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The effects of visual metaphor and cognitive style for mental modeling in a hypermedia-based environment

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Abstract

With the exponential growth of Internet technology, the notion of users' cognition when navigating such a vast information space has gained prominence. Studies suggest that metaphors can serve as effective tools to scaffold users' mental modeling processes. However, how users conceive of the metaphorical aid (as opposed to simply how they perceive it) remains questionable. Cognitive style, or the user's preferred way of information processing, has thus been posited as a possible factor affecting the success of the metaphorical approach in a hypermedia environment.

This study explores the effects of visual metaphors and cognitive styles on users' learning performances in terms of structural knowledge and feelings of disorientation. The results indicate that a visual metaphor could improve the quality of mental formation, yet simultaneously increase users' mental load during navigation. In addition, cognitive style is a crucial factor that can significantly affect users' learning performance.

Keywords: Visual metaphor; Cognitive style; Structural knowledge; Interface design

1. Introduction

As Internet technology continues to thrive, hypermedia stands to make a significant contribution towards facilitating the delivery of instructional materials. This technology is unique in that it presents varied, free access, in which users are given greater control to explore a subject matter at their own pace. Yet, such a unique feature also raises new challenges for designers. Not all users possess the self-regulatory trait to effectively develop and form the assumed mental model of the content domain. The strengths of "direct manipulation" and "user control" are not well adapted to every situation. It is thus necessary that hypermedia systems provide for users' expectations and preferences according to different interaction styles and modalities. Cognitive style has been highlighted as one of the most important individual characteristics, especially in environments where the potentiality to construct embedded information structures is essential (Chen and Macredie, 2002). In addition, research into human–computer interaction (Beasley and Waugh, 1996) considers the metaphorical interface as not only a pedagogical tool, but also as a mental mapping mechanism that shapes thinking. However, the available evidence for this notion is largely inconclusive.

This study aims to explore how cognitive styles affect users' mental formations and feelings of disorientation in hypermedia-based learning environments, by using either a visual metaphorical interface or a hyperlink interface.

1.1. Author-provided models or self-constructed models

In hypermedia, the puzzling problem of a self-constructed or a given model is often cited by researchers. According to Marchionini (1988), "*although self-directed and exploratory learning are worthy objectives to achieve*

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in a learning environment, freedom to learn does not seem to be a sufficient condition to assure effective learning" (p. 11). Developers who possess notions of constructivism may assume that the non-guiding format of hypermedia helps to cover the needs of a wider audience. However, while such an unconstrained navigation design might benefit expert users, it could also frustrate novice users. Norman (1981) stated that "*Users develop mental models of the devices with which they interact. If you do not provide them with one, they make one up themselves, and the one they create is apt to be wrong.*" (p. 150). In addition to the question of expert or novice users, users also have different preferences when it comes to figuring out appropriate models for themselves. An author-provided model may not always be welcome, particularly for certain users. Such a model might be incompatible with, or even contradict, their existing conceptions and information-processing tendencies. Underlying these two issues, the learner's mental model plays a decisive role. Briggs (1990) found that learners' mental models function differently when learners engage in two different circumstances: the externally-driven situation and the internally-driven situation. In the externally-driven situation, learners' mental models work as a communication device to mediate learning. In contrast, in an internally driven situation, learners' mental models lead, rather than mediate, for most of the conceptual jobs during learning. In particular, the regulation of mental models is highly associated with learners' cognitive characteristics.

1.2. Structural knowledge and disorientation

Scholars use different terms to describe the development of mental models, though these terms all portray similar phenomena. The present study adopted the development stage model, using Jonassen et al. (1993) designations: declarative knowledge (*knowing that*), structural knowledge (*knowing why*), and procedural knowledge (*knowing how*). Declarative knowledge is knowledge about the understanding of individual concepts. Structural knowledge is knowledge about "*the structure of interrelationships between concepts and procedures (elements) in a particular domain, organized into a unified body of knowledge*" (p. 5) (Koubek, 1991), and procedural knowledge is the knowledge which actively monitors the arriving information, and guides the execution of processing operations. Of these three, structural knowledge serves as the core knowledge which connects the declarative knowledge stage to the procedure knowledge stage. Experts consolidate their knowledge structures in a highly efficient way. It is thus considered helpful to externally map experts' knowledge structures for novices, and to establish a clearly articulated parallel between the user's tasks and the program design. Hypermedia appears to be such an appropriate scaffolding tool in which an expert's conceptual framework of a subject domain is visually presented to learners.

Structural knowledge also plays an essential role during hypermedia navigation. However, the problem of disorientation has long been known to be a detrimental factor in hypermedia activities (McDonald and Stevenson, 1999). Most researchers adopt Elm and Woodss' (1985) definition of disorientation: "*Getting lost in a display network means that the user does not have a clear conception of the relationships within the system, does not know his present location in the system relative to the display structure, and finds it difficult to decide where to look next within the system*" (p. 928). Elm and Woods describe disorientation in terms of degradation of user performance rather than subjective feelings of being lost. As a result, it is the internal knowledge structure, not the external guidance, which would alleviate the feeling of being lost. The intention of providing guidance information (author-provided mode) should not be misunderstood; the aim is not to reduce the feeling of disorientation. Instead, guidance is provided to facilitate learners in their construction of an internal knowledge structure.

1.3. Cognitive style

Since much of the work concerned with internally- or externally-driven situations is based on the generic model of information processing, users' tendencies to interpret incoming information have become a very important issue. The study of cognitive style has been a prominent and extensively researched area since the early 1940s (Spicer and Sadler-Smith, 2000; Graff et al., 2004; Ford, 2000). Unlike individual differences in abilities, which describe the level of performance measured by aptitude tests or so-called intelligence tests, style actually denotes a manner of behavior. Style is often fused with intellectual ability due to the assessment instruments overlapping style with ability (e.g., spatial ability). Recent empirical evidence (Peterson et al., 2003), however, has clearly discriminated style from ability. According to Curry's (1983) Onion Model, cognitive style is a feature of an individual's permanent personality in modulating his/her preferences of resorting to types of information processing modes. Such a habitual preference could be the manifest reflection of ability, in that one feels that one particular mode is more suitable than another (Riding and Pearson, 1994). In short, cognitive styles are usually placed along a continuum rather than polarized in the way that intellectual abilities are. Cognitive style is an individual's preferred and habitual mode of perception, imagery, organization, and elaboration during knowledge acquisition or problem solving processes.

In a virtual environment, comprehension and use of complex information starts with users locating information, and integrating that information with his/her existing knowledge. Users' cognitive styles of tending to apply the salient cues or explicit facilities provided by environments might dominate this interpretational process (Ford, 2000). Understanding these differences can help hypermedia designers cope with the variations in behavior exhibited by their users.

1.4. Wholist–analytic and verbal–imagery style models

Cognition-centered tradition has been one of the mainstream developments for 'style construct' in the past 60 years. By systematic assessment, scholars (Jonassen and Grabowski, 1993; Rayner and Riding, 1997) have been able to identify relationships among innumerable style dimensions, summarized into two conceptual families: the wholist–analytic cognitive style family and the verbalizer-imager cognitive style family. Individuals who fall into the wholist–analytic cognitive style family tend to process information in wholes or parts, while those who fall into the verbalizer-imager cognitive style family tend to think in words or images when they represent information. A 'style' model integrating the two cognitive style dimensions has been proposed: the wholist–analytic and the verbal–imagery. These two style families affect peoples' favored methods of processing (wholist–analytic) and representing information (verbal–imagery). An individual could be thus identified as a wholist-imager, an analytic-imager, a wholist-verbalizer, or an analytic-verbalizer.

Wholist (-imagery or -verbal) users are assumed to adopt a global strategy, and prefer information with explicit verbal or visual cues. In contrast, analytic (-imagery or -verbal) users tend to employ an analytical approach, and use self-constructed information cues either in verbal or visual modes. In other words, wholist users are likely to process information passively by operating under an external reference, as opposed to the "inner directness" of analytic users, who might prefer actively imposing their own structure (Chen and Macredie, 2002). With respect to the verbal–imagery style, imager users are similar to Paivio's (1971) and Richardson's (1977) definition of "visualizers" who prefer to represent information in mental pictures. In contrast, verbalizers tend to represent information by using words or verbal associations.

While the characteristics of cognitive styles could be categorized into these two dimensions that have been proven to be independent of one other, many classic cognitive style measurements, such as GEFT (Witkin, 1962) seem to neglect such issues. GEFT only assesses within one dimension, the wholist–analytic style family (field-dependent–independent), although participants in this test are prompted to visually trace simple items embedded within complex figures. Not surprisingly, many previous field-dependent–independent studies (Liu and Reed, 1994; Paolucci, 1998) might show inconsistent results, especially when measuring differences in the participants' performance in terms of using verbal or visual treatments.

Based on the above reasons, cognitive style in the present study will be examined within the Riding and Cheema's Integration Style Model (1991) (Fig. 1) which identifies four types of cognitive styles: wholist-imager, analytic-imager, wholist-verbalizer, and analytic-verbalizer. These four cognitive styles are hypothesized for implicitly conditioning the development of operative schemata, as well as users' overall cognitive structuring in a nonlinear environment

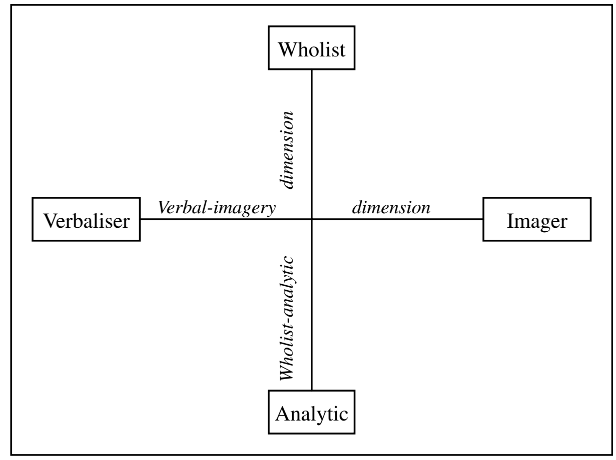

Fig. 1. Wholist–analytic and verbal–imagery style model (Rayner and Riding, 1997).

where a mode to regulate or to process data is of central importance.

Apart from the effects of users' individual characteristics on on-line learning, the representational aspect of hypermedia is another concern of this study.

1.5. Metaphor: structure-mapping theory

The graphic user interface has been commonly described to be the schematic or visual representation of an information system. Schematic representations show the nodes and links, and the conceptual relations between them, but the position of the nodes and the distance between them have no meaning, e.g., the London underground map. In a visual representation, each node is assigned a fixed position in the information space, and distance between nodes reflects some measure of the degree of relatedness between the information contained in the nodes. Both methods above represent what Halasz and Moran (1982) have called "conceptual models." The components and structures of these conceptual models accurately map onto the components and structures of the information system. Yet, it may not always be easy for novice users to implement an abstract conceptual model. Consideration of this issue suggests the usage of the metaphorical approach (Carroll and Thomas, 1982; McKnight et al., 1991) to find an image that is familiar to the user, e.g., the office metaphor and the filing cabinet metaphor, to help with the development of new cognitive structures based on existing ones. In addition to the familiarity issue, a supplied conceptual model must also be obvious to the user. People develop new cognitive structures by calling upon their prior knowledge (analogies or metaphors) as the basis on which to form a new mental model. Appropriately using metaphorical interfaces may have the potential to increase "the rate at which users can process, understand, and respond to a display" (Nepon and Cates, 1996, p. 1). The "transfer" function of metaphors suggests that interface designers may take advantage of visual metaphors to create a conceptual model in order to increase system learnability.

Based on cognitive perspectives, the power of metaphors in organizing information and creating persuasive rhetoric was first outlined by George Lakoff and Mark Johnson's work (1980). Lakoff and Johnson asserted that a metaphor could be defined as "conceiving one thing in terms of another" (p. 36). A metaphor permits its author to conceptualize and communicate meaning in terms of something previously experienced, or something that is concrete to viewers. A number of researchers (Alty et al., 2000; Stanney et al., 2003) have acknowledged the usefulness of analogies and metaphors in the acquisition of new information. By using a metaphorical interface, users are able to gain insight into an unfamiliar concept. In essence, metaphors act as cognitive aids to enhance the interface usability by allowing users to forecast what will happen.

According to Carroll et al. (1988), there are three primary research streams of metaphor studies. Operational analyses studies attempt to prove the measurable effects of metaphors on users' behavior or performance. Structural analyses studies address how metaphors may facilitate mental mapping or deductive reasoning between the knowledge of target domains and the knowledge of source domains. Finally, pragmatic analyses studies mainly focus on what types of contextual or objective issues might restrict the deductive functions of metaphors in practical terms. Within these three areas of study, structural analyses are highly relevant to interface design issues in the hypermedia environment, especially in terms of using graphics to help map knowledge structures from source domains to target domains. In this regard, researchers understand that visual metaphors possess the "cross-domain mapping" ability which could assist users in the formation of accurate mental models.

Developed by Gentner (1983), structure-mapping theory has been considered by many researchers (Chee, 1993; Schumacher and Gentner, 1988) as a concrete framework for the study of analogy and structural cues. In this theory, Gentner used the term "analogy" rather than metaphor. Analogies can be classified into two distinct types (Presmeg, 1997): explicit analogy and implicit analogy. According to Hsu (2006), metaphor is an implicit analogy, as it demonstrates similarities in an implicit way. This view is consistent with Gentner's statement regarding analogy: "The analogy conveys overlap in relations among objects, but no particular overlap in the characteristics of the objects themselves" (Gentner and Gentner, 1983). Structural mapping theory delineates implicit analogy as a holistic mapping role to facilitate users' deductive reasoning when transforming embedded system structures. In other words, metaphor is an interpretive strategy for users' tacit preferences. Central to this mapping process is delivery, for a system of relations which holds among the base elements also holds among the target elements. Rather than mapping object descriptions of *appearance* (Falkenhainer et al., 1989), the metaphorical mechanism maps high-order relations by which the experiential learning may take place.

1.6. Summary

To summarize, people differ in the way they identify appropriate models for themselves. However, it seems that a tradeoff always exists, no matter whether one uses an author-provided model or a self-induced method to acquire a mental model. What really matters might not be which approach the designer uses, but to what extent users can accept and apply it. As Vaske and Grantham (1990) suggest, the difficulties of learning in a computer-based environment are caused by the discrepancies between (a) individual mental representations and cognitive styles and (b) the given operations of the scope of action prescribed by the software. In other words, the differences in the content exposure (interface effects, e.g., hyperlink, visual metaphor) and the information processing patterns (cognitive styles) of users might greatly affect the behavior (disorientation) and learning results (structural knowledge) in a hypermedia environment. To address this research hypothesis, the following research questions were developed:

1. Are a subject's structural knowledge and feelings of disorientation significantly influenced by his/her use of a visual metaphorical interface compared with a textual hyperlink interface?
2. Are a subject's structural knowledge and feelings of disorientation significantly influenced by his/her cognitive style – wholist-imager, analytic-imager, wholist-verbalizer, and analytic-verbalizer?
3. Are a subject's structural knowledge and feelings of disorientation significantly influenced by the interaction between the different interface modes and the subject's cognitive styles?
4. Is there a relationship between users' structural knowledge and their feelings of disorientation?
5. Is there a relationship between users' structural knowledge and their feelings of disorientation in the groups using different interface modes?
6. Is there a relationship between users' structural knowledge and their feelings of disorientation for participants with different cognitive styles?
7. Is there a relationship between users' structural knowledge and their feelings of disorientation for participants with different cognitive styles in the groups using different interfaces?

2. Methodology

2.1. Research design

A 4×2 experimental design was manipulated to observe and analyze variables (Table 1).

Table 1
The diagram of research variables

Independent variables	VM				HL			
Dependant variables	WI	AI	WV	AV	WI	AI	WV	AV
Structural knowledge	X	X	X	X	X	X	X	X
Feeling of disorientation	X	X	X	X	X	X	X	X

VM, visual–metaphorical interface; HL, hyperlink interface; WI, wholist-imager; AI, analytic-imager; WV, wholist-verbalist; AV, analytic-verbalist.

2.1.1. Independent variables

There are two independent variables in the present study. The first independent variable consists of two types of interface modes:

(1) Visual metaphorical (VM) interface: Instructional material with a "student dormitory" visual–metaphorical interface.
(2) Hyperlink (HL) interface: Instructional material with a hierarchical-associative hyperlink.

The second independent variable consists of four types of cognitive styles: wholist-imager (WI), analytic-imager (AI), wholist-verbalizer (WV) and analytic-verbalizer (AV). A subject's particular style was determined by the subject's score on the Cognitive Style Analysis (CSA) computer program (Riding and Cheema, 1991).

2.1.2. Dependent variables

Two dependent variables are examined in the present study:

(1) Participants' structural knowledge: Structural knowledge is defined here as the compilation stage of a knowledge development theory. It is an interrelationship knowledge which associates declarative knowledge and procedural knowledge.
(2) Participants' feelings of disorientation: The feeling of disorientation is defined as the subjective feeling of being lost in a display information network.

The MANOVA model was applied first to test the two main effects of independent variables (interface modes and cognitive styles) as well as the interaction effect between the two on the dependent variables (structural knowledge and feelings of disorientation). Type III sums of squares take into account the influence of main effects before the influence of interaction effects are computed. One-way analysis of variance (ANOVA) was carried out to analyze the data further once the significant main effect of interfaces or cognitive styles was found (research questions 1, 2, 3). Also of interest was the correlation between participants' cognitive styles, usages of interfaces, structural knowledge, and disorientation. Pearson's correlation coefficients were used to explore the interaction relationships among these factors (research questions 4, 5, 6, 7).

2.2. Participants

To ensure serious participation during the experiment, participants had to have an interest in the learning content which was "Building a Personal Homepage". Therefore the participants were freshmen from four universities in northern Taiwan. Taiwanese college students usually have to take a course entitled 'Introduction to Basic Computing' as a requirement of their freshman year. One common assignment given in this course is building a personal homepage. The participants in this experiment were therefore volunteers recruited from this sample pool. A compensation fee of NT$200 was offered to each participant upon completion of the experiment. Participants' ages ranged from 19 to 26, with various majors in the School of Education and the School of Social Science.

A two-stage filtering procedure was administered to identify the most appropriate participants from an initial sample of 153 students at the beginning of the study. A 6-item computer-background question set was managed first through an email flyer to find the most appropriate participants: (1) the average number of hours per week spent on the Internet, (2) experience of a webpage account, (3) experience of using portal site homepage services, (4) experience of HTML editors (Frontpage, Dreamweaver, Pico), (5) knowledge of graphic editors (Photoshop, PhotoImpact), and (6) knowledge of programming languages (HTML, JAVA, Perl, VBscript, Javascript, PHP). Question (1) was designed to ensure that each participant had approximately equal online experience. The norm was set at 18 h per week based on a 2005 nationwide survey result of Taiwanese college students' Internet usage (Taiwan Network Information Center, 2005). Questions (2) to (6) were designed to pre-exclude participants who were familiar with the domain knowledge of building homepages.

The remaining 132 participants were then identified by a Cognitive Styles Analysis computer program. According to the results there were 36 wholist-imagers (WI), 32 analytic-imagers (AI), 34 wholist-verbalizers (WV), and 30 analytic-verbalizers (AV). Based on Riding and Pearson's (1994) findings, gender difference has very low correlation with these two style families (with WA family, $\rho = -.02$; with VI family, $\rho = -.04$; $^{**}\rho < .001$) and thus was not considered as a significant issue in this study.

2.3. Instruments

2.3.1. Cognitive Style Analysis

The computer-based Cognitive Styles Analysis was administered to determine participants' cognitive styles in terms of the wholist–analytic and verbal–imagery dimensions. This analysis program consists of three subtests. The first set of questions is designed to measure participants' positions in the verbal–imagery dimensions. Participants have to identify the relationship between pairs of words, and determine whether they belong to the same category. The second and third sets of questions are used to identify participants' positions in the wholist–analytic dimension. Participants answer the second set of questions by indicating whether the given geometric shapes are the same or different. The third set of questions is similar to Oitman et al. (1971) Group Embedded Figure Test (GEFT) in which participants need to distinguish a simple figure from within a larger complex figure that has been designed to obscure and embed the simple one.

2.3.2. Structural knowledge test

The structural knowledge test was adopted from the framework of previous studies (Antico, 1995; Lee, 2000) but the test items were replaced. This three-part test included "Concept recall", "Structural knowledge", and "Concept meaning". In the "Concept recall" section, participants were instructed to spend approximately 5 min listing on a sheet of paper as many concept names as they could, based on what they had just learned from the experimental site. This part was simply designed to help participants recall and focus their thinking on the concepts of the to-be-learned content. No score was gained from this part. The second part, "Structural knowledge", tested participants' knowledge of how concepts in the presented materials are related to one another. Participants were required to identify the most likely description (*includes, is part of, neither includes nor is part of*) that correctly illustrated the specific relationship for each given concept pair.

Example:

CONCEPT		CONCEPT	
Text Editor ...	A) .... includes .... B) .... is part of .... C) .... neither includes nor is part of	File Transfer Program	C

In all, thirty concept pairs were presented in random order. Ten pairs presented one concept that *includes* the other, and another ten pairs presented a concept that *is part of* the other, thus covering the two types of hierarchical relationships. A final ten pairs presented one concept that *neither includes nor is part of* the other, to cover the cluster relationship. The total score for this part was 30 points.

The third part, "Concept meaning," measured participants' declarative knowledge of building homepages, which is a necessary condition for the development of structural knowledge (Davis et al., 2003). Twenty-five single-choice test items required responses to demonstrate knowledge of the meanings of concepts as well as how those concepts could be applied in various homepage construction situations. The total score for this part was 25 points.

Example:

1. Please indicate the tool that will be used to create an HTML file
a. CuteFTP
b. Notepad
c. Spinweb
d. Firework

The sum of part 2 and part 3 scores represented a subject's structural knowledge. The highest score was 55 points. This method was considered more direct and more easily managed than other methods such as word- association, card-sorting and map-drawing. The word-association method has two intrinsic problems. First, the number of possible comparisons will increase dramatically once the measuring concepts increase (Jonassen et al., 1993). Second, this method alone might not be able to reveal the user's real state with regards to their understanding of the relationship between concepts (Driscoll, 1993). As for card sorting or map drawing, they were considered unfair for the HL group, since the VM group had been provided with a navigational aid to show concepts in their entirety.

The measurement properties of this instrument in the present study were tested. The results revealed apparent content validity (>.4, 79.582%) and reliability coefficient (Cronbach's $\alpha = 0.92$).

2.3.3. Disorientation assessment

The method of disorientation assessment was adopted from Beasley's (1994) questionnaire with eight test items. Participants were instructed to circle the response that best indicated their feelings of using the experimental sites, using a 7-point Likert scale. Higher scores indicated a higher level of disorientation. The highest score of the subject's feeling of disorientation was 56 points.

Example:

1. How often were you aware of where you were in the instruction relative to other, related concepts?

Never						Always
1	2	3	4	5	6	7

2.3.4. Learning content and structure

In order to obtain the actual effect of metaphors, Hsu (2005) suggested that the target domain knowledge should be complex and difficult enough to challenge users. Considering this point, the researcher selected "Building a Personal Homepage" as the target content to be learned because it involved complex concepts. With permission from a well-established computer knowledge base, the researcher adopted the content of building personal homepages to develop the experimental materials. Regarding the structure of the learning content, scholars (Batra et al., 1993; McDonald et al., 1990) have indicated that the information structure may strongly affect users' performance, especially in locating and extracting information from a hypermedia environment. In order to control the structure issue, a hierarchical-associative structure was chosen to arrange the learning content of the present study according to the suggestions of Gordon and Lewis (1993).

Hence, after filtering out some unnecessary items, concepts of personal homepage design were identified and rearranged into a 5-layer hierarchical-associative structure consisting of three main categories (Getting Accounts, Getting Tools, and Getting Started), and 48 concept nodes (Table 2). Two experimental web sites were then developed accordingly to investigate research hypotheses. Both sites had an identical information structure and content but had different interface layouts.

2.3.5. Interface layouts: hyperlink vs. visual–metaphor

Participants in the Hyperlink interface group (HL) (Fig. 2) applied hyperlinks embedded inside the content as the main method to browse through the interrelated concepts which appeared in the same display window. It was assumed to be a salient approach that no graphic aid was provided to visualize the information structure. Pages are basically connected by 51 hierarchical or eight associative links. For instance, if participants wanted to access concepts at the same layer but in different categories, like linking from "File transfer program" to "Network ID Starter Kit" which are both located in layer 3 (see Table 1), there are two possible approaches to complete this task. The first approach is to click hierarchically back to the parent node "Getting Tools" located in layer 1, then choose "Getting Accounts" in the same layer, and then follow the link to the sub-category "Account application" in layer 2 before arriving at the "Network ID Starter Kit" page in layer 3. The second approach is to click on the associated hyperlink embedded inside the description content of "File transfer program," which will directly bring in the "Network ID Starter Kit" page.

The previous method of connecting the nodes at the level above or below the current page was presented by the bullet format of hyperlinks to indicate points of interest, while the later approach associates relative concepts by direct hyperlink. However, the latter approach might not be available for each node. In addition, a "main page" link was mounted on the upper left corner of every page to enable participants to jump back to the main page whenever they needed. In general, the hyperlink interface provided minimal structural cues to participants. That is,

Table 2
The conceptual structure of "Building a Personal Homepage"

Building a Personal Homepage	Getting accounts	Basic Concept	WWW	Browser	
		Account Application	Network ID Starter kit	Network ID	Network ID Service
				Initial accounts	Student locker
					Web account
					E-mail account
	Getting tools	Production tools	Text Editor	Notepad	
				Word Pad	
				MS Office Word	
			Web page editing program	Editing software	Frontpage
					Dreamweaver
				Graphic software	Photoshop
					PhotoImpact
				Special effect software	Flash
					Firework
			File transfer program	CuteFTP	Change Authorization
				WS FTP	
				LeechFTP	
			Web browser	MS Internet Explorer	
		Tools at public lab.	MS Office		Frontpage
				CuteFTP	
					PhotoImpact
				MS Internet Explorer	
	Getting started	HTML	What is HTML?		
			Basic HTML		
		Create Homepage	Learn HTML		
			Text editor	Create by Notepad	
		Upload Homepage	Fetch by CuteFTP	CuteFTP	
		View Homepage	URL	MS Internet Explorer	

Fig. 2. Main page of Hyperlink interface group.

Fig. 3. Main page of visual–metaphorical interface group.

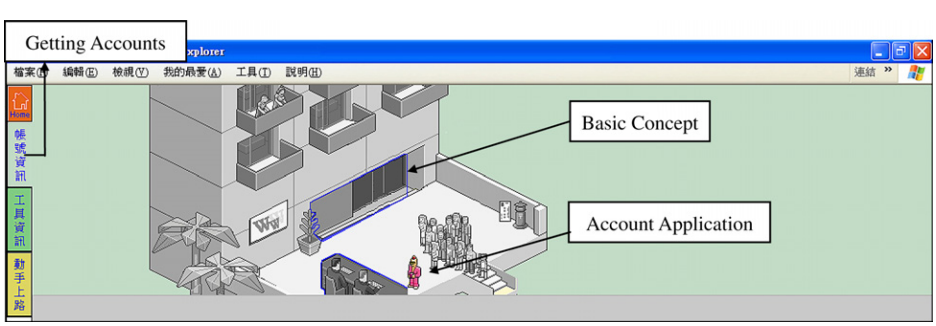

Fig. 4. Visual–metaphorical interface: Getting Accounts.

participants in this group had to extract the embedded structure within concepts by themselves.

In contrast, participants in the visual–metaphorical interface groups (VM) (Fig. 3) learned "Building a Personal Homepage" concepts through a graphic aid, the visual–metaphorical interface. According to the above-mentioned literature, the visual metaphor is capable of conceptualizing the target content structure in a meaningful way to map participants' domain knowledge, and as such to facilitate the generation of inferences and expectations (Otter and Johnson, 2000). The intention is that participants who use this type of graphic aid might have a better chance of forming accurate mental models by visually externalizing the content structure.

The development method of the visual–metaphorical interface adopted in this study was derived from Hsu and Boling (2007) and Alty et al.'s (2000) suggestions. Sixteen students (eight experts and eight novices) from four universities were invited to attend four brainstorming sessions. Based on the conceptual structure of "Building a Personal Homepage" (Table 2), students from each brainstorming session were encouraged to shout out their ideas or exaggerate the ideas put forward by others. Three possible metaphors: "Birds' Nest", "Mall", and "Student Dormitory", were proposed as a result of the brainstorming. Then, students discussed these three possibilities using the following metaphor design guidelines (Hsu and Boling, 2007) as the discussion framework: (1) user's prior knowledge concerning the metaphors; (2) mapping between the base and the target domain; (3) potential mismatch between the base and the target domain; (4) overall structures of metaphors in covering systems; (5) ease of representation; (6) manifestations/appearances of metaphors; (7) existing metaphors used in other software; (8) combining underlying and auxiliary metaphors. The "Birds' Nest" metaphor was rejected since it might violate guidelines 1, 3, and 6. As for the "Mall" metaphor, it was considered to be better suited to a profit-making web site rather than a personal homepage. The "Student Dormitory" metaphor was selected as the primary metaphor because it closely matched a college student's prior knowledge of a space with personal style in which they are allowed to store their possessions.

According to Cates's (2002) POPIT model (Properties, Operations, Phrases, Images, and Types) for visual–metaphorical interface design, three secondary metaphors "Applying for Dormitory," "The Furnishing and Design Tools," and "Starting Room Improvement" were developed to correspond to "Getting Accounts," "Getting the Tools," and "Getting Started" respectively (Figs. 4–6). By entering the "Student Dormitory" building, participants explored the concept of constructing personal homepages. The "Student Dormitory" building not only acts as a receptacle for hypertext documents but also shows information about contents. For instance, the room size represents the storage space of homepages; the room door (open or closed) indicates the state of accessibility to homepages; the room number gives information about the URL; the loading area located in the basement with a moving van illustrates the function of File Transfer Program, and so on.

The Internet Explorer window of the VM group was split horizontally into two parts. The above part consisted of the "Student Dormitory" interface which graphically conceptualizes the target content in a global way, and provides associative means between nodes. Other than the background color, the metaphor graphic was illustrated in gray tone to keep consistency with the hyperlink group. By pointing the cursor to the responsive areas on the graphic interface, a blue shaped frame would be highlighted to indicate the clickable objects. Once participants made their choice, the relevant information would be displayed in the bottom part of the window. The VM interface is different from the HL interface in two ways: (1) a visual–metaphorical interface was mounted on the top of the content window; (2) the original hyperlinks inserted inside the learning content were disabled and replaced by red colored text to index the possible choices.

In order to control the learning environment and also to remove unpredictable factors that might affect the final results, the browser's toolbar and address bar were removed and did not appear in either approach.

2.4. Procedure

Upon arrival, participants were given the Cognitive Styles Analysis computer program to identify their

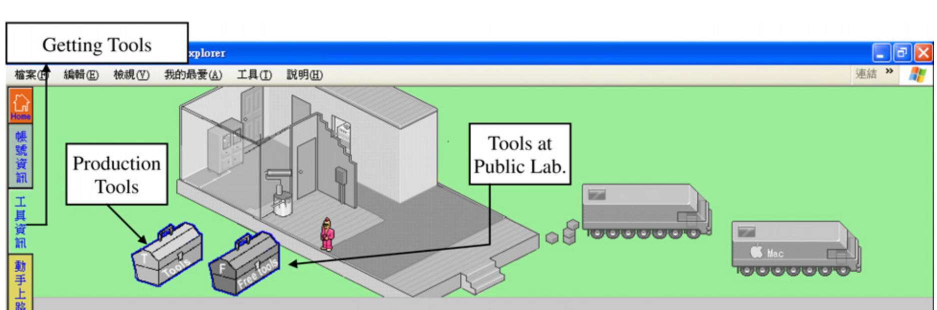

Fig. 5. Visual–metaphorical interface: Getting Tools.

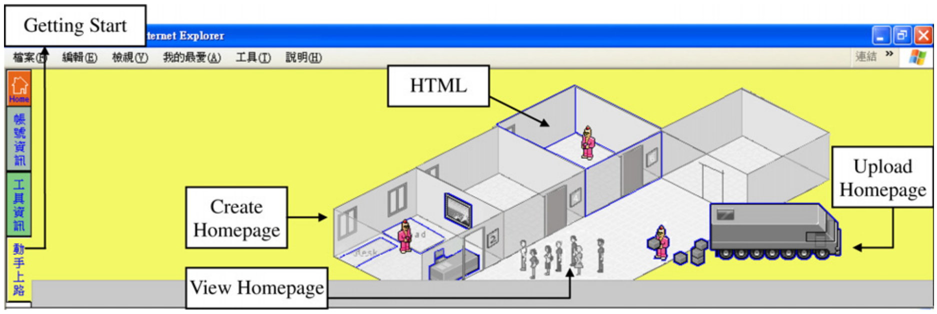

Fig. 6. Visual–metaphorical interface: Getting Start.

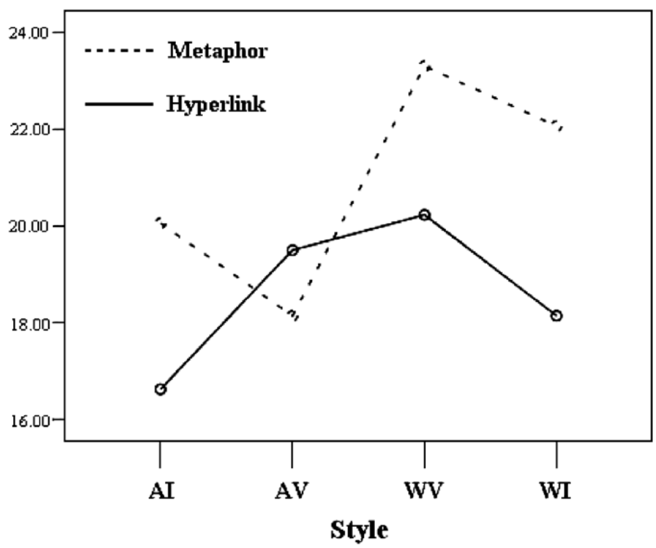

Fig. 7. Means of structural knowledge.

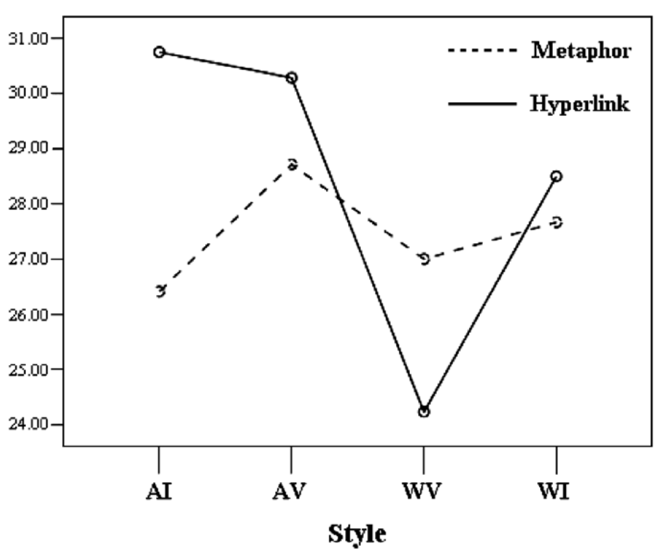

Fig. 8. Means of feeling of disorientation.

cognitive styles. Then, the researcher randomly assigned these participants into the Hyperlink interface group (HL) and the visual–metaphorical interface group (VM). Each group included approximate numbers of WI, AI, WV, and AV participants. According to the assigned group, a tutorial web page was loaded onto the subject's computer screen and started a 5-min practice session to master the interface operation. The tutorial web pages were created to simulate the physical environments of the two different versions of the experimental sites, but with different content. The content for this tutorial web page was "American's Life, Leisure, and Culture (1840-1860)" from the book *The Enduring Vision: A History of the American People* (Boyer, 2001). Without further questions, participants proceeded to the formal experimental stage. Before starting, both groups of participants were told that a post test would be given to measure their understanding of the concepts of the to-be-learned content. They were required to spend at least one hour learning the content of the assigned web site. A monitoring system (Morae 2.0) was installed on the participants' computers to ensure that participants had accessed and read each page. After the learning session, participants moved on to answer the structural knowledge test and the disorientation questionnaire. The average time required to complete the experiment was 2 h.

3. Results

Of the 132 test results, 16 were invalid, either because participants failed to follow the correct procedure or because they dropped out before completing all the tasks; therefore, 116 data sets were valid. Means and standard deviations of participants' CSA scores were: wholist-imagery (Mean = 1.38, 0.85; SD = 0.27, 0.13), wholist-verbal (Mean = 0.90, 0.87; SD = 0.08, 0.11), analytic-imagery (Mean = 1.44, 1.79; SD = 0.28, 0.35), and analytic-verbal (Mean = 0.88, 1.85; SD = 0.09, 0.53). The subject numbers in the visual–metaphorical interface group (VM) were: 17 WI, 14 WV, 15 AI, 13 AV. The subject numbers in the Hyperlink interface group (HL) were: 16 WI, 14 WV, 14 AI, 13 AV. (Figs. 7 and 8)

From residual analysis of dependent variable scores (Shapiro–Wilk = .98, $p = .26$), the population distribution of the present study can be assumed to be normal. The MANOVA analyses yielded three significant main effects: interface modes (Wilks' Lambda = .77, $F_{(2, 107)} = 15.63$, $p < .0001$), cognitive styles (Wilks' Lambda = .71,

Table 3
Effects of interfaces on structural knowledge (SK) and feeling of disorientation (Dis)

	Source	df	Sum of square	Mean square	F value	Pr > F
SK	Interfaces	1	153.924	153.924	20.9267	<0.0001
	Error	114	838.5156	7.3554		
	Corrected total	115	992.4396			
Dis	Interface	1	41.0348	41.0348	1.6495	0.2016
	Error	114	2835.957	24.8768		
	Corrected total	115	2876.991			

Table 4
Effects of cognitive styles on structural knowledge (SK) and feeling of disorientation (Dis)

	Source	df	Sum of square	Mean square	F value	Pr > F
SK	Cognitive styles	3	195.7004	65.2335	9.17	<0.0001
	Error	112	796.7392	7.1137		
	Corrected total	115	992.4396			
Dis	Style	3	219.733	73.2443	3.0872	0.0301
	Error	112	2657.258	23.7255		
	Corrected total	115	2876.991			

Table 5
Interaction effects of interfaces and cognitive styles

	Source	df	Sum of square	Mean square	F value	Pr > F
SK	Style * Interface	3	127.2256	42.4085	8.9172	<0.0001
	Error	108	513.63	4.7558		
	Corrected total	115	992.4397			
Dis	Style * Interface	3	185.5211	61.8404	2.7485	0.0464
	Error	108	2429.973	22.4998		
	Corrected total	115	2876.9914			

$F_{(6,214)} = 6.82$, $p < .0001$), and interactions (Wilks' Lambda = .72, $F_{6,214} = 6.26$, $p < .0001$) between the two, on the dependent variables for participants' structural knowledge and feelings of disorientation. Further analyses of ANOVA results are reported as follows.

3.1. Effects of interface types

The one-way analysis of variance for structural knowledge (Table 3) indicates that the interface design resulted in significant effects ($F_{(1,114)} = 20.93$, $p < .0001$). The VM interface group ($\mu = 20.83$) was superior to the HL interface group ($\mu = 18.53$) in the acquisition of structural knowledge. In contrast, no significant evidence was found ($F_{(1,114)} = 1.65$, $p = .20$) to support the hypothesis that the VM interface approach might be more effective than the HL interface in reducing participants' feelings of disorientation. The means for the VM interface and the HL interface were 27.41 and 28.60, respectively.

3.2. Effects of cognitive styles

The statistical results (Table 4) showed that participants' cognitive styles substantially affected their structural knowledge ($F_{(3,112)} = 9.17$, $p = .000$). The result of Scheff'e post hoc comparison indicated that AV participants ($\mu = 21.77$) significantly outscored WI ($\mu = 18.61$) (LSD = 3.38, $p = .000$) and WV ($\mu = 18.82$) (LSD = 2.95, $p = .000$) participants in the structural knowledge test. The largest difference occurred between AV and WI participants. A similar result was found in the test of subjective feelings of disorientation. Significant evidence was found when the disorientation scores of participants with different cognitive styles were compared ($F_{(3,112)} = 3.09$, $p = .030$). According to Scheff'e post hoc comparison, AV ($\mu = 25.62$) participants experienced significantly less disorientation than did WV participants ($\mu = 29.50$) (LSD = −3.89, $p = .004$) and WI participants ($\mu = 28.52$) (LSD = −2.90, $p = .025$). In fact, the highest level of disorientation was reported by WV participants.

3.3. Interaction effects of interface types and cognitive styles

An interaction effect was found ($F_{(3,115)} = 8.92$, $p < .0001$) (Table 5) between the use of different interfaces and the subject's cognitive style in influencing participants' structural knowledge. In the VM interface group, from the LSD multiple comparison, statistically significant differences were attributable for WV participants ($\mu = 18.14$) in comparison with AV ($\mu = 22.31$) (LSD = −5.16,

$p = .000$) and AI participants ($\mu = 22.07$) (LSD $= -3.92$, $p = .000$). As for participants in the HL interface group, from the LSD multiple comparison, significant differences existed when WI participants ($\mu = 17.06$) were compared with AV participants ($\mu = 20.23$) (LSD $= -3.61$, $p = .000$) and WV participants ($\mu = 19.50$) (LSD $= -2.88$, $p = .000$). Contrary to expectations, AV participants might by nature reject the use of the textual facility, but still succeeded in gaining the highest structural knowledge of both groups.

In addition, based on participants' structural knowledge scales, a measurement to identify which types of cognitive style participants might be affected most by different interface treatments was executed. The analysis results showed that WI ($F_{(1,31)} = 16.67$, $p = .000$) and AI participants ($F_{(1,27)} = 24.15$, $p = .000$) were the top two whose scores could be easily affected by different interface treatments, whereas AV ($F_{(1,24)} = 4.16$, $p = .01$) and WV ($F_{(1,26)} = 3.07$, $p = .09$) participants did not seem to be affected at all, regardless of which types of interface were applied.

As for feelings of disorientation, an interaction caused by the effects of interfaces as well as participants' cognitive styles was found ($F_{(3,115)} = 2.84$, $p = .009$). According to tests of between-subject effect, the strength of the interface factor was quite trivial ($F_{(1,108)} = 1.856$, $p = .176$). The major forces contributing to the interaction effect were participants' cognitive styles ($F_{(3,108)} = 3.255$, $p = .025$) and the combined result of cognitive styles and interfaces ($F_{(3,108)} = 2.748$, $p = .046$). In the attempt to measure the VM interface effect, using ANOVA analysis, no significant result ($F_{(3,55)} = 1.06$, $p = .382$) was found. That is, these four types of cognitive style participants felt no difference in terms of the disorientation issue when they used a VM interface to complete the learning task. On the contrary, a significant result ($F_{(3,53)} = 3.835$, $p = .015$) was found when the HL interface was applied as the navigational approach. There was sufficient evidence to indicate that different cognitive style participants did suffer various degrees of disorientation when they used the HL interface to complete the learning task. According to LSD multiple comparisons, significant differences existed when comparing AV participants ($\mu = 24.23$) with WI ($\mu = 30.75$) (LSD $= -6.519$, $p = .030$) and WV participants ($\mu = 30.29$) (LSD $= -6.055$, $p = .007$). The largest significant difference in the experience of disorientation was found between AV and WI participants. AV participants experienced the lowest level of disorientation.

Based on the participants' disorientation scales, a measurement to identify which types of cognitive style participants might be affected most by different interface treatments was managed. WV ($F_{(1,26)} = 6.02$, $p = .020$) and AI participants' ($F_{(1,27)} = 6.03$, $p = .022$) disorientation scales could be easily affected by different interface treatments, whereas AV ($F_{(1,24)} = .263$, $p = .612$) and WI ($F_{(1,31)} = .491$, $p = .492$) participants seemed to feel no difference in terms of disorientation, no matter which types of interface were applied.

3.4. Structural knowledge and feelings of disorientation

The result revealed a significantly negative correlation ($r = -.36$, $p = .000$) between participants' structural knowledge and their feelings of disorientation. To investigate in further detail, the analyses of different interface treatments corresponding to the correlation relationships between structural knowledge and feelings of disorientation were carried out as below.

3.5. Structural knowledge and feelings of disorientation: effects of interface types

The result revealed that there was a significant correlation ($r = -.672$, $p = .000$) between structural knowledge and feelings of disorientation for participants who used the visual–metaphorical interface to complete the task. In contrast, no significant correlation between these two dependent variables was found for participants in the Hyperlink interface group ($r = -.117$, $p = .387$).

3.6. Structural knowledge and feelings of disorientation: effects of cognitive styles

For participants' cognitive styles corresponded to the correlation relationships between structural knowledge and feelings of disorientation, only participants with WI ($r = -.355$, $p = .043$) and AV ($r = -.380$, $p = .042$) cognitive styles whose structural knowledge and disorientation were found to have significant correlations.

3.7. Structural knowledge and feelings of disorientation: interaction effects of interface types and cognitive styles

To examine whether interface treatments or participants' cognitive styles might or might not cause the differential scales among these correlation coefficients, the Fisher z transformations were applied here to test out the hypotheses. The level of significance was set at .1 (two-tailed test). For the test of interface treatments, because no correlation was found by the use of the hyperlink interface, there was no further need to apply the Fisher z analysis. For the test of participants' cognitive styles, only WI and AV were analyzed, as they were the only two groups to have apparent effects in strengthening the correlations between structural knowledge and disorientation. To that end, since the observed value of the test statistic ($z = -.108$, $p = .456$) did not exceed the critical value ($z_{cv} = \pm.9124$), there was insufficient evidence to infer that participants' cognitive styles had an impact on the correlations. Finally, for the test of different cognitive style participants in the groups using different interfaces, no observed value exceeded the critical value. For four types of cognitive style participants in the different interface groups, the correlation strengths between their structural knowledge and disorientation showed no difference.

4. Discussion

4.1. Structural knowledge

The experiment findings lend support to the view that the structural knowledge developed by participants is significantly affected by the way in which information is presented to them, and by the participants' information processing tendencies. The visual–metaphorical interface did help novice subjects to acquire better quality structural knowledge compared to the hyperlink interface, which was less capable of facilitating a structural mapping procedure. This result is consistent with McDougall et al.'s (2001) and Smolnik et al. (2003) results in which visual metaphor worked positively in helping participants' mental development. However, it may contradict Hsu's (2005, 2006) conclusions that since novices still fall short of complete and well-organized mental models, they may fail to make good use of the metaphorical approach. This contradiction likely exists because Hsu's studies applied verbal metaphor instead of visual metaphor to elicit the knowledge structure of the to-be-learned content. According to the 'limit capacity theory' (Lang, 2000), participants in Hsu's study not only had to receive the incoming new information, but also needed to visualize information transmitted from the auditory channel in a limited time. The storage process might thus be forced to give room to the coding and retrieval processes. As a result, the learner's storage performance was decreased. In addition, the subject issue might be another factor to bias the study results. Not just the expertise of the content domain (novice vs. expert), but also the participants' cognitive characteristics should be seriously considered, especially in terms of information processing.

According to the analysis results, participants' cognitive styles did significantly affect their ability to acquire structural knowledge. Overall, analytic-verbal and analytic-imagery style participants performed best in comparison with wholist-verbal and wholist-imagery participants. This finding is identical to those of previous studies (Lee, 2000) in which analytic type participants outscored wholist type participants. Pask (1988) portrays wholist type users as "large step" thinkers concerned with having a global entity described before going in-depth into each individual concept, whereas analytic type users are more inclined to apply a "small step" strategy without diminishing the entity, even if its description has been omitted. It seems that wholists' top–down processing preference does not help them much in the development of structural knowledge compared with the analyst's bottom–up learning approach. This interpretation of the difference between analysts and wholists also indirectly proves the development-stage theory of mental models (Jonassen et al., 1993). That is, users who construct mental models sequentially from the declarative knowledge stage hold a better chance of forming solid structural knowledge.

Interestingly, from the interaction analysis of interfaces and cognitive styles, participants' status in the verbal–imagery dimension seemed to play a more decisive role in comparison with the wholist–analytic dimension when determining their favorite interface applications. When participants were classified as verbal thinkers, they tended to prefer the hyperlink interface. For instance, wholist-verbal participants did not benefit, as hypothesized, from the use of the visual metaphorical interface. Instead, they acquired better structural knowledge through working with the hyperlink interface. In particular, when participants were classified as imagery thinkers, regardless of their wholist or analytic natures, participants' imagery attribute appeared to be more sensitive in facing different interface treatments than their contemporaries in the verbal continuum. As such, wholist-imagery and analytic-imagery participants' structural knowledge scores showed the greatest difference when the interface mode was managed between the visualization (visual–metaphor) and verbalization (hyperlink) format. The analytic-verbal subject was indeed an exceptional case. They were quite capable of adjusting their learning strategies by making good use of any supplied interface mode to develop their mental models.

4.2. Feelings of disorientation

In terms of the subject's feelings of disorientation, the visual–metaphorical interface did not lighten participants' cognitive load much in comparison with their counterparts in the hyperlink group. The possible reason is that the visual metaphor is a *mental scaffolding device* rather than a *navigational aid*. With the help of a visual metaphor, novice users are able to intuitively construct their understanding of information content. However, the simultaneous mental loads imposed by the additional metaphorical explanations might elicit more navigational problems, even if it helps to form a better quality of knowledge. Thus, the possibility of experiencing disorientation increases, especially in the beginning stage. Beside, users' cognitive styles might further exaggerate such a feeling.

According to the statistical analyses, cognitive style appears to be a significant factor in affecting users' disorientation feelings. Witkin and Goodenough (1979) revealed similar results that individual differences existed in spatial orientation performance. Lee and Boling (in press) investigated field-dependent–independent users in using a concept map interface. The study results indicated that field-dependent participants tend to feel high disorientation even though they have higher structural knowledge than field-independent participants. Similarly, the present study results showed that users with analytic or imagery styles possess better skills for dealing with this navigational problem. In contrast, the dependent nature of wholist or verbal users may lead them to experience more disorientation problems. That is, analytic users are relatively more capable of setting the learning paths by themselves, which might ultimately contribute to personal performance in a non-linear environment where information content is often presented discretely. Conversely, wholist users are more likely to have greater difficulty when required to provide organization as a conceptual aid (Witkin et al., 1977). Verbalizers are superior at working with verbal information but are less effective at keeping track of their spatial locations like imagers. As a result, participants who were classified to possess attributes of both wholists and verbalizers (wholist-verbal) showed the highest level of disorientation in comparison with other styles.

The interaction analyses of cognitive styles and interfaces revealed an interesting result. The provision of the content overview does not necessarily interfere with analytic or verbal users' learning. Theoretically, analysts and verbalizers could start with individual concepts and are comfortable processing information node by node, such as through hyperlinks. Yet this does not mean that they will completely forego the advantages of visual aids if they are helpful in directing their spatial locations. Consistent with Graff's (2003) findings, to provide an overview such as a visual–metaphorical interface, is also a beneficial way to improve these two types of users' navigation ability.

In general, the experiment findings showed that users' cognitive styles have a greater influence than interface modes on this dependent variable. Analytic and verbal users were quite flexible at adopting different interfaces, even those interfaces that did not fit their initial preferences. In contrast, wholist and imagistic users' performances were highly dependent on whether or not the interface was compatible with their cognitive tendencies.

4.3. Structural knowledge and feelings of disorientation

The research findings are consistent with Beasley and Waugh's (1996) and McDonald and Stevenson's (1996) conclusions that the more structural knowledge users gain, the less they will experience feelings of disorientation. Disorientation problems can be distinguished in terms of disorientation of spatial and conceptual navigations (Webb and Kramer, 1990). Both could be attributed to users' lack of coherent structural knowledge of the content. Different interface tools are proposed to facilitate knowledge formation and to minimize spatial and conceptual disorientation. Surprisingly, the results showed that in the visual–metaphorical interface group, users' structural knowledge is highly related to their feelings of disorientation. No significant correlation was found in the Hyperlink interface group. The possession of structural knowledge in the visual–metaphor interface group was more important than in the Hyperlink interface group. That is, the visual metaphor interface demands users with higher structural knowledge to manage it efficiently. Otherwise, it might just increase users' cognitive load and deepen feelings of disorientation.

As for the correlation of different cognitive style users' structural knowledge with their feelings of disorientation, wholist-imagers and analytic-verbalizers were the two types whose structural knowledge and disorientation were found to have significant correlations. Unlike other style users, wholist-imagers' characteristics led them to strongly favor and depend on the visual–metaphorical interface. As indicated in the above discussion, this visual aid demands users with better structural knowledge to use it sufficiently. Wholist-imagers depend heavily on such types of interface. Their structural knowledge thus plays a far more important role than others' in terms of feelings of disorientation. However, in the case of analytic-verbalizers, their structural knowledge functions as a completely different phenomenon. Analytic-verbalizers are inclined to rely on internal- rather than external-regulation strategies. Essentially, their structural knowledge will highly correlate with their feelings of disorientation.

5. Conclusion

It has been widely claimed that learning in a hypermedia environment requires higher-order cognitive skills such as the association and linking of different concepts or information (Ambrose, 1991). The use of interactive technology as a knowledge exploration tool has created a host of challenges and questions for designers. To address these problems, two classes of issues have been suggested (Locatis et al., 1992): the authoring-related issue and the learning-related issue. The authoring issue concerns the most appropriate way to represent information to users. The learning issue explores learners' cognitive characteristics which might affect their performance in a hypermedia environment. The present study serves to examine these two issues, visual metaphors and cognitive styles, and makes several contributions to our understanding of them in relation to hypermedia learning:

1. *For novice users, visual metaphor is a mental scaffolding tool rather than a navigational aid.* Visual metaphor does help users' constructions of structural knowledge, but the additional mental effort required will have negative effects on users' navigation performance.
2. *Users' cognitive styles play a more decisive role than interfaces do in determining their performances in terms of mental construction and navigation within a hypermedia environment*. Analytic users have better adoptive abilities compared to wholist users when taking advantage of visual and verbal interfaces. Analytic users also demonstrate strong navigation skills, as do imagers. Finally, users' tendencies in the verbal–imagery dimension will profoundly affect their preferences in choosing an interface mode.

3. *The disorientation problem should be understood as the problem of lacking tangible mental models rather than the subjective feeling of being lost*. The more structural knowledge users gain, the less they will experience feelings of disorientation. The direct and primary contribution of a good user interface is to speed up users' formation of system models. Thus, especially in the beginning phase, the primary concern should be to measure how well and how quickly an interface will help the mental modeling procedure, rather than its navigational effect.
4. *Users' knowledge of content domain and cognitive styles are two critical factors to ensure the success of a metaphor interface*. The user's expertise of information content will help save the mental space originally occupied by new knowledge learning, and devote it to the mapping mechanism of visual–metaphorical interface. Their cognitive tendencies in information regulations will further impact the intensity of the visual–metaphorical interface.

To sum up, providing metaphors does not necessarily endow novice users with the instant strength needed to remove the cognitive loads of navigation. The metaphorical interface serves better as a scaffolding tool than as a navigational aid. Novice users may need more time before their mental models can sufficiently manage the metaphorical interface, or their feelings of disorientation will intensify. Cognitive style is another important factor affecting users' performance when using the metaphorical interface. Users with wholist or imagery tendencies will no doubt strongly favor an interface, like a metaphor, that provides a global view and that visualizes information. However, the nature of analytic or verbal style doesn't reflect the same way on users' behavior as their counterparts do. Users with analytic or verbal styles are not solely attached to the analytical and verbal approaches, such as hyperlink. Instead, they demonstrate a rather surprising adjustability to take advantage of the visual–metaphorical interface. In other words, supplying a visual–metaphorical interface, in one way, is deemed necessary for wholist and imagery users, and in another way, seems not to disturb but rather to enhance analytic and verbal users' performance. Thus, it is safe to say that for designers, a visual–metaphorical interface does work for different styles of users, especially in the process of mental modeling. Although inevitable cognitive loads may still occur and increase the feelings of disorientation at the initial stage, users' performance will improve over time as their structural knowledge becomes integrated.

6. Limitations and future research

A major limitation of the present study is that, in developing the experimental web sites, different background colors were added to help discriminate among the three visual–metaphorical interfaces (Getting Accounts, Getting Tools, Getting Started). Although the main metaphor graphics were illustrated in gray tone, it is not clear how these background colors might affect the final result. In addition, the present study only measured how novice users' performance was modulated by their cognitive styles and assigned interfaces; whether the same variables might affect expert users is ambiguous. Future research is suggested to include expert users, and to explore the long-term effects of the metaphorical interface in contributing to the users' procedural knowledge stage in problem-solving scenarios.

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