Effects of Information Location in Learning Factual Information in a 3D Environment

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Abstract: The purpose of the study reported in this paper was to investigate the effect of two forms of presenting verbal information (co-located and non co-located) on learning and retention of knowledge in a desktop virtual environment. Co-located information refers to the spatial relationship between linguistic information (text and sound) and virtual reality objects. The effects of co-located information was assessed via post and retention measures of knowledge of factual information on the domain of safety training using a virtual chemistry laboratory. Results indicated a tendency for co-located information to produce a positive effect upon retention of declarative knowledge.

Introduction

One of the most attractive features of desktop virtual environments (DVEs) for instructional design is the possibility of integrating symbolic information with a three-dimensional (3D) graphical representation of physical settings. Textual and auditory annotations can be presented either in a separated area of the virtual environment scene or embedded to the virtual environment. Providing instructional messages in a separated area of the virtual scene is consistent with GUIs-based applications in which feedback information is often displayed in a dedicated area of the user-system interface. Embedding instructional messages in virtual scenarios allows to tie information to objects or scenes in which information may be perceived in a more natural form. By combining scenes and verbal information, co-located instructional messages can be more effective to deliver information. However, there has been little investigation into the learning implications of presenting instructional messages spatially contiguous to objects and scenes in a 3D environment. Furthermore, learning in DVE has been often measured at immediately learning, i.e., testing knowledge after instruction and few empirical studies have tested knowledge retention. The empirical study reported in this paper investigated the effect of two forms of presenting instructional messages (co-located and non co-located) on learning and retention of knowledge in a desktop virtual environment.

The 'spatial contiguity effect'

The learning implication of presenting separated information to the instructional content has been study by Mayer (2003), Moreno and Mayer (1999), Mayer and Anderson (1992) and Mayer (1989). They refers to the 'spatial contiguity effect' as the learning enhancement when words and pictures are presented near to rather than far from each other on screen in a multimedia explanation or on a page in a book. In an early study, Mayer (1989) found that a group of students who read integrated printed explanations (i.e., captioned illustrations placed nearby the text) on how tyre pumps work, produced about 75% more creative solutions to problem-solving questions than students who were given the same explanations with the text and illustration on separated pages. The results showed the superiority of presenting information spatially contiguously over presenting separated information.

Moreno and Mayer (1999) replicated Mayer's (1989) study in a computer environment to investigate whether the spatial contiguity effect also occurred in the context of multimedia instruction. In their study a multimedia animation with textual explanation next to a picture about lightning was given to a group of students. The same explanation was given to another group of students with the difference that the statement was printed at the bottom of the screen far from the centre of the picture. They reported that students in the co-located information group produced 43% more creative solutions on a problem solving transfer test than the group with separated information. Although the spatial contiguity effect was less salient in a multimedia environment than in printed material, the results showed consistency of a spatial contiguity effect across instructional material.

According to the cognitive theory of multimedia learning (Mayer and Moreno, 2002), the spatial contiguity effect occurs because learners are able to make connections between corresponding visual and verbal representation in working memory when information is presented simultaneously rather than successively. The spatial relationship between corresponding verbal representations and three-dimensional scenes may be more salient in VE instruction since virtual scenes may be perceived in a more natural form than 2D representations.

Linking perceptual data and symbolic information

Bolter, Meyer and Nichols (1995) explored an alternative approach for providing embedded information in an immersive virtual environment. The design approach aimed to provide information that allow users to form links between perceptual data and linguistic information related to it. A VE, which depicted the Georgia Tech Aquatic Center was designed to explore this approach. A number of objects were annotated with audio and text to describe information about the design of the facility, events that had been held there and information related to sports of swimming and diving. A usability study was conducted to investigate whether the use of embedded information that is tightly coupled to the virtual environment enhanced the relevance of both the virtual environment and the information. Bowman, Hodges and Bolter (1998) found that symbolic information that created relational links with the perceptual environment had a large positive effect on the perception and learning of the user.

Further studies by Bowman, Hodges, Allison, and Wineman (1999) revealed that VE instruction paired with a lecture on the same material provided greater learning and understanding than the lecture alone. This study compared three groups of students: a control group, in which students attended normal class presentations; an information group, in which students attended classes and explored the VE in order to recognize the spatial layout of the virtual zoo and to gather zoo exhibit design information; and a habitat group, in which students explored the VE with no access to embedded information in order to discriminate the value of embedded information for learning outcomes. Groups were tested on the material covered five days later. Although the differences were not statistically significant, the study suggests that embedded information in the VE tended to facilitate the association between spatial and factual information that supported students on the test.

An experiment on knowledge acquisition and retention

Using the approach by Bowman and colleagues for embedding symbolic information in an immersive VE (i.e., co-located instructional messages) and the principles of the 'spatial contiguity effect' in multimedia learning (Mayer, 2003; Moreno and Mayer, 1999; Mayer and Anderson, 1992; Mayer, 1989) the aim of the study was to (a) investigate whether the spatial contiguity effect discovered in multimedia instruction occurs in a three-dimensional environment and (b) the extent to which this form of delivering information in DVE design supports learning and retention of factual information.

Method

The experimental DVE. The experimental virtual environment used in this study depicted a highly realistic representation of an actual chemistry laboratory. It offered a contextual environment to learn about laboratory safety precautions divided into three instructional sessions: (1) *knowing the lab*, which aimed to show the position of safety points; (2) *laboratory precautions*, which showed risks involved with a chemistry laboratory including laboratory housekeeping, safety gear, handling chemicals, and storing chemicals; and (3) *responding to emergency situations*, in which trainees were able to perform emergency procedures. The contribution to knowledge acquisition of the third session was not included in the analysis presented in this paper. The learner activity in the VE was reduced to two simple user actions: the freedom to roaming inside the VE and a single click on objects for obtaining information. For example, clicking on a virtual cylinder lying on the floor displays housekeeping annotations for storing cylinders in a chemistry laboratory. Textual and audio annotations were displayed on virtual panels.

Two VEs were designed that differed only in the form that panels were presented, co-located and non co-located (see Figure 1). The co-located panels design, displays panels as part of the virtual scene. This design aims to foster a framework of association between information and virtual objects. These panels 'recede' as the user navigates away from them. The non co-located panels design, displays panels in the form of pop-up windows overlaying the virtual scene and remain visible until the learner closes the panel. This design intends to provide information 'on the outside' of the virtual environment. It was hypothesised that co-located information would facilitate the association between entities (objects, scenes, animation, etc.) in the VE and pertinent information about such entities. Conversely, non co-located information would not afford this perceptual cue as information is displayed in a way that is less closely coupled to the target object location. Therefore, learners in the co-located information condition would have the highest scores in a safety knowledge assessment.

Figure 1. A frame from the same vantage viewpoint shows co-located information (top) and non co-located information (bottom) designs regarding laboratory safety precautions for gas cylinders. Co-located panels are presented spatially linked to virtual objects; the learner needs to approach to them in order to read and listen to safety annotation. Non co-located panels move along with the view of the scene and safety annotation can be read and listen from any vantage viewpoint.

Participants. A total of 24 science students (12 females and 12 males) from the University of Sussex, mean age 24.13 years (SD 6.51), participated in the experiment. Participants were paid for their participation and allocated to either co-located information or non-collocated information condition. Experimental groups were evenly matched in terms of gender.

Materials. A DELL Pentium 1.8 GHz desktop PC with a 15” LCD flat colour screen, mouse, keyboard and speakers was used. The desktop PC was fitted with a graphics processor 64MB NVIDIA GeForce2 MX/MX 4000. The virtual chemistry laboratory was modelled with VRML and embedded in an HTML page. MS Internet Explorer and Cortona VRML browser were used to visualise VEST-Lab. A questionnaire with 12 questions was used to assess the learning of safety knowledge. 21 chemistry laboratory regulations were addressed in this assessment.

Procedure. Knowledge about laboratory safety was measured before training (pre-test), immediately after training (post-test), and a week later (retention-test). After completing the pre-test, participants were explained the objective of the study. They were told that the study would be to assess the effectiveness of a VE in providing safety training in a chemistry laboratory. Before participants proceeded to experimental tasks, they were allowed five minutes to become familiar with the VE. After familiarisation with the VE, instructions about the tasks to be performed were given to subjects in written and verbal form. The tasks consisted of two sessions as described below:

- *Knowing the lab*. Five minutes were allowed to locate the position of 6 safety points.
- *Laboratory precautions.* The task was to spot 10 laboratory precautions within a limited time of ten minutes.

Immediately after completing the two training sessions, students were administered a knowledge acquisition assessment within a limited time of ten minutes. Participants were asked to return a week later for the retention-test and to be paid for their participation. Both post and retention test were administered without VEST-Lab present.

Results and Discussion

A safety knowledge score was computed by counting the correct answers out of 21 multiple-choice questions. One point was given to each correct answer. Although the differences in test scores for the two groups were not statistically significant for location of information, the two groups of learners improved their knowledge after training (see Figure 2). Co-located information group showed positive retention of knowledge in which performance continues to improve beyond the post-test.

The results partially support the hypothesis stated that co-located information would provide the best resources for acquiring and retaining declarative knowledge since the ‘spatial contiguity effect’ observed in multimedia applications (Moreno and Mayer, 1999) and printed material (Mayer, 1989) was not evident at immediate learning in a desktop virtual environment. This might happened because learners in both experimental conditions perceived co-located and non co-located information in the same form. In other words, there was not distinction between information that was spatially displayed nearby virtual objects and panels 'on the outside' of the virtual scene. A more salient experimental user-system interface design for the non co-located information condition will be to present instructional messages separated to the virtual scene, for example, in a window located at the bottom of the VE window. However, there should be learning implications in providing textual feedback in two different windows. Brna and Cox (1998) and Cox (1996) found that providing information at the bottom of the screen separated from the main working window in a computer system was ineffective to support analytic reasoning task. Students failed to attend to or did not notice information displayed on, the lower part of the screen because they were concentrated on the problem solution in the main working windows. In DVE instruction this issue could be more prominent since interaction with a VE demands much attention that could prevent learners to attend instructional messages. Further studies are needed to clarify whether the 'spatial contiguity effect' was not evident because user-interface design issues or because learners were not able to make connections between corresponding three-dimensional scenes and verbal descriptions of safety precautions in working memory.

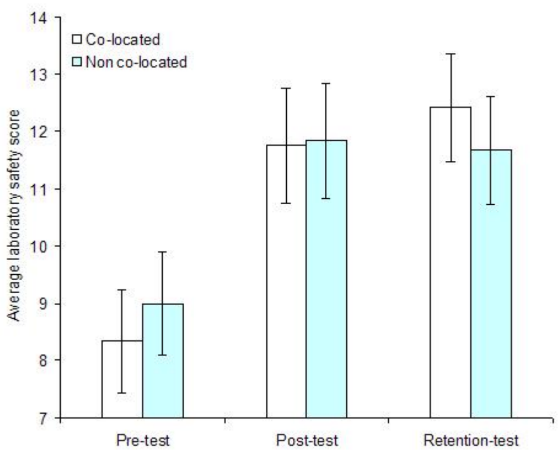

Figure 2. Average laboratory safety precautions score.

Unlike studies by Moreno and Mayer (1999) in multimedia learning, the present study aimed to investigate the 'spatial contiguity effect' beyond immediate learning. The results at retention-test suggest that verbal information that is spatially presented contiguous to objects in a virtual scene supports retention of knowledge. It seems to be that some processing occurred during learning which was expressed in performance terms after a delay. According to Tan, Stefanucci and Pausch (2001) the position of information with respect to objects in an environmental context where learning takes place supports retrieving of information. Tan et al., compared two groups (co-located and non co-located words) of 12 people who learnt three lists, each list with ten word pairs; each word pair consisted of a cue word and a target word. The co-located words group learnt words on three monitors located at different points of the learning environment; the non co-located words group learnt words on a single monitor. Participants were tested for retention away from the learning environment a day later by presenting them with cue words on a laptop computer and asking them to recall the corresponding target words. People on the co-located words group outperformed the non co-located group by remembering an average of fourteen words versus and average of nine words. The analysis of data also revealed a high correlation between remembered words pairs and location where they were learnt. Tan's et al. (2001) findings and outcomes at retention test of the present study suggest that learners encode spatial clues of the VE that facilitate retrieval of declarative knowledge. The result are also consistent with Bowman's et al. (1998, 1999) findings, who found that students form a link between perceptual data and linguistic information when they were presented embedded instructional messages in an immersive VE. However, the spatial elements of the virtual environment that contribute to knowledge retention were not clearly identified.

The results revealed an 'incubation' effect that can be considered as a form of 'spatial contiguity effect' in 3D environments. The practical implication for DVE design is that co-located information approach suggests an effective form for providing instructional information that supports long term retention of declarative knowledge. However, further studies in this direction are needed to investigate the extent to what spatial cues provided by the learning environment and interactivity contribute to knowledge retention.

Conclusions

The present study investigated the effects of information location is a DVE for teaching declarative knowledge in the domain of laboratory safety training. At immediate learning it was unclear why the ´spatial contiguity effect´ was not revealed.

The results showed a tendency for learners with co-located information to be more resistant to forget factual declarative knowledge. This 'incubation effect' can be interpreted as a form of 'spatial contiguity effect' described by Mayer (2003) in multimedia instruction. Although it was unclear how co-located information supported retention of declarative knowledge, it seems to be that co-located information affords additional spatial perceptual cues that facilitated retrieving of information. The co-located information approach suggest that may be more effective to provide learners with information that is spatially positioned in a DVE scene than separated to the virtual environment. It is important to point out that the present study did not consider individual differences in spatial ability, therefore, additional research is needed to determine the role of individual differences in DVEs learning. Future research includes the contribution of interactivity (i.e., actions by the learner that are afforded by the DVE) for knowledge acquisition and retention.

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