Virtual Cognition Laboratory: A Constructivist Approach Toward Learning

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Abstract. We have created a Virtual Cognition Laboratory to provide students and faculty with tools for creating laboratory modules for courses such as Cognitive Psychology and to support independent research involving the investigation of complex behaviors such as navigation. Our efforts have been guided by the constructivist theory of learning which suggests that learners will become better problem solvers when they are actively engaged in their own projects. Thus far, we have created three laboratory modules, The Virtual Office, The Virtual Maze, and The Virtual Mall to examine memory, navigation, and cognitive mapping, respectively. We have found that the introduction of virtual reality tools in our courses and research has fostered a better understanding for the research process and facilitated autonomous, experiential learning.

Virtual Cognition Laboratory

The Virtual Cognition Laboratory at Saint Anselm College was designed to offer students and faculty the opportunity to create virtual environments to conduct research projects within the context of courses such as Cognitive Psychology, Experimental Psychology, and Child Psychology. In addition, students have the opportunity to work with faculty to conduct independent research projects for the senior thesis in the Virtual Cognition Laboratory. In this article, we will offer recommendations for starting a Virtual Cognition Laboratory at an undergraduate institution and present the laboratory modules that we have created for students to conduct research using virtual environments.

The Virtual Cognition Laboratory was established in 1998 with support from the Helen V. Brach Foundation. Our goal was to create a laboratory using standard desktop computers and identify an all-in-one software package for creating virtual environments. Today, the Virtual Cognition Laboratory includes three desktop computers for in-house research, two portable laptops computer for field research, software from SuperScape, and peripheral devices such as headmounted displays.

Constructivist Theory of Learning

Our efforts to create laboratory modules using virtual reality tools is guided by the constructivist theory of learning (CTGV, 1991). Constructivists claim that learners will be likely to create new ideas when they are actively engaged in creating their own projects that they can share with others. In our courses, we use the laboratory modules to provide students with the opportunity to collect and interpret their own data. In some cases, students will discover that they could not confirm their hypotheses. This is an important learning experience in so far as it challenges students to examine what factors related to the experimental design may need to be reconsidered.

On the other hand, some students find that they are able to confirm their hypotheses, but they have new questions to investigate based on their experience conducting the laboratory module. At this point, these students are encouraged to translate their question into a new laboratory module and we provide them with a template from a
virtual environment that we have created, which might be appropriate for modification. These students are now actively responsible for their own learning, which is possible given the foundation that the laboratory modules provide for experiential learning.

**Designing Laboratory Modules**

Thus far, we have worked with students and faculty to create three unique laboratory modules, The Virtual Office, The Virtual Maze, and The Virtual Mall to study memory, navigation, and cognitive mapping. Before designing the virtual environments, a team reviews the current state of the research on a particular topic. Our review enables us to determine whether our research question would be suited for investigation using a virtual environment. We have found that research topics which have been investigated using a variety of methods including paper and pencil tasks, real world activities, and computer simulations are most readily translated into virtual reality laboratory modules. All of our virtual environments are drafted on paper with supporting details regarding dimensions, objects, textures, and colors before any programming using Superscape VRT is initiated in the Virtual Cognition Laboratory. Pilot testing is conducted with the first version of any laboratory module to identify design problems. Each laboratory module includes a script for the experimenter to follow when testing participants, a database template and recommendations for statistical analyses.

**The Virtual Office**

Schema theories attempt to explain how people remember complex situations or events (Alba & Hasher, 1983; Shoben, 1988). Early research in this area suggested that people were more likely to remember objects or events that were consistent with their schemas (e.g., Brewer & Treyens, 1981). However, contradictory findings have been reported suggesting that people seem to remember material best when it is inconsistent with their schemas (Davidson, 1994). According to a meta-analysis conducted by Rojahn and Pettigrew (1992), these discrepancies may be related to whether the participants’ memories were assessed in terms of recall or recognition in combination with the type of scoring methods used to account for guessing. In other words, research suggests that when people are asked to recall information, they are more likely to remember schema-inconsistent material better than schema consistent material. In contrast, when people are evaluated in terms of recognition, they are more likely to endorse schema-consistent material. However, when recognition responses are corrected for guessing, the research suggests that schema-inconsistent material is still favored.

Consequently, The Virtual Office study was designed to re-examine schema theory. Our Virtual Office includes 15 schema consistent objects and 15 schema inconsistent objects (Figure 1). All of the objects were obtained from the data warehouse for Supercape. The experimenter for the Virtual Office laboratory module has been trained to follow a script for standardization. Participants have been told that they are visiting the laboratory to take part in a maze study. Therefore, they are unaware that their memories for the Virtual Office will be tested. The experimenter’s first task is to introduce the participant to the navigation tools that they will use to move through a virtual environment. At this point, the experimenter brings the participant to a virtual hallway for practice navigating. When the participant is done practicing, the experimenter notes that he would like the participant to take a look through the Virtual Office that he has been building before starting the maze study. At this point, the experimenter gets up suddenly and tells the participant that he needs to get a record sheet and will be back momentarily. Each participant is given 20 seconds to explore the Virtual Office in the experimenter’s absence. Upon return, the experimenter either asks for recall memory for the items or recognition memory for the items in the Virtual Office.

We collected data from 20 college students in our Virtual Office study. Ten participants were asked to recall all of the objects they could remember from the Virtual
Office. The remaining 10 participants were given a recognition task listing 40 objects including an equal number of correct and incorrect schema-consistent and schema-inconsistent objects. In the recognition task, participants were asked to use a 1(definitely no)-6(definitely yes) point scale to indicate whether an object was in the Virtual Office.

![Figure 1. The Virtual Office](image)

Our preliminary results for recall indicated that on average 2.5 schema-inconsistent objects were reported compared to 1.5 schema-consistent objects. Participants providing recall did not list any objects which were not placed in the Virtual Office. In terms of recognition, schema-consistent correct items averaged 3.8 and schema-consistent incorrect items averaged 4.0. For schema-inconsistent objects, correct items averaged 3.5 and incorrect items averaged 1.0.

These results suggest that participants had better recall for schema-inconsistent objects compared to schema-consistent objects as noted previously in the literature by Rojahn and Pettigrew (1992). In terms of recognition, the results seem to suggest that people will rate schema-consistent objects that were not actually in the virtual environment as high as schema-consistent objects actually placed in the virtual environment. This suggests that schemas can mislead people such that they are more confident that schema-consistent objects were present when in fact they were absent.

In summary, this laboratory module provides students in courses such as Cognitive Psychology or Experimental Psychology with an opportunity to collect their own data to re-examine schema theory. In addition, this laboratory module can be modified to examine whether the number of objects in the Virtual Office influences the pattern of results obtained for schema-consistent versus schema-consistent recall and recognition. In terms of independent research, we have discovered that some students would like to create a new virtual environment to examine age-related changes in memory. In this case, one team is creating a Virtual Playroom for children and adding some modifications to the experimenter’s script.

The Virtual Maze

Most studies investigating gender differences in spatial abilities have reported that males outperform females on a variety of tasks (Halpern, 1992). A large number of these studies have utilized paper and pencil tasks involving object location memory or
the mental rotation of objects (e.g., Silverman & Eals, 1991; Vandenberg & Kuse, 1978). However, a handful of studies have been conducted to examine gender differences for complex behaviors such as navigation (e.g., Galea & Kimura, 1993).

In terms of investigating navigation, a variety of test protocols have been utilized including photographic slides of a route (e.g., Holding & Holding, 1989), in vivo route-learning (e.g., Kirasic, Allen, & Siegel, 1984), and computer-simulations (e.g., Devlin & Bernstein, 1995). In general, the results from these studies suggest that women do not perform as well as men using outcome measures such as pointing accuracy, amount of backtracking, and number of wrong turns. Our second laboratory module, the Virtual Maze, was designed to examine gender differences for navigation over repeated trials for three difficulty levels (2-turn, 4-turn, 6-turn).

In our Virtual Maze study we created a series of interconnected corridors for our virtual environment (Figure 2). The walls in the Virtual Maze do not permit participants to pass through them. There are no landmarks in the Virtual Maze. Participants have been told that they are visiting the laboratory to take part in a virtual reality study to examine route-learning skills. The experimenter’s first task is to introduce the participant to the compass that they will use to point back to where they started when they complete a particular route through a maze. Participants are required to navigate through a real world 2-turn task until they reach criterion (within 20 degrees pointing back to the route starting point using the compass), prior to beginning the testing protocol for the Virtual Maze laboratory. The testing protocol for the Virtual Maze laboratory requires participants to learn 2-turn, 4-turn, and 6-turn routes until they reach criterion.

![Figure 2. The Virtual Maze](image)

We collected data from 24 college students in our first Virtual Maze study. For the 2-turn and 4-turn mazes, there were no gender differences with males averaging 20 degrees and 30 degrees, for each respective maze, and females averaging 20 degrees and 32 degrees, for each respective maze. However, for the 6-turn maze females averaged 58 degrees and males averaged 40 degrees. Furthermore, when the number of trials to criterion were analyzed, the data indicated that males took fewer trials ($M=2.50$) to reach criterion compared to females ($M=3.80$) for the 6-turn maze.
These results suggest that gender differences for navigation are mediated by task difficulty level. Consequently, additional factors such as experience may underlie the gender differences reported for visuo-spatial skills in the literature. In terms of navigation skills, research has demonstrated that females tend to use a landmark strategy for navigation compared to males who tend to prefer a geometric strategy (e.g., Galea & Kimura, 1993). Consequently, the absence of landmarks in the mazes for this laboratory may have been particularly troublesome for females compared to males when the mazes were more complex.

In summary, this laboratory module challenges students in courses such as Cognitive Psychology or Experimental Psychology to examine whether there are gender differences in navigation. This laboratory module can also be modified to examine what factors contribute to gender differences in navigation by adding landmark cues to the virtual mazes. This laboratory module has generated a great deal of interest from students who intend to conduct independent research for their senior theses to examine gender differences in navigational strategies.

The Virtual Mall
In 1975, Siegel and White proposed a model for the development of spatial representations of large-scale space. This model is cumulative and hierarchical specifying the following four stages: landmark recognition only, route construction with landmarks, route construction with landmarks and metric distances, and finally configurational knowledge as evidenced by an understanding for multiple routes that can be used flexibly for environmental navigating.

Numerous studies have been conducted to examine these stages of spatial representation using a variety of research methods. For example, Cohen and Schuepfer (1980) used slide presentations to simulate a configuration of hallways and found that landmarks were central to second graders’ knowledge, that sixth graders exhibited relatively well-formed route knowledge, but only adults were able to coordinate route knowledge into an accurate configuration.

Using the real world as their laboratory, Cousins, Siegel, and Maxwell (1983) tested first, fourth, and seventh graders on a series of tasks to examine their cognitive mapping skills for their school campus. The results of their Guttman scale analysis provided support for Siegel and White’s model (1975). However, an editorial reviewer noted that the lack of consistent grade level differences on measures of route-metric and configuration-bearing knowledge suggests that familiarity affected performance.

Consequently, The Virtual Mall was designed to re-examine Siegel and White’s model (1975) for cognitive mapping. In our Virtual Mall study we used a basic floor plan, starting with a large square space and inserting a smaller interior square room in this area. The smaller interior square room has one door on each side. The larger exterior space has been designed such that each of the four walls include separate hallways leading to four different rooms. There are a total of thirteen rooms to explore, i.e., the one interior room with four doors and the twelve exterior rooms (Figure 3).

The experimenter introduces the participants in this study to the navigation tools by placing them in the Virtual Office. When the participant indicates they are ready to explore the Virtual Mall, the experimenter brings them to the interior room of the Virtual Mall. At this point, the participant is informed that they can explore the Virtual Mall until they are ready to draw a map for the next participant. Participants are given an unlimited amount of time to complete this task.

We are still in the pilot stages of collecting data for the Virtual Mall. At this point, we have tested 10 children ranging in age from 3-10 years of age. An inspection of the drawings that the children have provided indicates that their ability to represent the spatial layout for the Virtual Mall supports Siegel and White’s model (1975). For example, our youngest participant represented the Virtual Mall as one large square with three squares added to one side. In contrast, some of our older participants could produce an exact blueprint for the Virtual Mall.
These results are important to consider because they demonstrate that virtual environments can be used to tap into complex cognitive processes such as spatial representation. Furthermore, a stand alone virtual environment for testing makes it possible to conduct longitudinal work to investigate age-related changes in spatial representation, which would be very difficult to conduct in the real world. This laboratory module has not been introduced into any of our courses. We will be modifying the study to collect additional measures regarding performance in order to better understand the specific cognitive processes (e.g., memory, attention, etc.) required to gain configurational knowledge for a large-scale space. This will be the first laboratory module that we will introduce into our Child Psychology course.

Figure 3. The Virtual Mall

Conclusions
In general, we have discovered that our laboratory modules can be incorporated quite readily into a variety of courses, thereby providing students with hands-on learning opportunities. Each laboratory module comes with an experimenter script, database template, statistical analysis recommendations, and a list of key references. Students in our Cognitive Psychology and Experimental Psychology courses have had the opportunity to be both experimenter and participant in our laboratory modules. The students greatly enjoy these laboratory modules and we find that many want to initiate the next phase for conducting related research using virtual reality technology.

Consequently, we have discovered that students who have participated in these laboratory modules are more likely to conduct independent research. As independent researchers, these students are well prepared to identify significant research questions, formulate specific hypotheses, specify a sound experimental design, test participants, manage a database, conduct appropriate statistical analyses, and complete a thesis. In conclusion, our laboratory modules show students that virtual reality tools can be used to create an unlimited number of environments to examine their questions about human behavior.

References


