systems. Other theorists, mainly from the artificial intelligence camp, for example [2, 30], have argued for a single memory representation.
5. This study was conducted in 1995 when the Web was still in its infancy.
6. Some information was altered to safeguard confidentiality.
7. The significance of the path coefficients was tested using the Jackknifing routine [38, 41]. The Jackknifing routine operates by calculating the probability of obtaining a particular coefficient if the true value of the coefficient is zero. Therefore, the smaller the probability the higher the chance that the obtained coefficient is different from zero.

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Appendix A

General Instructions

HI THERE, AND WELCOME.

Thank you for participating in this study.

The British Columbia Cancer Research Center (BCCRC) has approached us, the researchers of this study, to design and implement a prototype computer system that captures past information of BCCRC. Your task in this experiment is to help us evaluate this system and see how this system can be used to help make better decisions.

You will be playing the role of a newly appointed board member of B.C. Cancer Agency (the parent organization of BCCRC). You will be using a computer system in performing these tasks. Every piece of information stored in the system is potentially important in helping you to perform the tasks. Therefore, we would like you to examine *all* of the information carefully. *Please do not skip any part of the information (visit all hypertext links)!*

Appendix B

Task Description Ia

BEING A NEW BOARD MEMBER of the British Columbia Cancer Research Center (BCCRC), you are naturally very keen to learn more about BCCRC.

Your first task is to familiarize yourself with BCCRC. The BCCRC's Organizational Memory System (OMS) will help you to achieve this. The system contains *REAL* information about BCCRC. It is constructed based on the principle of hypertext—in other words, you can get more detailed information about a particular topic/theme by clicking on a highlighted text corresponding to that topic/theme.

After you have finished examining the information stored in the OMS, we will ask you to answer a set of questions to *evaluate your level of understanding* of BCCRC. Some questions ask you about facts that you will examine, others will require you to make inferences based on the facts. Your score on this questionnaire will be part of your overall performance score, which will be used to determine the three best performers for additional cash awards. Again, each of the three best performers will be awarded an additional $30.

You will have 20 minutes to review information related to Task I. The lab assistant will inform you when the time is up. After that you will have five minutes to answer a set of questions.

If you have any questions, please ask the lab assistant now.

When you are ready to begin, inform the lab assistant.

Appendix C

Comprehension Test ID#:_____

Questions 1–8 are based on the facts in the OMS related to BCCRC that you have just examined. Please try your best to answer these questions. However, if you are uncertain about the answer to a particular question, leave it blank—there is no penalty for leaving it blank, but a quarter of a point will be deducted for each incorrect answer.

1. Who is the immediate superior of the Chief Operating Officer?
   a. Director of Operations
   b. Chief Executive Officer (CEO)
   c. Chairperson of the Board of Trustees
   d. Head of the Executive Committee

2. Who is the immediate superior of the Head of Medical Biophysics Department?
   a. Director of Radiation Oncology
   b. Director of Medical Oncology
   c. Director of Research
   d. Chief Operating Officer

3. Which of the following is the closest to the number of people working in the British Columbia Cancer Research Center (BCCRC)?
   a. 230
   b. 250
   c. 2,300
   d. 2,500

4. Which of the following is true about BCCRC?
   a. Its mission is to find better and effective ways for cancer control.
   b. It is a nonprofit organization that raises money by itself for cancer research.
   c. It is part of the British Columbia Cancer Agency.
   d. More than one of the above (please indicate which ones _____).

5. The Head of the Cancer Imaging Department would like to appeal for a higher salary increase. Whom should he approach?
   a. The Director of BCCRC
   b. The Director of Human Resources
   c. The Chief Executive Officer (CEO)
   d. The Executive Committee
   e. The Board of Trustees

6. Using LIFE device,
   a. the red laser light makes cancerous cells appear blue and healthy cells appear green.

b. the green laser light makes cancerous cells appear red and healthy cells appear blue.
c. the orange laser light makes cancerous cells appear blue and healthy cells appear red.
d. the blue laser light makes cancerous cells appear red and healthy cells appear green.

7. Which department created the world's first solid-state microscope for screening cancerous cells?
   a. Cancer Endocrinology
   b. Cancer Imaging
   c. Epidemiology, Biometry, and Occupation Oncology
   d. Medical Biophysics
   e. Medical Oncology-Laboratory Operations (MOLO)
   f. Terry Fox Laboratory

8. Which department is involved in chemotherapy research?
   a. Cancer Endocrinology
   b. Cancer Imaging
   c. Epidemiology, Biometry, and Occupation Oncology
   d. Medical Biophysics
   e. Medical Oncology-Laboratory Operations (MOLO)
   f. Terry Fox Laboratory

The following questions require you to make inferences based on what you have just learned about BCCRC. In other words, you may not be able to answer these questions based on the information you have just seen. *You need to think and deduce your answers from your understanding of the organization.* Try your best to answer these questions. However, if you are uncertain about the answer to a particular question, leave it blank—there is no penalty for leaving it blank, but a quarter of a point will be deducted for each incorrect answer.

9. To which one of the following research publications do you think the Medical Oncology Department of BCCRC is more likely to report their research findings?
   a. Journal of Biochemistry Research
   b. Journal of Applied Biochemistry
   c. Journal of Radiation Science
   d. Journal of Radiation Therapy

For Questions 10–15, please select one item from the following list that best matches the answer. *Each item can be used more than once.*

a. British Columbia Cancer Agency (BCCA)
b. British Columbia Cancer Research Center (BCCRC)

c. British Columbia Cancer Foundation
d. Cancer Endocrinology
e. Cancer Imaging
f. Epidemiology and Occupation Oncology
g. Medical Biophysics
h. Medical Oncology-Laboratory Operations
i. Terry Fox Laboratory
j. Radiation Oncology

10. One of the six departments within the Research Center recently opened the first *proton treatment research center* in Canada. Which department is most likely to be the one? _____

11. Which department is most likely to be the one pioneering the research in *Autologous Bone Marrow Transplant,* an important tool in treating *leukemia?* _____

12. John Dole has a Ph.D. in Electronics and Electrical Engineering. Which department is he most likely to be working for? _____

13. If a person would like to make a donation toward cancer research, which organization should they contact? _____

14. A pharmaceutical company would like to send their new drug that treats leukemia to an independent institution for further testing. Who should they contact? _____

15. A patient who has lung cancer would like to volunteer as a subject for new treatment. Who should they contact? _____

Appendix D

Validity of the Test Questions

THIS APPENDIX DISCUSSES THE VALIDITIES of the questions used to measure descriptive information, explanative information, and influence ability.

Qualitatively, the questions were developed based on their theoretical definitions used in the literature. Descriptive information is information in which the key components or events are described but not explained. Examples of questions testing descriptive information include questions such as: How many people work in BCCRC? Which department is involved in a particular type of research activity?

Explanative information, on the other hand, refers to information in which the functional relationships among two or more variables/ideas are expressed and explained. Examples of questions testing explanative information include questions such as: Who is the immediate superior of X? To whom should Y approach if he would like to appeal for a higher salary increase? Questions used in both descriptive and explanative information tests were based on information explicitly stated in the information presented.

Finally, inference ability is the ability to solve problems that are different from those previously learned. Questions in the inference test required the learner to generalize responses based on the information presented. Answers to these questions cannot be found directly in the information presented.

Note that in structural equation modeling terms, these questions are formative measures (rather than reflective measures). This means that each of these questions taps into part of the construct that it supposed to measure [8]. For example, each of the four questions in the explanative test measures one aspect of explanative information.

Quantitatively, there are several ways of examining discriminant validity. One is to calculate the average variance shared between the *constructs* and their *measures* (indicators), that is, the average variance extracted (AVE) and compare it to the variance shared between the constructs themselves [15]. The calculation of AVE involves taking the average of the loadings squared for all indicators that measure the construct of interest.[1] The loadings are interpreted on the extent to which the measure (indicator) is correlated with the overall component score (rather than with other measures).

Using this method, we derived a correlation-AVE matrix with descriptive information, explanative information, and inference ability as the three separate constructs. The matrix is shown in Table D1. Note that the diagonal elements are the square roots of AVE. Off-diagonal elements are the correlations among constructs.

The key evaluation criterion is that all the diagonal elements in a correlation-AVE matrix must be greater than the corresponding off-diagonal elements. All entries in Table D1 conform to this criterion. This analysis established the convergent and discriminant validities of the three constructs.

Table D1. Correlation-AVE Matrix for the Three Constructs

	Descriptive information	Explanative information	Inference ability
Descriptive information	0.841	—	—
Explanative information	–0.080	0.724	—
Inference ability	–0.302	0.459	0.762

NOTE

1. AVE = SUM (loading)**2/[SUM (loading)**2 + SUM (1 – loading)**2] (see [5, p. 306]). The equation can be simplified to the following form: AVE = SUM (loading)**2/N, where N is the number of latent variables involved in the construct of interest.