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VIRTUAL REALITY FOR LEARNING: SOME DESIGN PROPOSITIONS

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Abstract

Virtual reality (VR) technologies engage the senses to a greater degree than traditional forms of computer technology and can be effective tools for learning. However, little is known about how design aspects of VR systems influence the learner. This paper develops some design proposition for how VR technology is expected to impact the learner, integrating learning theory, media richness theory and VR development research. Design propositions are the first and critical part of a full information systems design theory that is needed to guide further development and evaluation of VR systems for learning.

Keywords: Virtual reality, learning theory, design theory, instruction theory

Introduction

Training and education continue to be critical both in traditional environments such as universities and in new environments of elearning and lifelong learning. Traditional environments are sometimes praised for the value of the face-to-face interaction while elearning environments are sometimes praised for their ability to deliver just-in-time education. However, tradition classroom environments can be removed from the application of learning and elearning environments can suffer from lean communication channels that are not as encouraging to students. Virtual reality brings new multi-sensory tools that have the potential for positive impacts on learning in both traditional and emerging learning environments.

However, for virtual reality systems to be effective, they should be well designed and support basic tenets of learning theories and for research to proceed effectively design must be specified. In the early days of GSS research, papers were published with conflicting results that may have been attributed to the different systems used in the studies (Pinsonneault and Kramer 1989; George 1992). When different types of software are used in experiments, comparison across experiment can have construct validity problems. Similar construct validity problems can exist when system development proceeds without an explicit link to the theoretical constructs being implemented.

An information systems design theory (ISDT) is a theory that links kernel theories to systems artifacts and design processes in support of a goal (Walls et al. 1992). This paper develops the first parts of an ISDT for VR systems that have the goal of improved learning and includes identifications of kernel theories, design propositions that link VR system design constructs to learning outcomes, and the boundaries to which those propositions are expected to hold. Instructional theories apply learning theories to instructional goals (Reigeluth 1983). Therefore this paper could also be considered an instructional theory. An instructional theory describes how instructional methods impact required conditions for learning which influence learning outcome (Reigeluth 1983) as pictured in Figure 1. Following this framework the next section will describe the learning constructs that influence learning outcomes followed by a section describing the constructs of virtual reality than can influence the learning constructs. The following section will integrate the learning and VR concepts into the beginning of an ISDT.

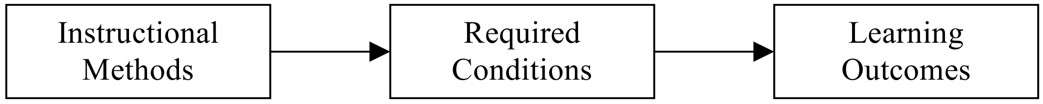

Figure 1. Instructional Theory Framework

Learning Theories

Learning theories are concerned with the link between learning conditions and outcomes. This section will first define outcomes and then define conditions that influence those outcomes.

Learning outcomes can vary widely depending on the environment. Learning to operate machinery and learning to design a computer system are different types of learning outcomes as is learning to enjoy the symphony and many learning researchers have developed taxonomies. One of the most heavily cited in higher education is Bloom's taxonomy of cognitive outcomes. Bloom's taxonomy include six levels of learning including knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom et al. 1956). Although Bloom's taxonomy captures much of the cognitive domain, it ignores the affective and psychomotor domains. The affective and psychomotor domains, important in their own right, can have interaction effects with the cognitive domain. For example, motivation clearly influences learning, but it can also be viewed as an outcome of learning in the affective domain. "Gagne … was the first to propose an integrated taxonomy of learning outcomes…" (Driscoll 1994, p. 335). Therefore Gagne's integrated taxonomy will allow us to develop an ISDT that can span a wide range of learning environments and also explore the boundaries of its application.

Gagne (1985) identified the five major categories of learning outcomes as verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills and is summarized in Table 1.

Table 1. Learning Outcome Constructs

Construct	Description
Verbal Information	Declarative knowledge or facts
Intellectual Skills	Procedural knowledge
Cognitive Strategies	Strategic control of thought processes; creative thinking
Attitudes	Feelings toward or about actions; values
Motor Skills	Control and application of muscles

Gagne developed nine events that can be applied to the learning process to achieve the desired outcomes. Emerging constructivist theories can call into question the assumptions behind Gagne's recommended events. This paper will consider how constructivist theories add to the relevant events identified by Gagne, rather than setting them as alternatives. Learning style research has also shown the value of using learning methods appropriate for the learner (Morgan 1997). Table 2 lists a summary of learning events.

If framed as opportunities for reducing uncertainty or equivocality, an analogy can be made between these events and organizational learning. In organizational learning uncertainty can be reduced using less rich communication, but equivocality can be more effectively reduced with rich media (Daft and Lengal 1986). Since much important information can be equivocal to the learner, a rich media can add value and it is here where VR technology can most help.

Virtual Reality

The term virtual reality is sometimes used in a very general sense to include any form of synthetic environment. This paper uses a more specific definition of a virtual reality system, sometimes call a virtual environment system, where "a machine is appropriately programmed computer that generates or synthesizes virtual worlds which the operator can interact" (Durlach and Mavor, pp. 1-2). This definition excludes systems such as teleoperation and augmented reality systems that have links to the real world, although those systems can also play a role in education. "…the purpose of a virtual environment system is to alter the state of the human operator…" (p. 2). This purpose is not unlike the purpose of instruction. Given this description, VR systems can be characterized as a set of advanced computer based technologies that encourage people to learn.

A VR system is any computer system that combines advanced computer input and advance computer output to provide a coherent model. This definition is quite broad in order to not overly limit its application. Advanced computer input includes devices such as mice, gloves, and full body motion sensors. Advanced computer output includes 3-D video, stereo video, sound, and physical feedback. The key is that the input and output is orchestrated to form a coherent model. An important result of this definition is that model may be a virtual world such as common to video games, but it may be an abstract data visualization.

Table 2. Learning Event Constructs

Construct	Description	School of Thought
Gaining attention	Focusing learner toward instruction	Gagne & Driscoll 1988
Inform learner of the objective	Setting expectations of what is to be learned	Gagne & Driscoll 1988
Stimulating recall of prior learning	Reminding students of previous learning that is a prerequisite for current learning	Gagne & Driscoll 1988
Presenting the stimulus	Essential elements of desired outcome	Gagne & Driscoll 1988
Providing learner guidance	Helping the student through the learning process	Gagne & Driscoll 1988
Eliciting performance	Demonstration of learning	Gagne & Driscoll 1988
Providing feedback	Evaluation of the learners performance	Gagne & Driscoll 1988
Assessing performance	Final evaluation of performance	Gagne & Driscoll 1988
Enhancing retention and transfer	Repetition or simulation to reinforce learning	Gagne & Driscoll 1988
Provide complex environment	Provide a rich and realistic learning environment	Constructivist (Driscoll 1994)
Social negotiation	Provide social opportunities for testing mental models	Constructivist (Driscoll 1994)
Multiple modes	Includes multiple modes of representation and ill structured problem domains	Constructivist (Driscoll 1994)
Nurture reflexivity	Help students to be aware of their own role in learning	Constructivist (Driscoll 1994)
Student centered	Allow student judgment in how and when to learn	Constructivist (Driscoll 1994)
Learning style	Provide learning activities that evoke multiple learning styles	Morgan 1997

The strength of VR systems is that they provide a greater degree of interactivity with the learner than traditional computers systems. Bandwidth, personalization/ presence, and structural organization can be viewed as dimension of interactivity (Zack 1993). Although developed in the context of communication between people, they are a useful way to describe how a VR system can communicate with the learner. However, any VR technology will have noise, such as resolution or response time, that may detract from its ability to deliver its rich content. These constructs and there meaning in the VR context is described in Table 3.

Table 3. Virtual Reality Constructs

Construct	Description
Bandwidth	VR systems can provide input to multiple senses at the same time.
Personalization/ Presence	VR systems can provide input to the senses that is more like real situations than traditional learning technologies.
Structural Organization	VR systems can react quickly to human input and allow the user to react and change strategies.
Noise	Limitation in technology such as resolution or response time that detract from its effectiveness.

A Virtual Reality for Learning ISDT

Boundaries

Boundaries specify the limits to the environments where an ISDT can be applied. In the case of VR, these boundaries are largely technological and rapidly changing as the technology improves. These boundary condition thus define some of the important areas for research into VR for learning systems.

Research is in its infancy on what can and cannot be simulated and is likely to be ever evolving. The first boundary condition is VR systems are limited to domains where useful virtual environments can be constructed.

Even when useful VR environments can be developed, limits to resolution and responsiveness or noise may keep them from being effective. Resolution is the detail in which a sensory operation is implemented. Responsiveness is the speed at which a system can respond to user input. Both contribute to the effectiveness and realism of a VR system and each have an impact on the require computing power. Long response times can have severe impacts on the perception of virtual environments (Sheridan and Ferrell 1974). Since resolution can effect the computing power required for responsiveness there is often a trade off between resolution and responsiveness. Two resultant boundary conditions result limiting the theory to domains where adequate resolution and responsiveness can be generated.

Propositions

Specific proposition can be developed for the relationship between system constructs and the events of learning. This section will present a summary of the types of propositions that can be created, rather than an exhaustive list.

Believable sensory input is an important distinguishing factor of VR systems. Some systems use advanced stereo visualization and headset to give the user the illusion of being completely immersed in another world. This can be more compelling than a flat video screen. This type of visualization and other advanced sensory outputs can have a positive impact on gaining attention, clarifying objectives, stimulating recall of prior learning, and presenting a stimulus among other effects.

VR systems can make fast response to the learner's input improving the elicitation of user response and providing fast feedback. User control allows the learner to pace the learning and choose how to use the VR tool improving both the student centeredness of the exercise and the match between the tool and the learner's individual learning style. VR systems ability to reinforce effects through multiple senses reinforce the impact and can improve the fit with learning style.

Noise and delay characterize the imperfection in real VR systems. Depending on the type system and its resolution, delays and noise may be introduced, interrupting the expected effects. The effects can moderate any positive effects that would be expected in an ideal VR system. They can also have negative main effects on attention. These propositions are summarized in Figure 2.

Future Research

Invention: Limits to what useful environments can be developed are primarily technical and as technology improves, limits will only be bound by our imagination. Invention of new type of virtual environments is needed for progress.

Evaluation: Although VR technology is progressing rapidly and has been for some years, evaluation of its effects on human learning is still in its infancy. The development of evaluation and evaluation methods is critical.

Systems Development: New systems and systems development methodologies must need to be explored so that systematic development can occur.

Resolution and Responsiveness: Research on how much resolution and responsiveness is required in various domains is needed to understand where technology can most effectively applied and where improvements in technology may be required for further progress.

Sensory Interaction: It appears that when multiple sensors are used they can reinforce the sensation. In some cases having multiple sensations can reduce the resolution required of other sensors. For example high quality sounds can greatly enhance a low quality video conference. Alternatively, inconsistent sensory inputs can have deleterious effects such as motion sickness.

Abstract Environments: VR realty environments can be developed that resemble reality, less abstract environments, as well as imaginary data visualizations, highly abstract environments. Research into the types of abstraction and how it should be applied is needed.

Conclusion

There are theoretically sound reasons to believe that VR systems can be developed to improve human learning. Recent technological developments make it practical to apply VR to many learning situations. It is therefore fruitful for researchers to focus on the development and evaluation of VR systems for learning and this framework begins to organize such work.

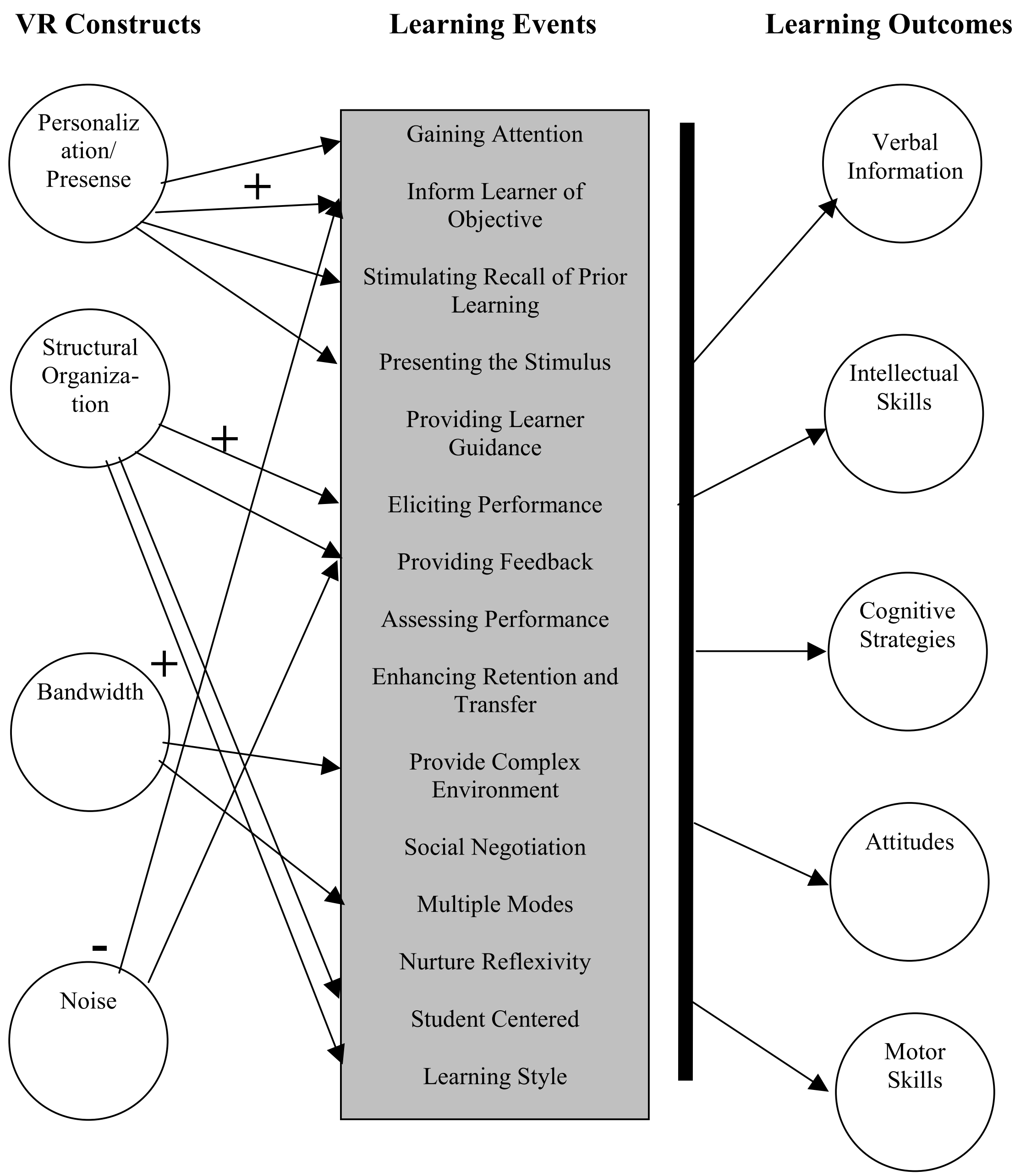

Figure 2. VR Design Propositions

References

Daft, R. L., and Lengel, R. H., 1986. Organizational information requirements, media richness, and structural design. *Management Science,* 32:5 (May), pp. 554-571.

Driscoll, M. P. 1994. *Psychology of Learning for Instruction*. Allyn and Bacon: Boston.

Durlach, N. I., and Mavor, A. S. 1995. (eds.) *Virtual Reality: Scientific and Technological Challenges.* National Academy Press: Washington.

Gagne, R. M., 1985. *The Conditions for Learning* (4th ed.) Holt, Rinehart & Winston: New York.

Gagne, R. M., and Driscoll, M. P. 1988. *Essential of Learning for Instruction* (2nd ed.). Prentice-Hall: Englewood Cliffs, NJ.

George, J. F. 1992. An examination of four GDSS experiments. *Journal of Information Science,* 18, pp. 149-158.

Morgan, H. 1997. *Cognitive Styles and Classroom Learning.* Praeger Publishers: Westport, CT.

Pinsonneault, A., and Kraemer, K. L. 1989. The impact of technological support on groups: An Assessment of the Empirical Research. *Decision Support Systems,* 5:2, pp. 197-216.

Reigeluth, C. M. 1983. Instructional Design: What is it and Why is it? In C. M. Reigeluth (ed.), Instructional Design Theories and Models. Earllbaum: Hillsdale, NJ.

Sheridan, T. B., and Ferrell, W. R., *Man Machine Systems*. MIT Press: Cambridge, MA.

Walls, J. G., Widemeyer, G. R., and El Sawy, O. A. 1992. Building an information system design theory for vigilant EIS. *Information Systems Research,* 3:1 (March), pp. 36-59.

Zack, M. H. 1993. Interactivity and communication mode choice in ongoing management groups. *Information Systems Research,* 4:3 (September), pp. 207-239.