2013

On the Impact of Stereo 3D Image on User Learning in the Web Environment

Heshan Sun
Clemson University, sunh@clemson.edu

Mary Peterson
University of Arizona, mapeters@email.arizona.edu

On the Impact of Stereo 3D Image on User Learning in the Web Environment

Heshan Sun
Clemson University
sunh@clemson.edu

Mary A. Peterson
University of Arizona
mapeters@email.arizona.edu

ABSTRACT

Recent technological breakthroughs have cultivated a Web3D movement. It is safe to say we will see more and more stereo 3D images on websites. This research investigates how stereo 3D can be employed on websites to influence user learning. A set of theory-driven hypotheses were developed to compare websites with embedded stereo 3D and websites with either static 2D images or virtual realities in terms of user comprehension, user control in learning, and user adoption of the website. Controlled experiments were conducted to test the hypotheses. The results show that stereo 3D can reduce learning effort and induce positive user attitude. At the same time, it can also reduce users' perceived control. While answering some fundamental research questions, this research also reveals that more investigation is needed regarding the use of stereo 3D on websites.

Keywords

Stereo 3D, virtual reality, learning, user technology acceptance.

INTRODUCTION

Recent technological breakthroughs in software, hardware and cyber-infrastructure have made it possible to display stereo 3D effects on websites. This research aims to contribute to this ongoing Web3D movement by investigating the relationship between stereo 3D and user learning. This research investigates two questions:

1. **Does Web-based stereo 3D influence user learning of information presented on the website?**
2. **Does Web-based stereo 3D influence user adoption of the website?**

It is important for information systems (IS) research to address these questions because the answers can inform future applications of stereo 3D technology.

To approach these research questions, we compare stereo 3D with two widely utilized presentation formats - static 2D images (2D) and virtual reality (VR) displays - on an education site. Stereo 3D, 2D and VR employ different depth cues (Table 1). Stereo 3D provides a stronger illusion of depth than either a 2D static image or a VR, display because of the addition of stereoscopic depth cues. More depth cues may enable a better understanding of the spatial relations represented in the image.

	2D	**Virtual Reality**	**Stereo 3D**
Depth Cues	**Weak** Only stationary monocular depth cues.	**Medium** Monocular and movement-based cues.	**Strong** Binocular disparity depth cue, but no movement cues.

Table 1. Stereo 3D, 2D, and Virtual Reality

We examine how websites using these three types of presentation formats influence user learning and how users adopt these websites. A website was created for this research. The website provides an educational experience: users learn about computer hardware on this site. The three presentation formats are embedded in the website, which is 2D in nature. For the stereo format, the website is a hybrid in which the stereo 3D images are displayed in the manipulation of a 2D website. In order to view the stereo 3D images, the viewer must wear stereo glasses.

THEORETICAL FOUNDATION

Multimedia Learning Theory

Learning is essentially a cognitive activity. This research refers to the multimedia learning theory (MLT, Mayer 2009; Sweller et al. 1998) to understand how stereo 3D works in the cognitive system to influence user learning. MLT has several messages useful for this research. First, a useful design should <u>facilitate user comprehension</u> so that the user can learn as much as possible. Second, a good design should make learning easy by reducing <u>the cognitive efforts</u> associated with learning. Third, a good design should <u>give the learner more control</u> over the information they receive.

In addition to the influence of stereo 3D images on learning, another important question is user adoption of website with stereo 3D images, given that it is a new innovation and user adoption of it remains unclear.

HYPOTHESES

Following MLT and Dillon and Gabbard's (1998) research, this research develops hypotheses with regard to the influence of stereo 3D on comprehension, learning control, and user adoption.

Hypotheses about Comprehension

In this research, <u>comprehension</u> is defined as the knowledge gained from the presentation format; it covers both *learning efforts* and *learning outcomes*.

This research posits that stereo 3D reduces learning efforts, defined as the cognitive resources associated with learning (Jiang et al. 2007). The rationale is that the human visual system is adept at recognizing and processing stereo inputs. After all, we see things in 3D on a daily basis (Sun et al. 1996). Previous research has suggested that properly deployed 3D cues consistent with the heuristics of object search can be easily recognized and processed by the human visual system and consequently do not necessarily increase cognitive load (Enns et al. 1990; Enns et al. 1991; Sun et al. 1996; von Grünau et al. 1994). Therefore, when provided appropriately, stereo 3D images can effectively represent nonverbal information and help form mental representations of objects.

H1: Compared to 2D or VR displays, stereo 3D displays reduce Learning Efforts.

The second aspect of comprehension is learning outcomes This research studies two factors related to learning outcomes: actual knowledge gained and perceived website diagnosticity (PWD), as suggested by prior research (Jiang et al. 2007). Actual knowledge refers to the extent to which the user actually understands the subject matter. Perceived website diagnosticity (PWD), is defined as the degree to which the user perceives the website aid him/her in understanding the subject of interest. Jiang and Benbasat (2007) showed that PWD has a direct effect on user's intention to use the website beyond the influence of actual knowledge.

This study hypothesizes that including stereo 3D on a website can enhance both actual knowledge and PWD, compared with websites using static 2D and virtual reality displays. Stereo 3D renders more information at once. Compared to 2D, stereo 3D is a richer presentation, providing more depth cues (Kumar et al. 2004). For instance, Kuman and Benbasat (2004) showed that viewer performance was better on a variety of tasks illustrated by 3D graphs rather than 2D graphs. This somewhat confirms the usefulness of three-dimensionality. Adding another depth cue in the form of stereo 3D is expected to produce yet better performance. Second, stereo 3D provides better spatial relationship. Thus, stereo 3D images free extraneous cognitive load — which may otherwise be needed to clarify the ambiguity of depth cues — for meaningful learning.

H2: Compared to 2D or VR displays, users rate stereo 3D higher in Actual Knowledge.

H3: Compared to 2D or VR displays, users rate stereo 3D displays higher in Perceived Website Diagnosticity.

Hypotheses about User Control

In the online learning context, we define user control in learning (hereafter "user control"), as the degree to which a user perceives that he/she has control over the *details* and *pace* of information delivery on a website (Dillon et al. 1998; Landow 1992; Landow et al. 1991).

Guided by this definition of user control, this study identifies two factors, which represent the detail and pace of information delivery. The first factor is perceived active control, defined as a user's perceived ability to choose information and guide an interaction (Jiang et al. 2010; Lowry et al. 2006). It concerns a user's control over the *details* of information delivery.

Stereo 3D is argued to *reduce* user control compared to VR and 2D displays. Stereo 3D has weakness of occlusion, meaning that the data in front hides the data represented at the back (Kumar et al. 2004). VR displays, on the other hand, enable the user to manipulate the image via keyboard and mouse control ―e.g. to move, rotate, and zoom in and out the image to see the hidden information and thus also to overcome the occlusion problem (Jiang et al. 2005; Kumar et al. 2004). For stereo 3D displays the added perceived depth may give viewers the impression that the data are hidden in layers and cannot be seen, reducing their perceived control over what information they can see in both VR and 2D displays.

H4: Compared to 2D or VR displays, stereo 3D displays will be rated lower in Perceived Active Control.

The second factor of user control is perceived navigability, defined as the degree to which navigating a website is free of effort (Salisbury et al. 2001; Wells et al. 2011). Perceived navigability represents the *pace* of information delivery. It is essentially a mental model (i.e., the organization of knowledge about how a system works or operates), regarding how to find and examine data (Webster et al. 2006). When a person perceives a website to be easy to navigate, he/she is likely to find and examine the data on the website at a desired pace.

Stereo 3D may reduce perceived navigability on a hybrid website such as ours that includes both 2D and 3D information because the user has to employ different navigational mental models in 2D and 3D. This may give them a sense of disorientation (Webster et al. 2006) and reduce their ability to navigate through the website, i.e., perceived navigability.

H5: Compared to 2D or VR, stereo 3D will be rated lower in Perceived Navigability.

Hypotheses about User Adoption of Stereo 3D Website

To conceptualize user adoption of the website, we refer to users' attitude toward the website and their intention to use it, two factors that have been used in prior research as major indicators of user adoption (Davis 1989).

This research posits that stereo 3D can enhance user attitude toward and intention to use the website through increasing multimedia vividness. Compared to 2D and virtual realities, stereo 3D can amplify the vividness of the website. It provides binocular disparity information and thus makes best use of the visual channel, increasing the breadth of the website. Stereo 3D increases the depth depicted by the website by enriching the details of the spatial relationships presented in the image, enhancing multimedia vividness. Such vividness rendered by stereo 3D can give the viewer a sense of "being there" (e.g., telepresence), and accordingly can create compelling experiences for the viewers (Hess et al. 2009; Nah et al. 2011; Qiu et al. 2005), which is crucial for user attitude and intention to use the website.

H6: Users will have a more positive attitude toward learning with the website with stereo 3D displays.

H7: Users will have stronger intention to use the website with stereo 3D displays.

RESEARCH METHODOLOGY

An experiment was conducted to test the hypotheses. The experiment included three groups, representing the three presentation formats. Subjects were randomly assigned to one of the three groups. Participants were informed that their task was to learn about six computer hardware components in preparation for an exam. For each group, the experiment website had a typical design with a title and a menu on the left side. The menu included links to six hardware components. When the subject clicked a link, information about the corresponding hardware appeared on the right side of the screen, including a short textual description of that hardware. Below the text was a 2D static image, a virtual reality image, or a stereo 3D image for the three groups.

Experimental Procedure

The experimental procedure included several steps. The experiment started with a warm-up exercise of stereo 3D. This was followed by the real learning session: subjects interacted with the website to complete the learning task. When the subject felt he/she had learned enough, he/she could click the "Exam" on the website to proceed to an exam. The exam included nine questions about the computer hardware images displayed earlier. A survey was administered following the exam. Incentives of course credits were offered to all students.

Measures

Appendix A lists the measures. Objective data were used to measure learning efforts such as Browsing Time (mean time spent browsing each page of computer hardware), Page Loads (number of times the six pages of computer hardware were loaded), and Exam Time (time spent on the exam). Exam scores (the number of correct answers) were used to measure Actual Knowledge, consistent with prior research that used recall performance as a measure of comprehension (Blanco et al. 2010; Hong 2004). Surveys were used to measure user perceptions, attitudes, and intentions.

Participants

Participants were students from a major university in the southwest of the United States. They were recruited from an undergraduate entry-level psychology class. Participants are all younger than 25 years old. Most are still in college and were female students. Subjects were randomly assigned to the three groups. ANOVA analyses indicated that the three groups were not significantly different from each other in age (p=0.366), gender (p=0.609), and education level (p=0.346).

DATA ANALYSIS AND RESULTS

ANOVA analyses were conducted to test the hypotheses. Table 2 summarizes the results of data analysis. Significant differences were observed in PageLoads between stereo 3D and 2D (sig.<0.05) and ExamTime (sig.<0.05), partially supporting Hypothesis 1, but there were no differences in Browsing Time. Neither Actual Knowledge nor PWD differed significantly across the three groups. Thus, neither Hypothesis 2 nor 3 was supported. Hypotheses 4 and 5 stipulated that stereo 3D displays would be rated lower in perceived active control and perceived navigability. Both hypotheses were partially supported. Stereo 3D group had a significantly lower perceived active control than VR (sig.<0.1[1]), but not 2D. It also had a significantly lower perceive navigability than 2D (sig.<0.05) but not VR. As for user adoption of website using stereo 3D, results showed that users were significantly more positive toward stereo 3D than toward 2D (sig.<0.05) and VR (sig.<0.1), supporting hypothesis 6. Nevertheless, people do not necessarily have a stronger intention to use stereo 3D websites than the other websites; thus hypothesis 7 was not supported.

	Hypothesis	Confirmed?
Stereo 3D → Comprehension	H1: Reducing learning efforts	Yes (partially supported)
	H2: Increasing actual knowledge	NO
	H3: Increasing PWD	NO
Stereo 3D → Learner Control	H4: Lower active control	Yes (partially supported)
	H5: Lower perceived navigability	Yes (partially supported)
Stereo 3D → Adoption	H6: More positive attitude	Yes
	H7: Stronger intention to use	No

Table 2. Summary of Hypothesis Testing

[1] Given the exploratory nature of this research, we use a loose criterion for significance level. A p value between 0.05 and 0.10 is considered an indication of marginal significance.

DISCUSSION

Major Findings

This research yields several interesting findings. First, stereo 3D can influence comprehension by reducing learning efforts. Second, users have a significantly more positive attitude toward websites that have stereo 3D displays than either those with static 2D displays or VR displays. Stereo 3D also reduced users' perceived active control and the perceived navigability of the website. Nevertheless, these factors did not reduce comprehension.

One interesting finding is that all three groups learned the same amount of Actual Knowledge. First, this is encouraging given that subjects in the stereo 3D group reported they had lower control and navigability over the website. Second, this may indicate that learners tend to be "satisficers." This is consistent with existing findings that students often take a passive learning approach and are thus satisficers (Hadar 2011). It is worth noting that learners may be maximizers in some circumstances, e.g., in business decision-making or in online shopping.

Limitation

A major limitation of this research is that we did not measure tele-presence, flow, and vividness that may explain the process through which stereo 3D influences user adoption. As mentioned earlier, these factors may clarify the mechanisms through which stereo 3D influences user adoption of the website. It could be a promising topic for future research.

Contributions

This research conceptualizes learning efforts and user control in learning. Having been referred to in prior research, they have not yet been systematically conceptualized. In addition, we developed a framework to study the influence of presentation formats on user learning based on MLT and Dillon and Gabbard's (1998) work. We hope this research can open a new area of research on stereo 3D, which has great potential in transforming learning, training, and e-commerce.

Research Implications

Stereo 3D in the Web environment represents a wide-open field for IS research. By investigating two fundamental research questions, this research shows that stereo 3D can reduce learning efforts and that people like stereo 3D. These two major findings, together with the finding that stereo 3D is accompanied with user control problems, necessitate further research in this promising yet under-studied area.

Practical Implications

This research has two encouraging messages to practitioners. First, stereo 3D has the potential to influence learning by reducing learning efforts. Second, users like stereo 3D. The results of this research show that people have a positive attitude toward websites using stereo 3D.

ACKNOWLEDGMENTS

Mary A. Peterson acknowledges the support of NSF BCS 096052. This research is partially supported by a grant from the Confluence Center, University of Arizona. Part of this project was conducted when the first author visited the Information Systems Department, School of Computing, National University of Singapore.

APPENDIX A: MEASURES

Learning efforts (Self-developed):
LE1. BrowsingTime (time spent on the six pages of computer hardware, in seconds)
LE2. PageLoads (how many times the six pages of computer hardware were loaded)
LE3. ExamTime (time spent on completing the exam, in seconds)
Actual knowledge (adapted from Jiang et al. 2007): The number of correct answers in the exam (0 to 9)
Perceived website diagnosticity (adapted from Jiang et al. 2007):
PWD1. HardwareOne is helpful for me to learn computer hardware.
PWD2. HardwareOne is helpful in familiarizing me with computer hardware.
PWD3. HardwareOne is helpful for me to understand how computer hardware functions.
Prior knowledge (adapted from Jiang et al. 2007): Are you familiar with computer hardware? (1, very unfamiliar, 4 neutral, 7 very familiar)
Perceived active control (adapted from Jiang et al. 2010):
PAC1. I felt that I had a lot of control over my visiting experiences at HardwareOne.
PAC2. While I was on HardwareOne, I could choose freely what I wanted to see.
PAC3. While surfing HardwareOne, I had control over what I can do on the site.
PAC4. While surfing HardwareOne, my actions decided the kind of experiences I get.
Perceived navigability (Salisbury et al. 2001; Wells et al. 2011)
PNV1. Navigating HardwareOne is easy for me.
PNV2. I find that my interaction with HardwareOne is clear and understandable.
PNV3. It is easy for me to become skillful at navigating the pages of HardwareOne.
Attitude (adapted from Davis 1989):
ATT1. I like learning on HardwareOne
ATT2. Learning on HardwareOne is a good idea.
ATT3. Learning on HardwareOne is appealing.
Intention to use (adapted from Davis 1989):
INT1. If HardwareOne is available online, I plan to use it for learning.
INT2. If HardwareOne is available online, I intend to use it for my future learning.
INT3. If HardwareOne is available online, it is very likely that I will use it in the near future.

REFERENCES

1. Blanco, C. F., Sarasa, R. G., and Sanclemente, C. O. 2010. "Effects of visual and textual information in online product presentations: looking for the best combination in website design," *European Journal of Information Systems* (19), pp 668–686.
2. Davis, F. D. 1989. "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quarterly* (13:3) September, pp 319-342.
3. Dillon, A., and Gabbard, R. 1998. "Hypermedia as an Educational Technology: A Review of the Quantitative Research Literature on Learner Comprehension, Control, and Style " *Review of Educational Research* (68:3), pp 322-349.
4. Enns, J. T., and Rensink, R. A. 1990. "Sensitivity to three-dimensional orientation in visual search," *Psychological Science* (1:323-326).
5. Enns, J. T., and Rensink, R. A. 1991. "Preattentive recovery of three-dimensional orientation from line drawings," *Psychological Review* (98), pp 335-351.
6. Hadar, L. L. 2011. "Adopting a ‘‘satisficing’’ model for school performance in students’ views of learning," *Educational Research and Evaluation* (17:3), pp 193–214.
7. Hess, T., Fuller, M., and Campbell, D. 2009. "Designing Interfaces with Social Presence: Using Vividness and Extraversion to Create Social Recommendation Agents," *Journal of the Association for Information Systems* (10:12), pp 889-919.
8. Hong, W. 2004. "Does Animation Attract Online Users’ Attention? The Effects of Flash on Information Search Performance and Perceptions," *Information Systems Research* (15:1), pp 60–86.
9. Jiang, Z., and Benbasat, I. 2005. "Virtual Product Experience: Effects of Visual and Functional Control of Products on Perceived Diagnosticity and Flow in Electronic Shopping," *Journal of Management Information Systems* (21:3), pp 111-147.
10. Jiang, Z., and Benbasat, I. 2007. "The Effects of Presentation Formats and Task Complexity on Online Consumers' Product Understanding," *MIS Quarterly* (31:3), pp 475-500.
11. Jiang, Z., Chan, J., Tan, B., and Chua, W. S. 2010. "Effects of Interactivity on Website Involvement and Purchase Intention," *Journal of the Association for Information Systems* (11:1), pp 34-59.
12. Kumar, N., and Benbasat, I. 2004. "The Effect of Relationship Encoding, Task Type and Complexity on Information Representation: An Empirical Investigation of 2D and 3D Graphs," *MIS Quarterly* (28:2), pp 255 - 281.
13. Landow, G. 1992. *Hypertext: The convergence of contemporary critical theory and technology*, (Johns Hopkins University Press: Baltimore.
14. Landow, G., and Delany, P. 1991. "Hypertext, hypermedia and literary studies: The state of the art," in *Hypermedia and literary studies*, P. Delaney and G. Landow (eds.), MIT Press: Cambridge, MA, pp. 3-50.
15. Lowry, P. B., Spaulding, T., Wells, T. M., Moody, G., Moffit, K., and Madariaga, S. Year. "A Theoretical Model and Empirical Results Linking Website Interactivity and Usability Satisfaction," the 39th Annual Hawaii International Conference on System Sciences, IEEE Computer Society2006.
16. Mayer, R. E. 2009. *Multimedia learning*, (2nd ed.) Cambridge University Press: Cambridge.
17. Nah, F. F.-H., Eschenbrenner, B., and DeWester, D. 2011. "Enhancing Brand Equity Through Flow and Telepresence: A Comparison of 2D and 3D Virtual Worlds," *MIS Quarterly* (35:3), pp 731-747.
18. Qiu, L., and Benbasat, I. 2005. "An Investigation into the Effects of Text-to-Speech Voice and 3D Avatars on the Perception of Presence and Flow of Live Help in Electronic Commerce," *ACM Transactions on Computer-Human Interaction* (12:4), pp 329 - 355.
19. Salisbury, W. D., Pearson, R. A., Pearson, A. W., and Miller, D. W. 2001. "Perceived Security and World-Wide-Web Purchase Intention," *Industrial Management & Data Systems* (101:3-4), pp 165-176.
20. Sun, J., and Perona, P. 1996. "Preattentive perception of elementary three dimensional shapes," *Vision Research* (36), pp 2515-2529.
21. Sweller, J., van Merriëboer, J. J. G., and Paas, F. G. W. C. 1998. "Cognitive architecture and instructional design," *Educational Psychology Review*:10), pp 251–285.
22. von Grünau, M., and Dubé, S. 1994. "Visual search asymmetry for viewing direction," *Perception & Psychophysics* (56), pp 211-220.
23. Webster, J., and Ahuja, J. S. 2006. "Enhancing the Design of Web Navigation Systems: The Influence of User Disorientation on Engagement and Performance," *MIS Quarterly* (30:3), pp 661-678.
24. Wells, J. D., Valacich, J. S., and Hess, T. J. 2011. "What Signals Are You Sending? How Website Quality Influences Perceptions of Product Quality and Purchase Intentions," *MIS Quarterly* (35:2), pp 373-396.