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Abstract

Purpose – The purpose of this paper is to explore whether children adopt a survey or a route approach when seeking information in a virtual world (VW), and whether their approach differs depending on whether they are experiencing positive or negative motivation. Different models were used based on disparate spatial recognition and conceptual abilities.

Design/methodology/approach – In total, 127 children operated a three-dimensional VW interface then they filled out a questionnaire. Structural equation modeling was employed to analyze weighted relationships among latent variables. Motivation (positive vs negative), information-seeking model (heuristic survey or detailed route) and the spatial markers, and complexity of patterns of the VW were examined.

Findings – The authors discovered that a highly motivated child tends to take a central route in the process of information seeking, whereas a child experiencing negative emotions and uncertainty prefers a survey approach using spatial markers to obtain information. In short, the type of motivation influences whether children adopt a heuristic or detailed perspective when searching for information on virtual interfaces.

Originality/value – It is believed that users combine perceptual activities (low-level cognition) with conceptual activities (high-level cognition) in order to save energy. Yet this study is the first to investigate the conditions under which children are prone to utilize spatial markers (based on visual working memory) or the sequencing of patterns (based on verbal working memory) to find information in a heuristic or detailed fashion. This study provides a fresh perspective regarding perceptual and conceptual integration for information visualization technology.

Keywords Virtual worlds, Information visualization, Children information seeking, Information space, Search user interfaces, Way finding

Paper type Research paper

Introduction

Children are generally eager to seek fun. As Bilal (2005, p. 204) noted, "In the children's eye the visual design of a successful portal is one with a fun name." Beheshti (2012) alluded to the significance of the visualization tools that are introduced in search user interfaces. Virtual worlds (VW) can be defined as computer-simulated interactive environments where users may participate (interact) through their avatars, whether for work or play, in a manner comparable to the real world (Messinger *et al.*, 2009; Yang and Yuen, 2012; Cudworth, 2014). Many researchers are engaged in studying how children use VW technologies to learn about natural science (Wrzesien and Raya, 2010), injury prevention (Schwebel *et al.*, 2008; Coles *et al.*, 2007), and education regarding emotions of shame that children may face in their virtual or real relationships with others (Rooney, 2015). We pose that the use of information visualization technology

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(in VW) might encourage children to analyze the framework of the database at hand and thus formulate operating strategies in the process of information seeking. Wu and Chen (2016) affirmed that when children are operating a two-dimensional (2D)- or three-dimensional (3D) interface, they either adopt an "exhaustive" or "focussed" approach when in search of information, depending on their cognitive load.

According to Petty *et al.* (1983), the elaboration-likelihood model (ELM) acts as a theory of persuasion, and can be used to illustrate how consumers either choose the central path and make a detailed diagnosis, or take a peripheral route to first get a rough impression of the information imbedded in the advertisement they are watching. The route they choose usually depends on how interested they are or what level of involvement they prefer. This theory reveals that preferred searching behaviors are related to the motivations of the participant. In other words, they use different strategies with higher or lower cognitive loads when dealing with message management.

This explains why children choose different searching strategies depending on whether they have stronger or weaker motivation (curiosity vs a sense of uncertainty that curbs the urge to explore) for operating a 3D interface. They either employ a central route to exhaustively ferret out information, or resort to a survey method to scan thematic information. Information visualization technology is expected to develop interfaces that better suit the various types of children's information-seeking behavior.

Literature review

Uncertainty and curiosity

Brashers and Hogan (2013) explained that those seeking medical information often feel a sense of uncertainty and want to take control over it. Uncertainty does not necessarily lead to anxiety; rather, a sense of ambiguity helps one stay positive and hopeful. When it comes to information seeking, uncertainty is caused by multi-dimensional, dynamic user experiences. Chowdhury *et al.* (2011) examined the way scholars seek information and make retrievals in an academic environment, discovering a non-linear, complicated relationship between uncertainty and the process of message seeking. They suggested that further exploration be made into the influence that positive and negative uncertainty (NU) exert on the information seeking and retrieval process.

Reynolds and Symons (2001) examined the process applied to text searches, such as that used when looking for a desired book. They stressed that children are influenced by both motivation and prior knowledge for the duration of information-seeking behavior. Jirout and Klahr (2012) attempted to construct an operating framework grounded in Loewenstein's (1994) "information gap theory of curiosity" to explain children's curiosity and exploratory behavior. For preschoolers, they "defined curiosity as the threshold of desired uncertainty in the environment that leads to exploratory behavior" (Jirout and Klahr, 2012, p. 125). The current study posits that the positive emotions aroused by curiosity and the negative emotions aroused by uncertainty both affect a child's motivation for exploration when using an information visualization interface.

Interface representation and cognitive load

Hall and O'Donnell (1996) compared how students obtained learning via "knowledge maps" and "text," documenting their motivation, anxiety, and concentration in a designated period of time. Results showed that the group that used "knowledge maps" had higher recall, subjective concentration, and subjective motivation. Therefore Hall and O'Donnell concluded that the positive impact of knowledge maps applies to subjective ratings of concentration and motivation as well as objective cognitive outcomes. Hearst (2009) revealed that human perception is very intense in imagery. Images convey messages more quickly and effectively than a full-length text, as information visualization can transform abstract information into a visual representation (VR) and thus provide new insights about that information. Using information visualization technology to change thematic materials into a data structure (such as a knowledge map) might be helpful for kids who are learning to search a user interface.

Sandamas and Foreman (2007) investigated how children aged 5-9 comprehend and construct spatial concepts in a VW compared with the physical environment. Despite their limitations in working memory, children can still find ways to transfer the knowledge obtained in the VW to the real world. There are very different outcomes in spatial learning depending on whether the child is having an actual experience or whether she/he is engaged in self-directed activities or passive observation. Their research suggests that observation is far more efficient than activity. Static observation helps a person save cognitive capacity so she/he can better comprehend the conception of space, while dynamic operations, too many operations, route selection, and allocation of assignments add to a child's cognitive load. Children might already have a heavy cognitive load because of the operating interface; therefore, they generally exhibit differing information-seeking behaviors on a virtual interface than in the real world.

Ware (2013, p. 375) explained that people use an "information scent," which can be defined as the information in the current environment that assists people in finding richer information clusters. An information scent helps people to select needed data from large amounts of information taken in during their visual thinking processes. They do this in order to decrease their cognitive load. A VW's interface takes advantage of the attributes of the virtual space. Thus the information scent is emphasized by the user when making decisions via both spatial working memory and long-term memory. This end result is that users will resort to different strategies when seeking information. Gottlieb *et al.* (2013) proposed computational and neural mechanisms to explain information-seeking, curiosity, and attention, stating that "information-seeking obeys the imperative to reduce uncertainty and can be extrinsically or intrinsically motivated" (p. 586). They suggested investigating representations of task-related vs open-ended curiosity mechanisms, with the coding of factors such as novelty, uncertainty or surprise when processing visual cues. Gottlieb *et al.* (2014) further analyzed gaze patterns in sensorimotor behaviors by asserting that "gaze is strongly sensitive to the relative uncertainty of competing subtasks" (p. 15503). They also suggested further exploration into the interaction between uncertainty and reward-based control. Considering human to urge to decrease the sense of uncertainty when dealing with spatial relationships, we can infer that when users operate a well-constructed information visualization interface, they make decisions based on an interplay between uncertainty and any rewards that may ensue. Therefore, by uncovering the relationships among the user's attention, decision making, and cognitive load, we will better understand how to formulate advanced information visualization systems.

Ways of exploration

When trying to comprehend spatial information, people consider the task at hand and the characteristics of the space (landmarks, routes, and survey knowledge) before making choices about which approach, the egocentric or exocentric one, to take (Ware, 2013). Henry and Polys (2012) observed the way users operated in an immersive virtual environment – specifically visualization interface that represented abstract data networks. They found that when people are working under a highly immersive environment, they have to concentrate on the data related to the task at hand. Under such conditions, interface users only need to make a minimal effort to quickly obtain correct knowledge from abstract database networks. Meanwhile, they may decide to choose a navigation technique that prior experiences lead them to believe might improve their understanding of the space. Zhang (2008) discussed how spatial knowledge and coupled movements can be manipulated for ease of navigation. For example, if users can easily observe the icons and the relationship between the icons and the environment under different scalings with only a click of mouse, it is easier for them to perform their work. In contrast, in real world situations, people have to conform to the limitations of the physical environment.

Riding and Rayner (1998) described cognitive styles as approaches preferred by people for organizing (collecting, analyzing, and evaluating) and presenting information. Yuan *et al.* (2011) clarified the information-seeking behavior displayed by participants when using an information visualization system, affirming that users with a holistic cognitive preference tended to be more satisfied while searching for results than did their counterparts who used analytical methods in the same process; this was true though the latter found significantly more correct answers. Park and Black (2007) called attention to the frequently used keywords typed by users who preferred an analytical cognitive style. Users who adopted a holistic approach (grounded in survey) have very different tendencies toward the comprehension of spatial information than those using an analytical approach. Users applying the two different cognitive styles tend to be swayed by differing moods during the search process.

As a result, children who conduct searches over a virtual interface are under the mixed influences of curiosity (positive force) and uncertainty (negative force) so they might very well choose a different strategy than when they make discoveries in the physical world. Thus the interplay among the visual interface user's perception, attention, memory cross-referencing, and reward mechanisms are worth further exploration. Also warranting further research is the subject of children's cognitive styles and their responses to various interface characteristics while engaging in VW searches.

Research model

Observed variables of motivation

The following presents the observed variables of motivation. According to Scarpi (2012), consumers who shop online can be split into two groups: the hedonic group that searches for tips or messages on a whim, to seek fun, or due to curiosity, and the utilitarian group whose primary aim is to accomplish specific tasks. For those with pleasure-seeking inclinations, Carroll (2004) advised that the level of fun they experience influences their notions of usability. Gurland and Glowacky (2011) scrutinized relevant theories of motivation in children and concluded that kids value rewards, seeing them as a sign of encouragement. As for people with utilitarian motives, Case (2012) found that an individual who senses a problematic situation and lacks internal knowledge regarding that situation would want to seek informative and useful information. The latent variable of positive motivation (PM) contains observed variables, including fun (Fun), motivated (Moti), informative (Ifmv), and useful (Usfl).

Kuhlthau (2004) stated that people are subject to confusion, depression, or even suspicion while seeking information. Tenopir *et al.* (2008) stressed that a difficult task might trigger negative emotions. The latent variable of NU contains observed variables such as confused (Cfus) and difficult (Dift).

Observed variables of interface representation

Ware (2013, p. 373) elaborated on the process of seeking information over a visualized interface, stating that "Consistent layout is essential for spatial memory to support revisiting an information entity having a spatial representation." Another manifestation is that "procedural instructions can be more useful when the task itself requires navigating from data object to data object (node), taking certain actions at each […] The cognitive representation of that task is likely to be topological and process oriented, not spatial." The above-mentioned characteristics are very common in interfaces used by people who search for "information scent" in visualized interfaces. In reality, this procedure is to be divided into components, which are made up of a section of path that denotes the trend in the right direction, and/or a visual spatial working memory marker. Once the user picks one of them, she/he proceeds with the next visual query. Apparently the participant's span of visuo-spatial working memory (hereafter VSWM) is related to her/his cognitive load and thus causes a hindrance to the process. Ware (2013) pointed out that common people are able to work with three chunks in VSWM and/or six paths. Therefore the characteristics of a virtual interface can be categorized into: first, he number of spatial markers available and second, complexity of the patterns that emerge. Thus the latent variable of spatial marker-memory (SM) consists of base memory (Bsmo) and landmark memory (Ldmo) as observed variables, while the latent variable of the complexity of patterns-strategy (CP) comprises such observed variables as operation efficiency (Opef), direction sense (Drsn), goal identification (Gldf), and direction judgment (Drjm).

Observed variables of searching approach

Kosslyn (1987) assessed two types of knowledge representations: categorical information (or route spatial knowledge) and coordinate representation (or survey spatial knowledge). When a user makes searches over a virtual interface, route knowledge is better utilized when there is simple page representation and fewer functions, with only a small amount of information exhibited at one time. This reduces information overload. Although a less complete information structure might involve an overwhelming amount of information processing on cross-functional or cross-page operations. Survey knowledge denotes to an individual's comprehending of the sequence of events or the overall structure of a task, thus an individual applying survey knowledge implements absolute coordinates (exocentric) as a way-finding strategy. In a VW interface, an effective survey knowledge feature can offer an individual a full picture of all the functions of an interface and where they are positioned within the interface. Yet when too much information is shown at the one time, users may incident information processing overload (Kitchin, 1997).

Coluccia *et al.* (2006) studied how participants used environmental feature-labels, locations, and roads when learning and drawing city maps. They found that participants used VSWM in environmental learning and spatial navigation while trying to remember as many features of a map as possible, all at once, in a single image. This explains why the user draws the roads from a simultaneous, holistic view instead of a sequence of remembered locations. Map information was globally coded and simultaneously maintained in the visuo-spatial sketch pad (or the mental map). In addition, Sprague *et al.* (2007) described how humans respond to a VW with an elaborate visuo-motor mechanism, thereby giving constraints and specifications of the abstract behaviors that guide them; for example, which visual routines, dynamic reference frames, and simplified computations can help them visualize the above specifications. Sprague *et al.* (2007) declared that the model using vision draws needed information from environmental measurements while gaze allocations may be selected to minimize the risk of losing the reward in the set of running micro-behaviors. Along this line of reasoning, the latent variable of survey-heuristic (SH) comprises observed variables like identifying categorized zone (Idcz), identifying sequential passing icons (Ispc), intuitive location reflection (Itlc), and figure out map (Fgop). The latent variable of route-detail (RD) contains the observed variables including referential landmarks (Rfld), passing icons prearrangement (Pipr), directions recalled (Drrc), and turning arrangement (Tuar). Table I shows observed variables and related latent variables.

Table I. Observed variables and question statements

Items	Observed variables	Question statements for subject responses
Positive motivation (PM) – latent variable		
x1	Moti	This 3D website arouses my interest in learning and stimulates me to think independently
x2	Fun	I have so much fun playing games using this 3D website
x3	Usfl	Categorizing the subjects on this 3D site helps me spot the common concepts in our homework
x4	Ifmv	Categorizing the subjects on this 3D site helps me more quickly find out what the content is about
Negative uncertainty (NU) – latent variable		
x5	Dift	I don't think this website offers sufficient procedural instructions; therefore I'm unsure of how to use it
x6	Cfus	There seems to be a cluster of icons on this website and I am getting confused
Spatial marker-memory (SM) – latent variable		
y1	Bsmo	I am able to move across this 3D game, knowing where the starting point is
y2	Ldmo	I can/will remember the houses or a certain tree along the way in this 3D game
Complexity of patterns-strategy (CP) – latent variable		
y3	Opef	I know how to quickly find the button I need in this game
y4	Drsn	I know which direction I would have to go to find "Natural science" in this 3D game
y5	Gldf	I can recall which area contains the sought-after goal when I play this 3D game
y6	Drjm	I can identify the point at which the prior "Art" area and the next "Sports" area diverge
Survey-heuristic (SH) – latent variable		
y7	Idcz	I could identify the area I was in when I was playing this 3D game
y8	Ispc	I can recall the sequence of buttons that were pushed in the game
y9	Itlc	I could instantly figure out which location I was in when I was playing this game
y10	Fgop	I could remember vividly how the map of this area was shaped when I was playing the 3D game
Route-detail (RD) – latent variable		
y11	Rfld	I tried to locate a certain house or tree as a referential point for my exploration in this 3D game
y12	Pipr	I want to have a pre-understanding about which buttons/icons I can expect in the process of finding the goal
y13	Drrc	I am able to remember what turns I've taken in this 3D game
y14	Tuar	I want to have a pre-understanding of where to take a left or right turn when I set off to seek the goal

Hypotheses

Motivation's influence on cognition

Zhu and Watts (2010) developed a model grounded in the theories of cognitive fit, working memory capacity (WMC), and information load to assess the effectiveness of network visualizations. Their research results demonstrated that cognitive fit and working memory interact. "High cognitive fit visualization reduces demand for conceptual processing by moving this processing into the perceptual processing realm" (p. 340). "Low WMC users can perform the focal task using particular visualization, and if necessary, modify the visualization to a lower level of complexity" (p. 341). Hence when operating a visualized system, people resort to perceptual processing (lower cognitive load) as a replacement for conceptual processing (higher cognitive load), thereby decreasing the complexity of work via visualization and focus on specific areas.

User gratification theory (UGT) (Brashers, 2007), elaborated on this phenomenon by showing that users with different motivations may turn to different channels to obtain information. This study proffers that a user with stronger motivation tends to opt for conceptual processing, which requires a high cognitive load, and employs multiple strategies to examine what they have acquired from the interface and determine what the next response will be. Hence we present the first hypothesis as follows:

H1. "PM" exert a stronger influence on the CP than on SM.

When the user is slightly motivated (NU), she/he will be inclined to spare effort and opt to use perceptual processing and SM to decide next-phase operations for the sake of effort reduction. Consequently we present the second hypothesis as:

H2. "Uncertainty" (NU) has a stronger impact on SM than on CP.

Interface approach

Münzer *et al.* (2006) suggested that users operate computer-assisted navigation as a way to obtain route and survey knowledge. They have a memory of the system only after they had actually passed a given location. Meanwhile, active encoding can be seen as the primary explanation for how a user acquires superior spatial orientation knowledge via the map. Those who take the survey approach when encoding need spatial markers as referential landmarks. They thereby form a heuristic picture before they can construct a map in their minds. Third hypothesis is as follows:

H3. SM has a stronger influence on SH than CP does.

When one is route oriented, one tries to employ a multitude of individual-centered strategies to explore hidden directions and routes. Hence the fourth hypothesis is presented as:

H4. CP exerts a stronger influence on RD than does SM does.

Motivation influences search approaches

Rains and Tukachinsky (2015) used UGT to explain the sense of uncertainty – a mix of expectation and vulnerability – felt by the people who seek health-related information over the web. The desired uncertainty level displayed by a user can be regarded as an indicator of the influence on appraisal intensity and the user's willingness to continue seeking information amid uncertainties. Here, we combine the ELM (Petty *et al.*, 1983) and hypothesize that when one has a stronger motivation, one tends to operate the interface in an analytical, continuous way, using an exhaustive approach by taking the central route:

H5. PM exerts a stronger influence on RD than on SH.

The user who feels uncertain and weakly motivated tends to take a heuristic survey and a peripheral route so as to discover information from a macro-perspective:

H6. NU makes a stronger impact on SH than on RD.

Figure 1 shows relationships among latent variables and hypotheses.

Research questions

RQ1. When using a visualized interface, what will be highly motivated or highly uncertain users use to guide them – spatial markers or the complexity of patterns?

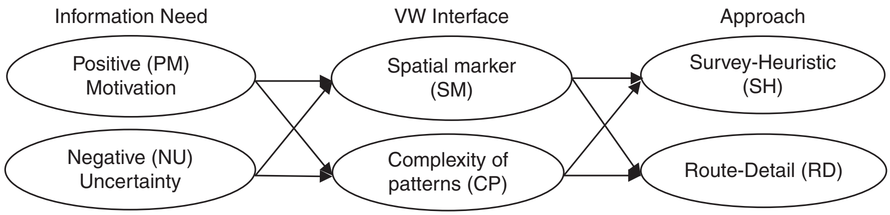
RQ2. When a user chooses spatial markers to navigate the interface, what kind of approach will she/he take: a SH or RD? When users choose the complexity of patterns, what approach do they prefer?

RQ3. For a user with PM, regardless of whether she/he chooses spatial markers or the complexity of patterns as an operating skill, will she/he take a SH or RD approach? What will a highly uncertain user choose if made to choose between the SH or RD approach?

Methodology

Participants

According to Piaget, children in the concrete operational stage (aged 7-11) are growing in their ability to reason with logic, categorize items, and discover the relationships between things. Children at this age are undergoing fast visual development, which plays an important role in interface design (Hourcade, 2007). It follows that children this age would be able to maneuver the 3D (survey+route) interfaces in which multiple objects exist on different layers and form a knowledge map. A total of 127 students from second to fifth grade classes from schools in Taipei participated in this study. Of these, 42 were age 8 (33.1 percent), 16 were age 9 (12.6 percent), 39 were age 10 (30.7 percent), and 30 were age 11 (23.6 percent). Sixty-four participants used the 3D-survey interface (35 males (54.7 percent), 29 females (45.3 percent)), and 63 participants used the 3D-route interface (30 males (47.6 percent), 33 females (52.4 percent).



Notes: *H1*: Path values of PM→CP greater than PM→SM; *H2*: Path value of NU→SM greater than NU→CP; *H3*: Path value of SM→SH greater than CP→SH; *H4*: Path value of CP→RD greater than SM→RD; *H5*: Path value of PM→RD greater than PM→SH; *H6*: Path value of NU→SH greater than NU→RD

Figure 1. Conceptual model of users-seeking information in a VW interface

Measures

Consent for the children to participate in the study was obtained before the research began. After participants were separated into groups according to age in their school, each participant received three tasks. Subsequent tasks only appeared when the previous one had been completed. The differences between the three lay in whether the information seeker had a thorough understanding of the search topic (biology, literature, or sport) and the searching situation (daily assignments, non-curriculum searching, and unfamiliar professional knowledge). The tasks were designed to show whether interface spatiality is helpful for those seeking information; therefore, the users were only told to find the database node itself, instead of actually searching in the database.

Task 1: you come across a problem when you are doing your biology assignment, and your teacher tells you that the "Taiwan Ecological Notes Database" might contain useful information. Now, try to find the "Taiwan Ecological Notes Database."

Task 2: when you want to take a look at some animations, your teacher tells you that "Chijon Tsai's Comic Animation Database" might have some good references for you. Now, try to find "Chijon Tsai's Comic Animation Database."

Task 3: you encounter problems when you are doing a physical assignment, and your teacher tells you that "Sports Animation" might have some useful information. Now, try to find "Sports Animation."

The 3D-survey interface (Figure 2, left) has all the nodes gathered into five groups in the shape of a cherry blossom, which offers a clear center and polar coordinates on a flat surface. An overlook function allows the children to experience two visual hierarchies, either from above or from a flat angle. Children can use the overlook function to get familiar with the entire structure of the database, then they can use the mouse scroll wheel to zoom in and out. They are able to use the mouse to go in every direction and click on specific nodes; however, processing and memorizing the theme map might increase the user's cognitive burden. Although the 3D-route interface (Figure 2, right) is the same virtual space as a 3D-survey interface, users can only zoom and move around nodes using the mouse scroll wheel and the keyboard in a 2D interface. Yet because only a small amount of information is shown at one time, it is relatively easy for the children to process information.

Results

Equations for path analysis

This study employed structural equation modeling (SEM, LISREL 8.72) as developed by Jöreskog and Sörbom (1996) to undertake path analysis. γ and β exhibit the

Figure 2.
3D-survey (left) and 3D-route (right) graphic search interface

relationship between exogenous and endogenous path factors (latent variables). The corresponding equations are as follows:

$$SM = \gamma_{11}(PM) + \gamma_{12}(NU) + \text{measurement errors}. \quad (1)$$

This equation indicates that PM and NU influence SM:

$$CP = \gamma_{21}(PM) + \gamma_{22}(NU) + \text{measurement errors}. \quad (2)$$

This equation indicates that PM and NU influence CP:

$$SH = \beta_{31}(SM) + \beta_{32}(CP) + \text{measurement errors}. \quad (3)$$

This equation indicates that SM and CP influence SH:

$$RD = \beta_{41}(SM) + \beta_{42}(CP) + \text{measurement errors}. \quad (4)$$

This equation indicates that SM and CP influence RD.

Measurement model

Factor loading represents the relevancy between individual variables and factors; standardized loadings are commonly between 0.56 and 0.76. When the *t*-value reaches 0.001, it is deemed significant. Statistical results prove that both convergent validity and the identification of measurement model are acceptable (Kelloway, 1998, p. 107). Results are shown in Table II. The squared multiple correlations (SMC) reveals how a

	Items	Latent variables SEM factor loadings λ (*t*-values)	Squared multiple correlations
Exogenous			
PM	Moti	0.71 (8.42***)	0.50
	Fun	0.76 (9.22***)	0.32
	Usfl	0.61 (6.98***)	0.37
	Ifmv	0.56 (6.34***)	0.57
NU	Dift	0.75 (5.30***)	0.57
	Cfus	0.58 (4.66***)	0.33
Endogenous			
SM	Bsmo	0.74 (–)	0.55
	Ldmo	0.76 (7.10***)	0.58
CP	Opef	0.69 (–)	0.47
	Drsn	0.69 (6.63***)	0.48
	Gldf	0.56 (5.56***)	0.32
	Drjm	0.62 (6.07***)	0.39
SH	Idcz	0.66 (–)	0.44
	Ispc	0.70 (6.42***)	0.48
	Itlc	0.70 (6.45***)	0.49
	Fgop	0.58 (5.51***)	0.33
RD	Rfld	0.65 (–)	0.43
	Pipr	0.61 (5.80***)	0.37
	Drrc	0.65 (6.14***)	0.43
	Tuar	0.75 (6.84***)	0.56

Note: ***$p < 0.001$

Table II. Coefficients for reliability and convergent validity single observed variable is reflected in latent variables (Table II). For example, the explained variance of the observed variable "Moti" and "Bsmo" in PM and SM (as latent variables for each) are 50 and 55 percent, respectively.

Structural model

This study used SEM to perform path analysis and obtained statistical results as follows. Indicators of overall fitness: RMSEA = 0.013(< 0.05), norm $\chi^2 = 164.68$ ($p = 0.40 > 0.05$) (AGFI: 0.85; NFI: 0.93; NNFI: 0.99; CFI: 0.99; IFI: 0.99; RFI: 0.91; GFI: 0.88; SRMR: 0.059). Results show that this hypothetical model highly corresponds to the empirical data. Table III exhibits all path coefficients (β or γ) and SMC. All of the *t*-values were significant, suggesting that all of the coefficients can be used for subsequent path analysis.

Path analysis

By comparing a participant's emotions and working memory, we obtained results showing PM exerts a stronger influence on CP ($\gamma_{21} = 0.84$***) than it does on SM ($\gamma_{11} = 0.61$***); therefore *H1* is supported. NU has a stronger impact on SM ($\gamma_{12} = 0.39$***) than on CP ($\gamma_{22} = 0.24$*). Hence *H2* is supported.

A comparison of the weights of working memory and spatial knowledge show that it is SM ($\beta_{31} = 0.63$***) rather than CP ($\beta_{32} = 0.33$***) that affects whether children adopt an SH approach. *H3* is supported. In addition, CP ($\beta_{42} = 0.62$***) proves to be more forceful than SM ($\beta_{41} = 0.38$**) in encouraging children to take RD as an approach. Hence *H4* is supported.

A comparison of the "weights" that emotions and spatial knowledge exert on route reveals that PM holds more sway over RD (0.75***) than it does over SH (0.66***). Consequently *H5* is supported. NU has a stronger impact on SH (0.33***) than it does on RD (0.30***). Hence *H6* is supported.

Discussion

A 3D model is a user-friendly model that resonates with people's navigation experience in the real world. By adding familiar icons and real-life themes to the model's framework, this design is believed to be very helpful for children who are not familiar with the use of hyperlinks when seeking and understanding information. Information visualization depends on the user's perception of patterns, so they are able to find the needed messages through intuitive identification with the framework at hand. The pairing of differing conceptual frameworks and visualized models can cause a discrepancy of cognitive loads among users, which further leads to varied user responses and identification results in the information-seeking process. This paper explores how children employ identification strategies and interfacial characteristics,

Latent variables	SM	CP	SH	RD
PM	0.61 (5.33***)	0.84 (6.86***)	0.66 (5.82***)	0.75 (6.30***)
NU	0.39 (3.34***)	0.24 (2.42*)	0.33 (3.53***)	0.30 (3.43***)
SM			0.63 (4.09***)	0.38 (3.01**)
CP			0.33 (2.52*)	0.62 (4.27***)
Squared multiple correlations	0.49	0.74	0.75	0.80

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table III. β and γ (*t*-value) of latent variables such as spatial markers and the complexity of patterns, as a way to spare effort. It also examines how kids with higher or lower motivation use different mapping skills (SH vs RD) to construct a map that contains nodes and a thematic framework that they will then use in further searches.

The relationship between motivation and type of interface

The support for *H1* shows that children who are positively motivated tend to examine the complex patterns constituted by all nodes imbedded in the interface. This supports the idea that children have an inclination and ability to adopt strategies for navigation when using a novel interface. Under these circumstances, children resort to detailed diagnoses using verbal-propositional processing and long-term memory to conjure up relevant symbols, images, and patterns that help to evoke non-visual information. The support of *H2* suggests that children who are feeling uncertain and less motivated tend to use spatial markers to determine the distribution of nodes in the thematic structure of the interface.

The relationship between interface and models of information seeking

The characteristics of information visualization help users to transform conceptual loads into perceptual formulations. The question here is: What approach (survey or route) will a child with limited cognitive capability take? In other words, will a child employ visual-based memory (through perception and accessibility) over verbal-based strategies (via conceptual development and pairing), or is the opposite true? Statistical results show that *H3* is supported. Children prefer the survey method, using spatial markers (which are memory related) to construct the whole structure of a knowledge map. The evidence in support of *H4* shows that a route-oriented user will emphasize the complex patterns by making herself/himself the center, and thus find the corresponding directions and hidden patterns.

The relationship between motivation and information-searching models

Web-based searches take place in a VW. Interfaces have a clear display of spatial associations so that users are able to do searches through visual perception. Users often develop effort-reduction mechanisms that are contingent on the level of motivation, visual attention, and reward available for effort reduction. Children may employ several techniques – information visualization, or visual or verbal working memory – to overcome the information gap, and children with differing levels of motivation will choose different mapping skills and different methods of envisioning the framework of a map in their minds. The results in support of *H5* affirm the premise that motivation exerts a more remarkable influence on route choice than survey choice. Hence when one is strongly motivated, she or he is inclined to adopt an analytical method to construct spatial order, which is in line with what Petty *et al.* (1983) alluded to as taking a central path for exhaustive examination. The evidence in support of *H6* suggests that uncertainty holds a stronger sway over survey choice than route choice. This explains why a weakly motivated person tends to stress accessibility of information over pairing of conceptual ideas, and takes a peripheral path in their survey of information nodes.

There are times when children do not have sufficient perceptive, experience, and cognitive capability to which to make a sound judgment. Having experiences on a VW interface can help children avoid harm that might occur if they make inappropriate real-life choices. VW is therefore ideal for repetitive practice (Coles *et al.*, 2007). VW experiences can help children integrate their life experiences into concrete reasoning ability as they learn to seek useful information while using a VW interface. Aldrich (2009, p. 6) said the following about children's use of VW interfaces, "Knowledge is useful only in context, and VWs provide a context ideally similar to the context in which the context will be eventually be used."

Emotions trigger a release of chemicals in the brain, which further affects memory. The fear of an upcoming test is a good example. A test-taker is forced to memorize as much information as he or she can in order to pass the examination. This explains why a VW interface design must take a user's positive and negative emotions, and his or her comprehension of the context into consideration when designing reading materials with the aim of improving information seeking and learning. However, with proper design, a VW interface is able to decrease cognitive load. Children might adopt very different strategies from searching books in the physical environment in order to save cognitive energy. This study confirms that children, when they have PM, tend to seek information using a VW interface that provides detailed and complex patterns for an exhaustive search, whereas those with negative or uncertain motivations prefer to use an interface that is noted for SM survey. This way, they are able to distinguish what is familiar and what is not, thus deciding if the information on a VW interface can be quickly searched using peripheral clues or should be explored using diagnostic skills.

Conclusions and suggestions

With advances in VW design and computer and web-based technologies, much of the discourse regarding visual-contact approaches, social interactions, and immersive experiences has explored how human cognitive abilities and responses that emerge in the real world can also be stimulated by a VW interface. Other topics of interest are the differences that exist in VW experiences and real world experiences, where physical energy and vision are both required. This study demonstrates that information seeking and gaze-oriented behavior are influenced by uncertainty and reward-based mechanisms, both in physical and VW environments.

Curiosity and uncertainty play an important role in reward and risk evaluation. When people search for objects in a 3D physical/VW environment, the complex mechanisms of visual- and verbal-working memory, long-term memory, and other cognitive abilities interplay. Under the influence of an interplay of visual attention and reduction of cognitive load, curious users tend to adopt an egocentric (route) approach for an exhaustive examination, whereas more uncertain users want to use an exocentric (survey) approach that skips details to get a rough impression. This suggests that information visualization interfaces may provide people with a multitude of sections that can vary in spatial size, procedural length, and externally stimulated/internally (emotionally) driven characteristics. Users are then able to freely choose which sections they use to seek information without strenuous effort or taking too much time.

Parsons and Sedig (2014) suggested that the adjustable properties (appearance, complexity, configuration, density, dynamism, fidelity, fragmentation, interiority, scope, type) of VR have a significant effect on cognitive processes. When improved VR is integrated into interfaces it can improve the quality of human-information interaction. Further research might focus on changes to these adjustable properties under various motivations: how would various spatial dimensions and patterns of diverse complexity impact the information-searching behaviors of children?

This study explores how curiosity and uncertainty play an antithetical role in shaping children's motivations through observations of their information-seeking behaviors in small databases. Yet we did not disclose the correlation between specific tasks and the depth and breadth of acquisition of information they were able to obtain in a set period of time. We suggest that further research be done in order to pinpoint the correlation between one's motivations (social gathering for instance) or uncertainty and the depth and breadth of acquisition of information.

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