Interactive Effects Between Cognitive Preferences and Instructional Strategies in Museum Learning Experiences

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Abstract: The wide opportunities offered by web-mediated environment have successfully convinced museums around the world to utilise the technology in enhancing their visitors' learning experiences. However, museum's visitor profiles are expected to involve diverse characteristics such as gender, background, and prior knowledge. These visitors' profile differences thus enforce museum curators to be mindful of how to present their online exhibits to ensure they afford more effective learning experiences. Yet, the rising interest in creating online museum environments presents fresh dilemmas for museum curators and their exhibit designers to understand the visitors' numerous differences. Meanwhile, examining cognitive differences in individuals is now becoming essential in understanding and explaining the complexities of effective human-computer interaction (HCI) whereby suggest that individual cognitive preferences may have an impact on how environmental variables affect learning. Accordingly, this research proposed that allowing for an individual's cognitive preferences may provide an appropriate solution to improve the design of the museum exhibits, particularly in the web-mediated environment. Applying the quasi-experimental design, the research investigated the interactive effects between the participants' cognitive preferences and the museum information representation formats within two different instructional strategies. The findings reveal that cognitive preferences do have an effect on the participants' performance in their museum learning outcome. Accordingly, an interaction effect was noted between the participants' cognitive preferences and the instructional strategies in their museum learning performances. The findings from this research help to understand how learners' mental models may work to enhance their information processing through the web-mediated instruction they receive thus provide the empirical evidence that it is important to understand how specific multimedia format can better present the online museum exhibits.

Keywords: cognitive preferences, instructional strategies, multimedia formats, museum learning, web-mediated environment, human-computer interaction

1. Background

Museums have been well accepted as informal settings for learning (Falk and Dierking 1992; Black 2005). Although the role of museums in supporting the formal education of the general population is usually associated with visits to a physical museum, web-mediated museums are emerging to provide more information to many people, as well as further enrich their life-long learning experiences. The recent development demonstrates that the web-mediated museum environment has now been recognized as a 'cognitive space' in which a museum operates to deliver pertinent information and exhibit their artefacts. Initially, the adoption of multimedia in museum exhibitions started as a mechanism to digitise their collection (Witcomb 2007). However, as museums grow alongside the advancement in Information and Communication Technology (ICT) exhibiting tools, museums utilise these technological tools for more than recording their collections into electronic databases or embedding the exhibition itself as an ICT artefact. Instead, museums are now optimizing the use of these media tools to enhance and facilitate the process of learning particularly using the Web-mediated communications tools that offer new learning opportunities (McKay 2003).

Apart from that, museums need to consider the diversity of their visitors' profiles derives from various characteristics such as gender, background, and prior knowledge. These visitor profile differences thus enforce museum curators to be mindful of how to present their online exhibits to ensure they afford more effective learning experiences. Additionally, the rising interest in creating online museum environments presents fresh dilemmas for museum curators and their exhibit designers (Brown 2006; Marty 2004; Soren 2005) to understand their visitors' numerous differences (Peacock and Brownbill 2007). There is evidence that individual differences in cognitive preferences may have an impact on how environmental variables affect learning as demonstrated by Mendelson and Thorson (2004) and Riding and Staley (1998). The literature does reveal there are various investigations that have been conducted to determine the changing needs and demands of the online museum visitor per se. Nevertheless, the emerging interest in the adoption of web-mediated tools should serve to re-emphasize the need for the exhibit designers to clearly understand how their online visitors process their website information. Accordingly, this paper proposes that allowing for an individual's cognitive preferences may provide an appropriate solution to improve the design of the museum exhibits, particularly in the web-mediated environment.

2. Web-mediated instructions

Multimedia instruction provides broad opportunities and creates many new possibilities for learning environments. New forms of content delivery, for example, add variety to learning which could create interesting learning spaces. In web-mediated instruction, multiple modes of the virtual-oriented representations allow the instructions to be presented for more than one modality. With this implied recognition for cognitive difference, goes the assumption that a learner may learn more meaningfully. This strategy may explain the different approaches that are implemented in the design of web-mediated museum exhibits. In the case of the Melbourne Museum for example, they use multiple exhibit formats to exhibit their online artefacts as depicted in Figure 1. As researchers appear to have been primarily concentrating on combinations of text and pictures (Schnotz and Bannert 2003), it can be seen that the museums do apply such practice by using both verbal (text) and visual (images) in their exhibit display techniques.

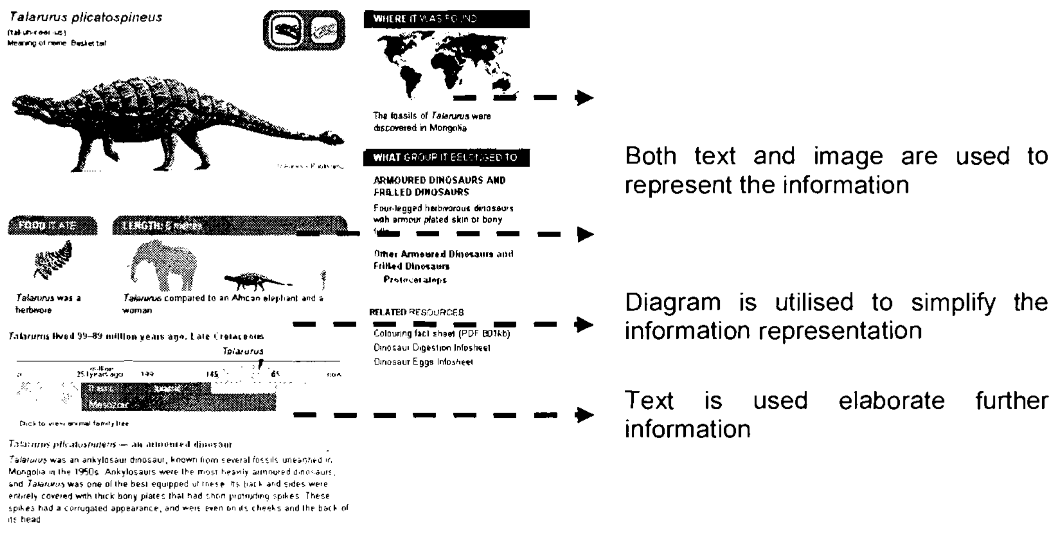

Figure 1: Example of Dinosaur Walk's webpage using multiple representation formats

Multimedia instruction involving words and pictures that are intended to foster learning (Mayers 2009) has prompted new efforts to promote learning. Despite the benefits for promoting learning offered by web-mediated technologies, many suggest that even professionally developed instructions have failed to achieve recognizable learning benefits (Spector and Davidsen 2000; Schnotz and Lowe 2003) as the potential of the technologies can only be realised if the design and use of the technologies are derived from the understanding of how the users learn (Laurillard 2006; Leflore 2000). Furthermore, literature in the area of multimedia learning and instructional design suggests well-designed educational programs should consider both the human cognitive perspective and multimedia principles (Leflore 2000; Merrienboer and Kester 2005; Sutcliffe 2003). This argument is strengthened by the limited capacity of the human brain for information processing (Miller 1956), indicating that understanding human cognitive psychology is an important aspect when designing multimedia instructions, particularly in online learning environments (Sorden 2005). Even so, there has been little or no consideration given to the interactive effect of the differences in cognitive preferences (McKay 2003) and the exhibit's design, during the online exhibit designing process (Berry 2000).

3. Individual cognitive preferences

Individual differences have been a priority for researchers to explain the complexities of effective hûman-computer interaction (HCI), suggesting that understanding cognitive preferences is critical for the success of any web-mediated information systems (IS) development (Elsom-Cook 2001; McCracken and Wolfe 2004; Sharp et al. 2007). The continuous call for investigations into cognitive science indicates of how important it is to address this part of individual differences during the design process. Of particular interest in the educational context, special attention should be given to the relationship between the various multimedia instructions (presentation formats) with the way humans process the information particularly to achieve effective learning (Mayer and Moreno 2002). Various investigations were conducted to determine the changing needs and demands of the web-mediated museum visitors, yet rarely emphasis the need for the exhibit designers to clearly understand how their online visitors process their website information cognitively. Accordingly, understandings individual's cognitive preferences may provide an appropriate solution to improve the design of online exhibits.

3.1 Cognitive style

Cognitive style has been described as *"an individual's preferred and habitual approach to organizing and representing information"* (Riding and Rayner 1998) or in other words, the way an individual processes the information they receive. More recently, there is a growing interest in pursuing research on cognitive preference as demonstrated by the number of new studies that involve web-mediated instructional environments. As most of these studies have been conducted in formal educational settings (Chen et al. 2006; Chen and Lui 2008; Graff 2003; Hannafin et al. 2009), this research hopes to add to the literature by examining an informal web-based educational environment.

Over the years, there have been numbers of models and human-dimensions that have described cognitive style. Various terms have been used by well known researchers to describe cognitive styles; Riding and Cheema (1991) argue that, despite these various names, they appear to be measuring the same thing. Consequently, they condense earlier researchers' style constructs into two families (or dimensions) of cognitive preference (Table 1) which is still one of the most useful models for explaining cognitive differences in recent years.

Table 1: Well known research terms for humans' information processing (McKay 2000).

Terms describing cognitive differences	Researchers
Levellers-Sharpeners	Holzman and Klein (1954)
Field dependence-Field independence	Witkin, Dyke, Patterson, Goodman and Kemp (1962)
Impulsive-Reflective	Kagan (1965)
Divergers-Convergers	Guilford (1967)
Holists-Serialists	Pask and Scott (1972)
Wholist-Analytic	Riding and Cheema (1991)

3.1.1 Wholist-Analytic dimension

According to Riding and Rayner (1998), the Wholist-Analytic dimension is inherent and thus, each individual's cognitive preference is unique and is therefore likely to be a fixed aspect of the individual's (cognitive) functioning (Riding and Rayner 1998; Sadler-Smith and Riding 1999). This cognitive-dimension operates within the actual organisation and structure of the information received by the individual, which is either organised as wholes or as parts, and thereby affects the preference for instructional delivery method, media and learning performance (Sadler-Smith and Riding 1999). Wholists typically view ideas as wholes and are unlikely to be able to separate the information they receive into smaller parts. In contrast, analytics prefer to process information in parts and find it difficult to incorporate smaller pieces of information into a whole entity. Within the wholist-analytic dimension, individuals may perform at their best given the appropriate structure of information respectively.

3.1.2 Verbal-Imagery dimension

The other cognitive preference dimension, which continues to stimulate research in education, is the Verbaliser–Visualiser dimension. The first verbal - visual model was introduced by Allan Paivio in 1971. In that model, he proposed a verbal and a visual cognitive system as the two components of the Verbal-Imagery dimension of cognitive styles (Paivio 1971). The Verbal-Imagery dimension denotes an individual's thinking mode (Riding and Sadler-Smith 1997). Since the Verbal-Imagery dimension interacts with the way information is presented. For example, for text, images and diagrams; it is anticipated that an individual with a verbal preference for that task will perform better given a textual information piece, rather than an image (Sadler-Smith and Riding 1999). Moreover, verbalisers may work better with verbal information, whereas imagers may work better with spatial information (Graff 2003; Riding and Rayner 1998). However, the idea that an individual possesses strength only for a certain dimension (verbal or visual) has been challenged by Antonietti and Giorgetti

(1998). They demonstrate that the verbal and visual dimension is independent; thus, there is a possibility *"...... for an individual to be strong or weak in both dimensions"* (McEwan and Reynolds 2007). A recent finding in neuroscience study also confirms that the Visual-Verbal dimension is anatomically and functionally independent (Kraemer et al., 2009). Moreover, a development in the Verbal-Visual cognitive styles literature suggests that a visual system could be categorised into an object and spatial dimension (Blajenkova et al. 2006; Kozhevnikov et al. 2005; Kozhevnikov et al. 2002). This further suggests that instead of being bipolar, the Verbal-Visual dimension of cognitive styles is three-dimensional (Blazhenkova and Kozhevnivkov 2009; Kozhevnikov 2007).

However, based on observed behaviour choices (Riding and Rayner 1998), a person's cognitive preference is anticipated to be one of four style groups (Figure 2), which are: analytic-verbaliser, analytic-imager, wholist-verbaliser or wholist-imager. Each of the four style group may have different basic preferences towards mode of instruction. As an example, learners who are from the analytic-verbaliser category may prefer text in contrast to those analytic-imagers who may perform better given a captioned picture or diagram. Therefore, it is likely that different individual with different cognitive preferences will perform differently in a given context. Taking into consideration such preferences in individual cognitive performance reveals the various approaches that are implemented in the design of web-mediated learning environments.

Text *Speech* *Diagrams* *Pictures*	ANALYTIC *processing* VERBALISER *thinking mode*	ANALYTIC *processing* IMAGER *thinking mode*	*Diagram* *Picture* *Text* *Speech*
Speech *Text* *Picture* *Diagrams*	WHOLISTS *processing* VERBALISER *thinking mode*	WHOLISTS *processing* IMAGER *thinking mode*	*Picture* *Diagrams* *Speech* *Text*

Figure 2: Possible preferred modes of expression (Riding and Rayner 1998)

4. Integrating multimedia learning and cognitive styles

As discussed earlier, learning through multimedia instructions involved the use of more than one medium of expression or communication; with the intention to promote learning. To do this, properly designed multimedia instructions should be in place (Mayer 2009). Essentially, it is important to note that the way information is represented may influence how individuals attend to appropriate pieces of information (Kolloffel et al. 2009; Mendelson and Thorson 2004). This recognition is further confirmed by Mayer and Moreno's cognitive theory of multimedia learning as illustrated in Figure 3.

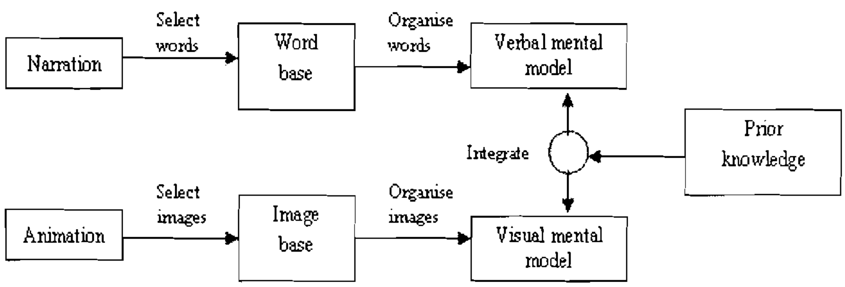

Figure 3: A cognitive theory of multimedia learning (Mayer and Moreno 2002)

The above model shows the cognitive activities where the students need to select relevant words or images, and then organize them into a mental representation to integrate the corresponding representations (Mayer and Moreno 2002). Thus, this model may indeed tap into both sides of a student's thinking mode to exercise their thinking preferences as: the narration uses textual information, while the animation may force them to watch the images. With this duplicity of cognitive activity, the student may be forced to think about the information while reading the words. With consideration of individual cognitive preferences, exploring this relationship in an informal learning context such as a museum would become valuable if the empirical evidence could add to the body of knowledge as well as to the practise in designing the instructions for effective learning. To do so, the research aim was to investigate how the online museum information system interface facilitates students in their museum learning experiences for a range of cognitive learning preferences.

5. Research question

The question raised by this research is "does the interaction of a museum's instructional strategies and a learner's cognitive preferences affect the development of their museum experiential learning?". Four hypothesises were tested in order to provide empirical evidence thus answer the research question. The first hypothesis attempts to provide the evidence whether the instructional strategies affects the learning performance of participants with different cognitive preference in order to cover the overall purpose of the study. As it is necessary to see the effect of each independent variable on the learning performance, the second and third hypotheses were formulated to enable the separate comparisons. Finally, the fourth hypothesis was formulated to conclude the analysis of the interactive effects between the instructional strategies and the cognitive preference on the museum learning experience.

6. Experimental design and data collection

As the online museum visitors are likely to emanate from the formal educational sector (Peacock et al. 2009), the data was collected from primary school students aged ten to twelve years old. The participants were selected from schools visiting the Dinosaur Walk exhibition at the Melbourne Museum. In the research design, it is important to note that the whole cohort for a particular school group had the opportunity to participate in this research. As the students' prior knowledge was considered in the research experiment, students in a particular group were anticipated to share similar backgrounds and to have received the same level of educational experience as others of the same group. By employing a quasi experimental design, each individual group was tested as a whole 'population' to avoid underestimates and statistical errors during the data interpretation.

The fieldwork experimental design has three phases (in the primary schools and the museum). The first phase involved a screening test to measure the participants' cognitive preferences, using the cognitive style analysis (CSA) (Riding 1991) screening test. The CSA and a pre-test to determine the participant's prior domain knowledge related to the museum exhibits were conducted prior to the museum visit. Based on the cognitive preferences identified from the CSA, participants were equally split into the treatment group; either the online museum or the physical museum visit treatment groups.

In the second phase, the treatment groups were given access to either the online museum or the physical museum treatment respectively. For the online session, participants were given 30 minutes to browse the existing web pages of the Dinosaur Walk exhibition in the Melbourne Museum website. Meanwhile, participants of the physical visit treatment group were taken to explore the Dinosaur Walk exhibition in the Melbourne Museum within the same length of time. The final research phase was a post-test to measure any improvement in the cognitive performance (or learning outcomes) derived from the museum's learning exhibits which was conducted at then of the museum visit.

7. Analysis and results

The data gathered using the pre test and post instruments were analysed using the Winstep Software that applies Rasch Measurement Model. The model which is probabilistic and inferential allows analysis of an individual performance relative to the instrumentation as "*the person ability and item difficulty are conjointly estimated and placed on a numerical scale*" (Sick 2008) called logit. A logit is a unit of measurement described as "interval scale in which the unit intervals between locations on person-item map have a consistent value or meaning" (Bond and Fox 2007) or referred as uni-dimensionality. This occurs when the data fit the model and reliability of item placement is established.

The results indicate that for the overall participants' performances, those in treatment 2 performed better with mean of 43.0 compared to those in treatment 1 with mean score of 39.1. Nevertheless, the maximum and minimum scores of both treatment groups reveal that although maximum score was achieved by participant in treatment 2 at 56.0, the minimum score also comes from treatment 2 group at 18.0. Meanwhile, maximum score for treatment 1 group is slightly lower than treatment 2 at 53.0, yet the minimum score is far better than treatment 2 at 26.0. The maximum and minimum scores of both treatment groups are summarised in Table 2.

When it comes to the comparison between genders, the results clearly indicates that the male participants perform better in both instructional strategies. To ensure this is not resulted from gender bias in the instrumentation, further analysis was conducted using the Item DIFF function in the Winsteps software. The analysis shows that the instrumentation is not gender bias as only one item (Q9) indicative of favouring the female participants, out of the overall 21 items. The comparison between genders is displayed in Figure 4.

Table 2: Summary of the max and min score of the treatment groups.

	T1 (47) Online	T2 (44) Physical
Max Score	53.0	56.0
Min Score	26.0	18.0

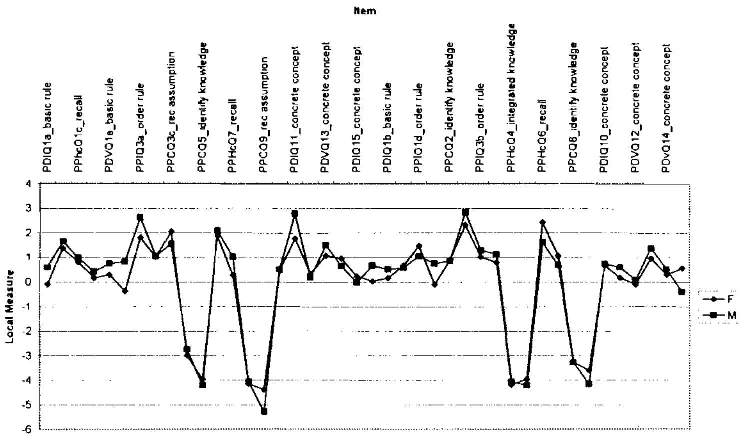

Figure 4: Participants' performance according to gender

The next analysis involves comparison between the cognitive preferences. Based on the summary statistics generated from the specification function in Winsteps, means (verbaliser T1, verbaliser T2, imager T1 and imager T2) were then analyzed to see if there is any improvement in their performance in both instructional strategies thus determines if there was an effect of cognitive styles and instructional strategies on participants' cognitive performance. The result is summarized in Table 3 shows that there is a significance difference in the participants mean score between both instructional strategies whereby for all cognitive preferences group indicate a better performance in T2 (as illustrated in Figure 4).

Table 3: Summary of mean scores according to cognitive preferences

	V-I dimension		W-A dimension	
Instructional strategies	Verbal	Imagery	Wholist	Analytic
T1 (Online)	39.9	38.5	39.5	38.6
T2 (Physical)	42.6	43.4	42.8	44.8

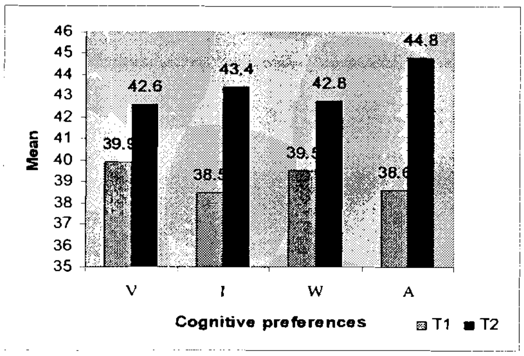

Figure 4: Participants' performance according to instructional strategies

The next measurement, and also the main focus of the research is to look into the interactive effects of the cognitive preferences and the instructional strategies indicates an interaction effect (Johnson and Christensen 2008) does occur as shown in Figure 5a and 5b. This result indicates that there is an effect for both independent variables. In addition, the effectiveness of instructional condition depends on the interactive effect of the individual's cognitive preferences and the instructional treatment.

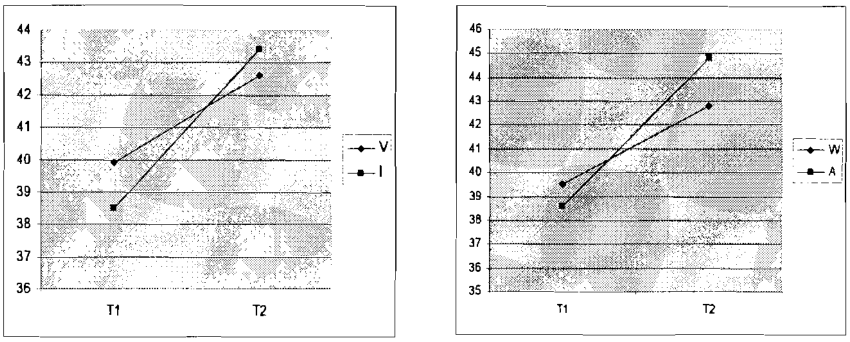

Figure 5: Interactive effects between V-I and W-A dimension and the instructional strategies

8. Discussion

This study aims to investigate differences in learning performance for individuals with difference cognitive preferences (verbaliser or imager) with the museum instructional strategies (online and physical exhibits). Firstly, the results from this study reveal that there is improvement in the learning performance for both instructional strategies. Nevertheless, it could be seen that verbaliser performs better in the online environment as compared imagers. This could be the consequence of both textual and graphical information being displayed together in the online that distort the focus and concentration of the imagers. Moreover, some of the information is displayed in either text or graphical only, could possibly cause imagers to focus more on the images and miss some of the verbal information.

Meanwhile, for verbalisers, they tend to focus more on the textual information therefore achieved better scores. This could be used as an indicator that online museum environment represents both textual and graphical information in a relational architecture could be an effective way to help learners with verbal cognitive preference in their learning process. This situation however differs in the physical museum in which some information could only be observed from the physical objects (exhibits). This finding is consistent with the rationale that imagers will try to picture their environment as a whole thus scored better than verbaliser.

As for the wholist-analytic dimension, the result reveals interesting findings showing that wholists perform better than analytics in the online instructional treatment. Perhaps the combination of both textual and graphical information on the screen helps wholists to capture the knowledge easily than analytics. Meanwhile, despite having both textual and graphical information (similar to the online), the way the information being presented in the physical museum (scattered individually as objects / individual exhibits) allows analytics to process the information in chunks hence perform better than wholists. Accordingly, an interaction effect was noted between the participants' cognitive preferences and the instructional strategies in their museum learning performances.

9. Conclusion

The roles of technology in supporting web-mediated museums not only have to consider individual differences in their visitors' cognitive preferences; we propose that they more importantly serve as a new type of learning environment in their own right. Consequently online museums should be reconceptualised as effective HCI environments, whereby learners may construct their own meanings (Jonassen et al. 1999). ICT tools are often used to support the acquisition of knowledge (Inglis et al. 1999); the information that a learner receives from an external source can then be stored in their memory to retrieve later on. Consequently, suggesting that researchers need to understand how specific ICT tools can better present online museum exhibits, as well as understand how learners' mental models may work to enhance their information processing through the web-mediated instruction they receive.

The cognitive preferences of museums' visitors must be considered for developing the virtual-oriented information representations for their future online museum exhibits. Today, despite the emerging emphasis on multimedia with an increased expectation for virtual-oriented exhibits, these new web-mediated environments integrate both visual and verbal instructional formats. As people have their own cognitive preferences, more research is needed to predict measurable results for a broader range of human cognitive abilities (McKay 2003). The findings from this study may serve to inform museum staff involved in online exhibit design and development that may also be transferable to other web-mediated learning environments.

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