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Consideration for Cognitive Preferences to Enhance Effective HCI in Online Exhibits

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***Abstract*: Clearly, giving consideration to online museum visitors' cognitive differences challenges curators when planning their exhibits. There are interactive effects between the visitor's cognitive preferences and the exhibit's display format on the quality of the resulting human-computer interactions (HCI). The rapid growth of web-mediated technology extends the opportunity to fulfill exhibit facilitation. Although there is research that investigates individual cognitive differences for more traditional learning environments, the concept of online museum exhibits broadens the scope for further research. This paper discusses the interactive effects of cognitive preferences and online museum exhibits, to highlight the need for the consideration of individual cognitive differences when designing the HCI involved in online exhibits.**

***Keywords*:** Human-computer interaction, cognitive preferences, web-mediated instruction, online learning, museum exhibits**.**

I. Introduction

Examining cognitive differences in individuals has been a topic of interest for researchers when explaining the complexities of effective human-computer interaction (HCI). They suggest that understanding cognitive preferences is critical for the success of any web-mediated information systems (IS) development and indicates that understanding computer users involves multiple perspectives [1]. Moreover, the rapid growth of web-mediated environments appears to offer opportunities to enhance students' learning outcomes. We suggest that these interacting factors may also apply to user-centred-design (UCD) practitioners, when customizing their instructional strategies to better fit their instructional outcomes [2].

The online museum's visitor profiles are expected to involve diverse characteristics such as: gender, background, and prior knowledge. We believe these visitor profile differences enforce museum curators to be mindful of how to present their online exhibits to ensure they afford more effective learning experiences. The rising interest in creating online museum environments presents fresh dilemmas for museum curators and their exhibit designers to understand their visitors' numerous differences [3][4]. 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 [5]. Accordingly, this paper suggests that allowing for an individual's cognitive preferences may provide an appropriate solution to improve the design of online exhibits. The current literature reveals that virtual museum visitors are likely to emanate from the formal educational sector [6].

There are various investigations which 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. Even so, there has been little or no consideration given to the interactive effect of the differences in cognitive preferences [7] and the exhibit's design, during the online exhibit designing process [8]. Although there has been ongoing debate on the relevancy and the extent to which cognitive aspects can or cannot contribute towards the effectiveness of the HCI, we believe that individuality such as cognitive preferences emerge as important factors in UCD.

Cognitive style has been described as *"an individual's preferred and habitual approach to organizing and representing information"* [9] or put 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 for example: [10] [11] [12] our research hopes to add to the literature by examining an informal web-mediated educational environment. To address the importance of accommodating individual differences in cognitive preference in the web-mediated museum environment, this paper commences with a discussion on online museums that are emerging as innovative web-mediated educational institutions. We then discuss the two dimensions of cognitive preference (wholist-analytic, verbal-visual) as described by Riding and Cheema [13].

II. Museums as Instructional Settings

Museums have been well accepted as informal settings for learning [14][15]. Although the role of museums in supporting the formal education of the general population is usually associated with visits to a physical museum, online museums are emerging to provide more information to many people, as well as further enrich their life-long learning experiences. As shown in the Melbourne Museum's annual report which recorded a growing number of online visits each year since 2007 indicates that the online environment has been recognized as a 'cognitive space' in which a museum operates to deliver pertinent information and exhibit their artefacts. Another example is the millions of visits each year that are recorded by the Virtual Museum of Canada (VMC) on their website. With such outstanding figures, the potential to promote this type of novel learning environment has become an important agenda for many museums around the world [16]. Due to the complexities of web-mediated instruction, questions are now being raised about how museums will embrace this dilemma through information and communications technology (ICT) tools to improve their visitors' experiences. In general, it would appear that museum curators do try to design their interactive exhibits for a broad range of visitors.

A. *Web-mediated Instructions*

Often, the notion of museum instruction has been interchangeably used as a human-being's process of 'meaning making' for their visitors [17]. As an informal learning environment, an online museum thus affords a free-choice setting where the visiting experience is determined by the visitors' locus of control [15]. Accordingly, individual preferences are acknowledged within the general museum community. Consequently, Kolb's experiential learning theory involves: divergers, assimilators, convergers and accommodators [14]. These profiling characteristics are well recognized by the curators, as they design the instructional strategies for their museum exhibits; Kolb's model is reflected through the various exhibit designs. We believe it is important to note that it is very difficult to design one instructional strategy that suits everyone [18]. Recently, during an informal discussion for our research with a museum expert, it was revealed that, "*although we (the museum) need to follow certain instructional design rules, we (the museum) don't really want our visitors to be restrained by that. Instead, we want them to freely explore and make the most out of that space*".

In addition, as compared to the formal educational settings, museum learning highly depends on object-oriented exhibits that are delivered in a physical orientation. Nevertheless, as the 'physical' information is transformed into a virtual-oriented representation in a web-mediated environment, it is anticipated that the learning experiences rely heavily on the abstract nature of the virtual representation.

Museum learning experiences have been conceptualized as the interaction of personal, social and physical contexts [17]. Consequently, these three categories are organized within a contextual model of learning that are accepted as an active (learning) process as well as a (learning) outcome [14], relying upon one's mental capacity [15]. Even so, whatever (event/data) has been stored within an individual's mental structure it may be interpreted in parallel, as it potentially matches with an individual's existing prior knowledge, or resides as (unprocessed) information until it meets a situation that turns it into knowledge. Therefore, when considering an online museum as the instructional platform, the need for *"an individual to fully understand the overall structure becomes increasingly important"* [11].

B. *Information Representations*

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 online museum exhibits. In the case of the Melbourne Museum, multiple exhibit formats are used to exhibit their online artefacts as depicted in Figure 1.

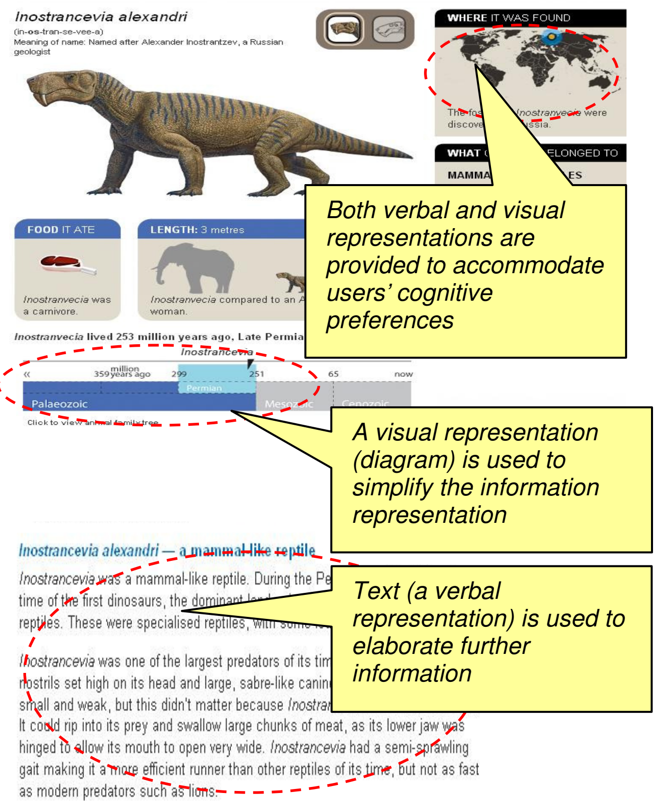

Figure 1. Example of multiple representation formats in the Dinosaur Walk exhibition.

As researchers appear to have been primarily concentrating on combinations of text and pictures [19], we suggest that it can be seen that the museums do apply such practice by using both verbal (text) and visual (images) in their exhibit display techniques. By doing this, the exhibits are presented in a relational architecture which provides the opportunity for the students to see related text and graphical images all at once.

It is important to note that the way information is represented may influence how individuals attend to appropriate pieces of information which further confirmed by Mayer and Moreno's cognitive theory of multimedia learning [20] as illustrated in Figure 2.

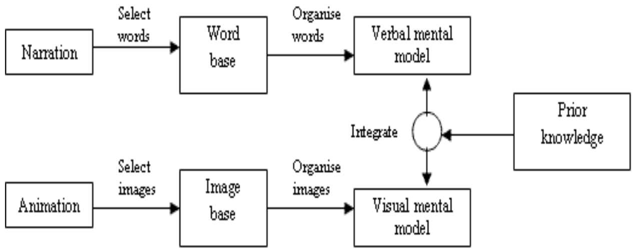

Figure 2. Cognitive theory of multimedia learning [20].

The model in Figure 2 shows the cognitive activities where the students need to select relevant words or images, then organize them into a mental representation to integrate the corresponding representations [20]. We believe that 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. We suggest that with this duplicity of cognitive activity, the student may be forced to think about the information while reading the words. The next section on cognitive styles will have further discussion on the information processing.

III. Considering Cognitive Preferences

Cognitive preference (which some researchers identify as a cognitive strategy according to Riding & Rayner [13] is a human psychological dimension that is *"integrally linked to a person's cognitive system"* [21] which assumes that an individual will *"…… learn differently and that these differences are identifiable and quantifiable"* [22]. As such, cognitive preferences are understood to be an individual's preferred and habitual approach to organising and representing the information they receive, it potentially provides *"……… an extensive and more functional characterization of students than could be derived from intellective abilities"* [23]. As such, researchers have attempted to substantiate the promises of cognitive preferences to enhance the expected educational outcomes. In doing so, Messick [23] listed six educational impacts that cognitive styles should have, to include: (1) improving the instructional methods by providing a foundation to guide the appropriate presentation (delivery) mode, (2) providing the opportunity to better understand students' way of thinking (information processing) which may help to broaden the educational goals and outcomes, (3) enhancing students learning and thinking strategies, (4) enriching teacher behaviour and conceptions, (5) expanding guidance and vocational decision making and finally, (6) tuning the stylistic demands of learning environments.

A. Wholist-Analytic dimension

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 [13] 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 preferences (Table 1) which is still one of the most useful models for explaining cognitive differences in recent years.

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

Table 1. Well known research terms for human's information processing [9].

According to Riding and Rayner [9], 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 [9][24]. 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 [24]. 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.

B. Verbaliser-Visualiser 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 [25]. The verbal-imagery dimension denotes an individual's thinking mode [9]. Since the verbal-imagery dimension interacts with the way information is presented, for example in 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 [24]. Moreover, verbalisers may work better with verbal information, whereas imagers may work better with spatial information [9][11]. However, the idea that an individual possesses strength only for a certain dimension (verbal or visual) has been challenged by Antonietti & Giorgetti [26]. 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"* [22]. A recent finding in neuroscience study also confirms that the verbal-visual dimension is anatomically and functionally independent [27].

However, new development in the verbal-visual cognitive styles literature suggests that instead of being bipolar, the verbal-visual dimension is 3-dimensional as studies by Kozhevnikov and colleagues propose that a visual system could be categorised into an object and spatial dimension [28].

Nevertheless, from the educational research literature it can be identified that all verbal-visual cognitive preference studies focus on two bodies of knowledge [22]. The first investigates the affects of students' cognitive preferences on their ability to learn from different types of material [for example: 5, 29] and the second tends to focus on the effect on success when students choose/are given learning material that matches their cognitive preference, for example: [30][31]. From this assumption, it may be concluded that students' cognitive preferences do have an impact on learning in specific environments.

Based on observed behavior choices [9] as illustrated in Figure 3, a person's cognitive preference is anticipated to be one of four style groups, 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-based 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 3. Possible preferred modes of expression [9].

Despite the extensive work carried out in the area, further exploration on information processing remains important and substantially peculiar in coping with the rapid advancement of ICT tools. Therefore, our research study is designed to continue the exploration of how students' cognitive preferences affect information processing in a web-mediated environment that replicates a physical museum setting.

IV. Experimental Design

The research participants were primary school students aged 10 - 12 years 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 will have the opportunity to participate in this research. As the students' prior knowledge was considered in our 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, we consider each individual group tested as a whole 'population' to avoid underestimates and statistical errors during the data interpretation.

The fieldwork experimental design has three phases (which was conducted in the schools and the Melbourne museum). The first phase involved a screening test to measure the participants' cognitive preferences, using the Cognitive Style Analysis tools (CSA) [32]. 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 ratio, participants were allocated to a treatment group (online or physical visit).

The next research phase was the actual museum activities (or visiting period), in which the treatment groups were given access to either the online museum or the physical museum respectively. For the online session, participants were given access 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. Finally, a post-test was administered to measure any improvement in the cognitive performance (or learning outcomes) derived from the museum's learning exhibits to conclude the experiment. The experimental design for the research study is illustrated in Figure 4.

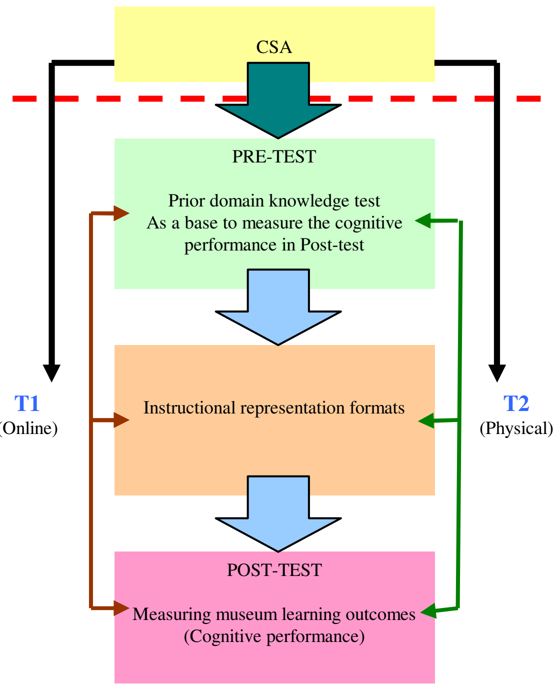

Figure 4. Experimental design of the research study.

V. Instrumentations

As the research study was using existing museum exhibition, the instrumentations used to measure the cognitive performance have been self-developed according to the specified learning content within the exhibition. A calibration experiment was carried out in a school with students in grade 5 and 6 (aged 10 to 12) according to the research design and follows the same methodology as the main experiment which has been discussed earlier to ensure accuracy, homogeneity and reliability of the measure. This calibration experiment was conducted to validate the testing instrument as well as to check the reliability of the research design.

VI. Procedure

A pilot test of 30 students was then conducted. Prior to the experiment, all participants were required to undergo the cognitive style analysis screening test (CSA) to identify the participants' cognitive preferences. The test was carried out three weeks before the experiment and took place in the school library within a designated area for the experiment. Although it was suggested in the manual that the test could be finished within 30 minutes, participants were informed that they could take as long as they needed to complete the test to avoid anxiety. Nevertheless, the experiment reveals that most of the participants took less than 30 minutes to finish the test.

A scattered graph (Figure 5) which plotted each participant's CSA ratio of a particular school group was used to split the participants into two treatment groups. Each pair of participants with nearest verbal-imagery ratios were identified and one anonymously assigned treatment 1 (T1-online) and the other assigned treatment 2 (T2-physical).

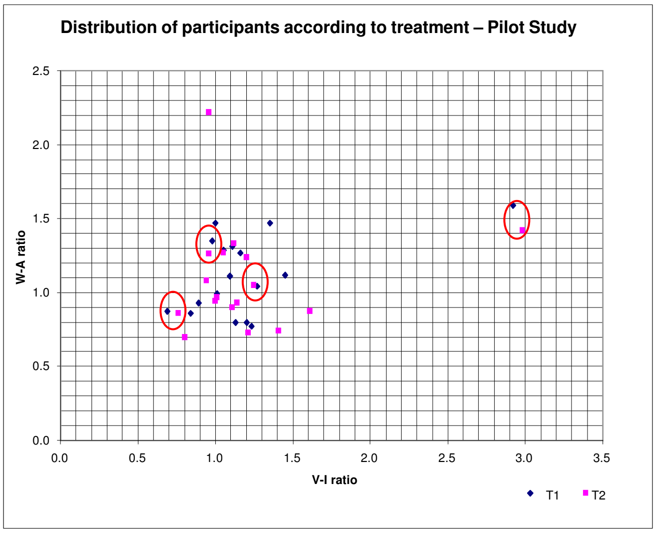

Figure 5. Distribution of participants according to treatment.

The online experiment for T1 utilized the school computer facilities. The participants were allocated 30 minutes to complete each phase of the experiment that started with the pre test. Once the pre test had been completed, the instruments were collected before further instruction was given for the participants to proceed with the 30 minutes online museum experience.

After 30 minutes, all participants were asked to turn off their computer. This was then followed by a post test. The time allocated for the post test was also 30 minutes. In all sessions, participants were reminded and monitored to work independently. The total experiment for T1 was conducted within 2 hours.

In comparison, the T2 experiment was conducted without any computer usage in a pre booked activity room in Melbourne Museum on the very same day. In the activity room, the participants were seated 4 to a table. Similar to the T1 experiment, T2 were also given 30 minutes to complete the pre test.

After all questionnaires had been collected, the participants were brought into the Dinosaur Walk exhibition floor to experience the physical exhibits. This exhibition visit took 30 minutes and was followed by the post test. The post test was conducted in the same activity room and 30 minutes was allocated for the test. The total timing for T2 experiment also took around 2 hours which verify the estimated timing for both experiments.

VII. Preliminary Results

The learning experiment outcome was measured by taking an individual participants' improvement in their test scores between the pre and post tests. Based on the scores differences, the four group means (verbaliser T1, verbaliser T2, imager T1 and imager T2) were then analysed to determine if there was an effect of cognitive styles and representation formats on participants' cognitive performance.

The results indicate that the overall participants' performances are better in online treatment group (T1) with the mean differences (between pre test and post test) of 3.33 as compared to only 1.75 for the physical museum treatment group (T2). The mean differences between pre test and post test for both treatment groups is presented in Table 2.

	Pre test	Post test	Differences
T1	56.67	60.00	3.33
T2	67.14	68.89	1.75

Table 1. Mean differences between pre and post test according to treatment groups.

Looking at the interactive affect of cognitive styles with treatment group reveals that there was very little difference in performance of verbaliser in treatment 1 compared to treatment 2. However, looking at the result for the imagers shows a difference with imagers in treatment 1 showing an improvement of 10.65. Imagers in treatment 2 also show an improvement although the percentage is not as much as in treatment 1. The mean percentage differences for both cognitive styles between pre and post test scores are displayed in Figure 6.

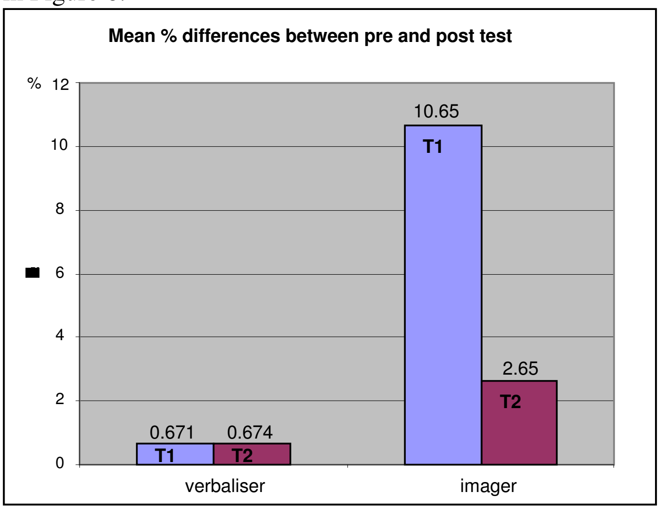

Figure 6. Mean % differences between cognitive preferences.

Based on the mean analysis, it is clearly shown that imagers performed better than verbaliser in both treatment conditions. The next measurement that looks into the interactive effects of the independent variables (cognitive styles and instructional conditions) indicates an ordinal interaction effect [33] does occur as shown in Figure 7. Performance increment for the verbalisers is almost unnoticeable (with very little change); meanwhile the graph clearly shows that performance decreases for imagers in treatment 2. 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.

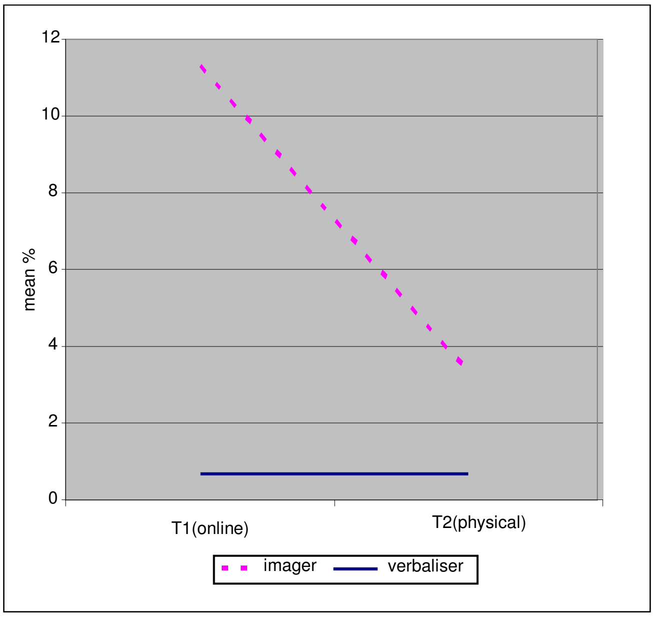

Figure 7. Interactive effects between cognitive preferences and treatment conditions.

VIII. Discussion

This study aims to investigate differences in learning performance for individuals with difference cognitive preferences (verbaliser or imager) with the way museum information is being presented (online and physical exhibits). Firstly, the results from this pilot study reveal that there is improvement in learning performance as demonstrated by the increment of the mean scores for both treatment groups. However, it could be seen that imagers perform better than verbaliser in both treatment conditions with a higher mean in the online museum environment. This could be used as an indicator that the online museum environment which represents both textual and graphical information in a relational architecture could be an effective way to help learners with imagery cognitive preference in their learning process. This finding is consistent with the rationale that imagers will try to picture their environment as a whole.

It is noted that there is very little difference for verbaliser performance in both treatment group. 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 verbalisers. Moreover, some of the information is displayed in either text or graphical only, could possibly cause verbalisers to miss some of the information. This result could be a similar case in the physical museum in which some information could only be observed from the physical objects (exhibits). Accordingly, an ordinal interaction effect was noted between the participants' cognitive preferences and the instructional conditions in their museum learning performances.

IX. Conclusion

The role of technology in supporting web-mediated museums not only has 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 [34]. ICT tools are often used to support the acquisition of knowledge [35]; the information that a learner receives from an external source can then be stored in their memory to retrieve later on. As a consequence, we are 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.

Findings from this pilot study have demonstrated that differences in instructional conditions and formats exist between individuals with different cognitive preferences. However, further investigation and exploration is needed towards a better and refined analysis of the data. Other detailed statistical measurement and variables should be included to provide salient findings.

Nevertheless, the practical implication and consequences of this finding suggests that cognitive preferences of museum' visitors must be considered for developing the virtual-oriented information representations for their future online museum as well as the physical 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.

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Author Biographies

Asmidah Alwi received a Bachelor's degree in Information Technology from Universiti Utara Malaysia in 1998 and the MSc degree in Computer Science from Universiti Putra Malaysia in 2000. She is a lecturer at the College of Art and Science, Universiti Utara Malaysia and currently pursuing her doctoral degree at the School of Business IT and Logistics, RMIT University, Melbourne. Her research interests are mainly in human dimensions and interaction design in the area of human computer interaction (HCI) with focus on e-learning.

Elspeth McKay is an Associate Professor of Information Systems (IS) at the RMIT University, School of Business IT and Logistics, Melbourne, Australia. She is passionate about designing effective eLearning resources for the education sector and industry training/reskilling programmes, including: investigations of how individuals interpret text and graphics within Web-mediated learning environments. She has designed e-Learning tools implemented through rich internet applications; including: ARPS - an advanced repurposing pilot system, COGNIWARE - a multi-modal e-Learning framework, GEMS - a global eMuseum System, eWRAP - Electronic work readiness awareness programme, EASY - Educational/academic (skills) screening for the young, offering enhanced accessibility through touch screen technologies. Over the last decade Dr McKay has published extensively in the research fields of HCI and educational technology. In recognition of her contribution to the professional practice of IS research, she was elected as a Fellow of the Australian Computer Society (FACS).