Using Virtual Reality with and without Gaming Attributes for Academic Achievement

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Abstract

A subcategory of computer-assisted instruction (CAI), games have additional attributes such as motivation, reward, interactivity, score, and challenge. This study used a quasi-experimental design to determine if previous findings generalize to non simulation-based game designs. Researchers observed significant improvement in the overall population for math skills in the non-game CAI control condition, but not in the game-based experimental condition. The study found no meaningful, significant differences in language arts skills in any of the conditions. This finding has implications for the design of future learning games, suggesting that a simulation-based approach should be integrated into the gaming technology. (Keywords: games, education, simulation, CAI, motivation.)

INTRODUCTION

Computer-assisted instruction is a widely studied and supported method of teaching. Numerous meta-analyses and review articles have been published showing small but positive effect sizes supporting CAI over other teaching methods (Bayraktar, 2001; Chambers, 2002; Christmann & Badgett, 2003; Cohen & Dacanay, 1992; Fletcher-Flinn & Gravatt, 1995; Kulik, 1994; Lowe, 2001). CAI is defined as any program that augments, teaches, or simulates the learning environment used in the traditional classroom (Quyang, 1993), including Web-based instruction, self-running simulations, drill-and-practice programs, and multimedia classrooms (Murphy et al., 2002). Learning games are just one form of CAI that have the following additional attributes: motivation, reward (feedback), interactivity, score, and challenge. Support also exists for this specific type of CAI and its effectiveness in the classroom (Vogel et al., 2006). However, it remains unclear as to whether or not learning through games will improve upon traditional CAI results.

Motivation to Learn

The primary thrust of the use of games within the domain of CAI is to increase students' motivation to learn, by presenting the learning material in a form that encourages engagement and thereby increases practice. Research suggests that interacting with computers leads to increased motivation (Ju & Wagner, 1997; Kafai, 2001; Rieber, 1996). Specifically, environments such as games that have increased learner-control and learner-created feedback over traditional computer-centered CAI result in higher levels of motivation (Nastasi & Clements, 1993; Roussos, Johnson, Moher, Leigh, Vasilakis, & Barnes, 1999). Play, another factor prominent in games but less visible in CAI, has been supported in educational research as a necessary component of motivation (Lardinois, 1989, in Siemer & Angelides, 1995; Rieber, 1996; Romme, 2003). When people play, they allow for more efficient learning and cognitive material intake than they would in a more traditional setting (Baltra, 1990; Pange, 2003). Thus, play has the potential to engage students in the learning process, which may lead to increased learning. Further, the level of *interactivity* between the user and program defines the depth of involvement of the user in the activity (Bangert-Drowns & Pyke, 2001). Games are expected to have a higher level of interactivity compared to traditional CAI methods, again potentially leading to improved results. The amount of appropriate *challenge* in the program can also help scaffold the learning of the individual. If the challenge is too high, the learner may feel hopeless and quit trying, but if the challenge is too easy, then the learner may become distracted and lose interest. An optimal (and possibly dynamic) level of challenge needs to be identified in order to capture the learner's attention and interest and motivate them to continue to try to move to the next level of learning. Together, these three components (play, interactivity, and challenge) define a certain level of motivation. Rewards and scores are the final components of a game. They give feedback to the user in an attempt to both demonstrate correct versus incorrect answers, but can also act as a motivating entity. When a student is oriented toward receiving more points or rewards, she/he may work faster and/or more efficiently. In an educational game, that would translate to more questions being answered or result in faster or more efficient learning.

Simulation in Gaming Technology

Researchers have documented the effectiveness of simulation as a learning tool over the last 30 years (Farrel et al., 2003; Lintern, Sheppard, Parker, & Yates, 1989; Lintern, Roscoe, Koonce, & Segal, 1990; Tkaz, 1998). Moreover, simulation has been identified as being particularly effective at training skills and procedures, as it allows learners to practice these behaviors in an artificial environment that mimics the real world. The utility of simulations in education has been examined at greater length elsewhere (Chaffin, Maxwell, & Thompson, 1982; Thurman, 1993), but extensive evidence exists showing that simulation is a highly effective way to communicate skills and operational knowledge to learners (Salas & Cannon-Bowers, 2001). Given that the use of simulation is a highly effective method of educating, researchers have argued that learning games incorporating digital simulation are ideally suited to learning in multiple domains, and may represent the future of learning in technological societies (Aldrich, 2004). The boundary between simulations and games can become blurred on occasion, but taxonomies exist to aid in understanding and differentiation between the two (Schmucker, 1999).

Learning games may represent an effective way of delivering simulation to a wider population of learners than currently have access to such systems. A number of studies have shown significant transfer of learning from digital games to real world applications in a number of domains (Jentsch & Bowers, 1998; Jones, Kennedy & Bittner, 1981; Tkacz, 1998; Van Eck, 2000). However, simulation-based games are associated with a number of drawbacks, including the difficulty and expense of developing such systems. Moreover, the open-ended nature and nonlinear presentation of material characteristic of simulations may not mesh well with the rigid structured environment of current classrooms and curricula.

Teach-Test Methodologies

Another avenue through which games increase effectiveness is in the design of the game itself and the way in which the game presents learning material. Systems such as CAI use non-interactive "teach-test" methodologies, trading the known advantages resulting from the use of simulation in learning for the decreased cost and development time and increased teacher acceptance of traditional linear teaching methods. It is unknown whether this tradeoff in lower transfer-of-training results, based on teach-test methods for reduced costs and development time, will have the same results in games.

Developers have created games for the educational market. So-called "edutainment" games have existed for decades (Prensky, 2001). Such games typically use a very different structure from simulations, commonly presenting the material to be learned in a linear, predetermined manner, which is mediated by the overall structure of the game. This can be accomplished in many ways, but one common presentation format is to alternate segments of game-play with segments of learning (Prensky, 2001).

Due to the high level of control over the structure and order of presentation of the material to be learned, such systems are much more easily integrated into classrooms and traditional learning environments. Additionally, it is probable that educators and administrators would more easily accept such systems, as they can more easily be made to support state- and federally-mandated education requirements. Equally importantly, these games are quicker, cheaper, easier to make, and they require less specialized expertise than simulation-based approaches (Aldrich, 2004). Therefore, if it could be shown that such approaches to learning-game design were effective at engaging and enabling learners, these systems could be quickly and easily deployed in classroom and other learning environments around the country.

However, it has not yet been shown that game-enabled instruction is effective using games that use a more traditional rather than simulation-based approach to learning. The aim of the present study is to examine whether a maximal effort application of this type of approach, using virtual reality and incorporating the work of professional educators and system designers, could produce a learning game that can increase learning in both hearing and deaf children beyond the improvement seen in simple CAI.

Virtual Reality Technology

The system used in this study utilizes virtual reality technology. VR for educational purposes involves using three-dimensional figures on a computer to represent accurate objects and scenarios. Navigation in any direction is possible, and activities, games, or tests can be combined with scenes to create meaningful educational experiences. Two main benefits of VR over traditional two-dimensional CAI are the three-dimensional, life-like experience and the individual's control over the program. These make VR a distinct learning experience that can aid in comprehension of complex ideas and skills (Roussou, 2004).

Special populations with different learning needs, such as deaf children, may particularly benefit from VR technology. It has been suggested that children who are deaf think in more concrete terms than their peers (Cromby, Standen, & Brown, 1996; Myklebust, 1964 in Passig & Eden, 2000a), making skills such as reading comprehension or higher-level mathematics very difficult to learn. Using VR with these non-traditional students exposes them to problem-solving and inductive thinking in less abstract ways, possibly allowing them to connect the abstract concepts with the concrete scenarios on the screen that represent those concepts. Further, research has demonstrated that using three-dimensional VR, compared to the conventional two-dimensional computer games and graphics, can significantly improve deaf children's flexible thinking skills, or the ability to see problems from different points of view (Passig & Eden, 2000b). Without causing frustration in other people, it also provides redundancy of information and control over the task, which may increase the child's motivation for learning (Cromby, Standen, & Brown, 1996).

The VR program used in this study has been tested in its original form as a CAI program. It was designed to help the children to link the *idea* of the questions to the meaning of the question by demonstrating it in the VR program. For example, instead of simply reading a word problem that asked "If Bessie the cow has 2 quarts of milk, Callie has 6 quarts of milk, and Nellie has 3 quarts of milk, who has the most milk?" the student sees the question, as well as several cows with milk, *and* bottles holding accurate amounts of milk. The pictures allow children to see the relationship between the bottles of milk and might help them to understand the concept of "most." The results showed that using the program in this format lead to significant increases in understanding complex mathematical concepts such as geometry, spatial sense, graphing, and some areas of language arts such as reading comprehension (Vogel, Asberg, Vogel, & Bowers, 2006). However, transferring the knowledge to a wider range of testing in math and language arts showed fewer clear benefits. While scores in math were significantly improved, the same pattern was not present in the language arts section. This discrepancy has lead to further investigation by the researchers.

The goals of the present study are two fold: first, to identify whether the use of a virtual reality learning game based on traditional linear teaching methodologies can increase learning beyond the level of improvement expected from the use of a CAI format, and second, to determine whether hearing and deaf children benefit equally from the use of such technologies.

METHODS

Forty-four children ages 7 to 12 years from a public elementary school in Florida were included in this study. There were 25 females and 19 males. The elementary school used for this study was chosen because it houses a unique computer lab devoted to testing VR programs for educational settings. Primarily, these programs are used with the deaf education program; however, regular education classes are utilized occasionally as well. Students were chosen in two ways. All the deaf students whose parents allowed them to participate were included. The hearing sample was chosen through a volunteer process. The teachers volunteered their students and then those students whose parents allowed them to participate were included. Teachers received no instruction on the computer; however, students were given basic directions.

The original number of children in each grade included: 12 second graders, 13 third graders, 9 fourth graders, and 10 fifth graders. The final analysis excluded two children (one in third and one in fifth, both were deaf, one female, and one male) because of excessive absences. Eleven of the remaining children were deaf and 31 of the children hear normally. All teachers of the children who are deaf used the total communication method in their classrooms (a combination of signing and speaking), and all the children who are deaf were taught in a segregated classroom environment. General Dynamics-Advanced Information System created the VR programs—one system as a CAI program and another system with gaming attributes.

Prior to the beginning of the computer sessions, all children completed a pretest that covered language arts and mathematics. The subject areas tested included determining the main idea of stories, identifying relevant supporting details and facts, arranging events in chronological order, and algebraic thinking such as describing and analyzing patterns, relationships, graphs, symbols, and functions. Each test was 15 questions in length, and the children were given 15 minutes per section to complete the tests.

This study used a quasi-experimental unequal control group design to compare the two conditions. Students were split randomly and equally into either the control or experimental group. The control group used the CAI program while the experimental group used the program with gaming attributes. During the following two-week session, the children were involved with their respective computer programs for 10 minutes per day. Students were given basic instructions about how the program works and then encouraged to navigate through the program individually. Acquisition and transfer of knowledge were tested using a posttest similar in design to the pretest, but with different questions. Immediately following the last intervention on the computer, students were given the posttest in paper form. Both pre and posttests were delivered in this format. The tests were based on the standardized tests used in the state of Florida called the FCAT (Florida Comprehensive Assessment Test). Though no validity or reliability tests were conducted on the tests used in this study, their content, format, and order mimicked that of the FCAT, which is highly tested each year.

RESULTS

Overall

Using a one-tailed, exact probability test, participants across groups did not perform significantly differently on the posttest compared to the pretest in the language arts section. However, in the math section, there was a significant increase in scores (p=0.032), suggesting that in either condition, students improved their performance on the posttest. Neither the control group nor the experimental group performed significantly differently in the language arts tests. Further, this study found no significant difference in change scores between the two groups. However, the control group performed significantly better on the math posttest compared to the pretest (p=.006), while the experimental group showed no significant difference. Thus, using a two-tailed, exact probability test, which compared the control group versus the experimental group in the math section, there was a significant difference in change scores (Mcont=1.15, Mexp=0.00), p=.044, suggesting that the children using the traditional CAI program learned more in the math section compared to those using the program augmented with gaming attributes (see Table 1). Each grade was compared separately. Table 2 contains a list of the results.

Table 1: Overall Control vs. Experimental Group Difference Scores

Group	Difference Scores	Test	*p*-values
Overall Language	-.49	One-tailed	.090
Overall Math	.49	One-tailed	.032
Control Language	-.75	One-tailed	.086
Control Math	1.15	One-tailed	.006
Experimental Language	-.36	One-tailed	.278
Experimental Math	0.00	One-tailed	.500
Delta (Exp vs. Control) Language	—	Two-tailed	.637
Delta (Exp vs. Control) Math	—	Two-tailed	.044

**Indicates significant result.*

Table 2: Individual and Comparison Difference Scores per Grade Level

Grade	Second	Third	Fourth	Fifth
Control Language (Difference Scores) (One-tailed)	-0.67	-1.17	0.25	-.125
Control Math (Difference)	1.00*	2.17*	1.25	0.25
Experimental Language (Difference Scores) (One-tailed)	0.17	-2.00	0.60	0.00
Experimental Math (Difference Scores) (One-tailed)	0.00	0.50	-0.20	-0.40
Delta (Experimental vs. Control) Language (p-values) (Two-tailed)	.634	.642	.808	.465
Delta (Experimental vs. Control) Math (p-values) (Two-tailed)	.249	.181	.356	.893

**Indicates significant result.*

Hearing Status

The groups were divided by hearing status and compared. The difference scores in the deaf/hearing-impaired group from the pretest to posttest were not statistically significant in either the math or the language arts sections. In addition, the difference scores in the hearing group for the math section were not statistically significant. However, in the language arts section, a decrease was found (collapsing across conditions) from pretest to posttest, suggesting that using the computer to practice reading skills, regardless of the condition, resulted in reduced comprehension for children who hear normally but not for deaf children. Data indicated no significant differences between the difference scores of these two groups in the language arts or the math sections (see Table 3).

Table 3: Difference Scores Compared by Hearing Status

Group	Difference Scores	Test	p-values
Hearing Language	-1.00	One-tailed	NS
Hearing Math	.26	One-tailed	.155
Deaf Language	.73	One-tailed	.166
Deaf Math	1.36	One-tailed	.064
Delta (Hearing vs. Deaf) Language	—	Two-tailed	.058
Delta (Hearing vs. Deaf) Math	—	Two-tailed	.091

**Indicates significant result.*

Students Who Are Deaf

Finally, this study made comparisons between the deaf control and deaf experimental groups. The deaf control group's difference scores from pretest to posttest did not change significantly. However, there was a significant improvement in the math section (p=.023), suggesting that using the VR program with the CAI method resulted in improved math skills. No significant changes were observed in the experimental group in either the math or language arts sections. Further, this study found no significant difference when comparing the change scores between groups in the language arts section, suggesting that regardless of the type of program used, the performance of the deaf children did not benefit or decline because of using the VR program. However, a significant difference in change scores between groups was found in the math section (p=.033), favoring the CAI version of the VR program over the gaming version (see Table 4).

DISCUSSION

The present study expanded existing methods of CAI to determine if they could be improved upon by presenting the same learning material in the same format, but embedding it in the structure of a video game. While evidence supporting the effectiveness of learning games has previously been established (Jentsch & Bowers, 1998; Tkacz, 1998), previous studies have used games built around simulation-related approaches. The goal of the present study was to extend these findings to games that do not rely on simulation-based learning paradigms, but instead incorporate traditional educational approaches to structuring and presenting material.

Table 4: Difference Scores Compared by Hearing Status

Group	Difference Scores	Test	*p*-values
Deaf Control Language	.20	One-tailed	.440
Deaf Control Math	3.20	One-tailed	.023
Deaf Experimental Language	1.17	One-tailed	.119
Deaf Experimental Math	-0.17	One-tailed	.421
Delta (Control vs. Experimental) Language	—	Two-tailed	.529
Delta (Control vs. Experimental) Math	—	Two-tailed	.033

**Indicates significant result.*

Reading Skills

The lack of any observed improvement in language arts skills regardless of condition or hearing status suggests that CAI may represent a less effective means of teaching language arts skills to children. This might be due to the way in which the material was presented in the pre and post test, or it might be a result of inadequate organization or poor presentation of the learning material. An alternative explanation is that language arts skills may be simply harder to teach, regardless of method, and that the participants did not use the system often or long enough to obtain results. Additionally, the concrete representations of language arts may be more difficult to produce compared to mathematics. This may impede the impact of the visualization component used in VR to aid comprehension.

One disturbing finding was that the performance of hearing children inexplicably became worse in the post-test of this study. The effect itself was directly attributable to the enormous drop in performance of the 13 third grade students in the study who had normal hearing. This finding would appear to suggest that the drop was due to the influence of a variable outside of the control of the study. Third grade students in the experimental condition showed a large negative change score, while all other grades showed either no change or a modest increase in performance on the same test. It is noteworthy that in the state of Florida, all third grade students are required to read on grade-level to be promoted to fourth grade. This requirement generally leads to intensive reading work for this specific grade. As the current study was conducted at the end of the school year, it is possible these children were simply overworked in reading during their required classroom time leading to a decrease in concentration during the posttest phase.

Mathematical Skills

The observation of a significant main effect with regard to math skills, such that participants' math scores increased significantly from pretest to posttest when collapsing across condition and hearing status, would seem to suggest that CAI may generally be an effective method in training math skills, regardless of the approach used when designing the system. However, examining the effect further reveals that this overall difference is mostly due to a large significant improvement in difference scores on math test performance from pretest to posttest in the control condition. The experimental group showed no such improvement, suggesting that the use of the learning-game format not only failed to improve math skills, but actually negated the improvement resulting from the use of the CAI system altogether. While participants in the experimental group did no worse than those in the control group, they did not improve significantly from pre to posttest. Participants in the control group did improve from pre to posttest. This finding is reinforced by the significant difference in change scores on the math test between conditions, such that there was a significant difference between pre- and post-study math scores in the control group but not in the experimental group. Potentially, the use of the computer's representation of mathematical problems allowed students, regardless of hearing status, to better visualize the problems. This concept has been supported in other settings (Chou, Hsu, & Yao, 1997; Drake, 2003; Gadanidis, Sedig, & Liang, 2004; Lowe, 2004; Ploetzner & Lowe, 2004), suggesting that the ability to concretely represent abstract concepts aids in comprehension of mathematics.

Non-Simulation Games

The current study failed to extend the findings of Jones, Kennedy, & Bittner (1981), Povenmire & Roscoe (1973), Lintern et al. (1989), Lintern et al. (1990), Tkaz (1998), or Farrel et al. (2003) to games utilizing non-simulation based content. The implications of this are significant to the future development of learning games. One interpretation of these findings is that games designed to enable learning should rely on a simulation-based approach rather than the linear and structured presentations traditional in educational environments. This is unfortunate, in that simulation-based learning games are more difficult to incorporate into existing educational curricula than games relying on traditional educational approaches such as the one examined in this study.

While more research into the utility of learning games as teaching tools is still necessary, this study suggests that attempts to integrate traditional linear presentation of material in learning-game format may be a less effective strategy than simulation-based approaches. While it is difficult to determine exactly why this is, a number of hypotheses can be proposed for further research. It is possible that the children enjoyed the game part but were bored by the learning material. Because of the sharp division between the learning and game content inherent in this type of design, the participants might have rushed through the learning material in order to reach the game more quickly. In doing so, they may have failed to devote adequate attention to learning. By contrast, the participants in the control condition did not have the experience of the game condition to compare to the traditional CAI. Consequently, they might have found the novelty of the VR setup sufficiently engaging and motivating in and of itself, and therefore were more likely to pay attention to the learning material. One lesson that designers of learning game systems might draw from this is that learning material must be presented in a manner that is organic and non-disruptive to the game. This is much easier with simulation games in which the game content itself is educational, but it may also be possible to integrate learning material into other types of games successfully. In order to work, however, such systems must ensure that the entire experience is engaging and motivating to avoid the effect observed in this study.

Deaf Sample

The findings specific to the deaf children who participated in the study largely mirrored the experience of the hearing participants. Deaf children did not experience any improvement in language arts skills in either condition. They did, however, exhibit a significant improvement in math skills following the use of the system. Deaf children in the control group (who received non game-based CAI) improved more than their counterparts in the experimental group (those who used the game). Again, as the pattern is the same as observed in the hearing group, it is believed that the same issues have contributed to greater improvement in the traditional method versus the lower results in the game method.

Impact of Learning Games

It is important to note that these findings should not be interpreted as discounting the usefulness of learning games. Ample evidence exists supporting the usefulness of such systems in multiple learning environments, a small portion of which is identified in the introduction to this article. The present work does, however, seek to differentiate between learning games which are based on simulation technologies or other integrated learning tools and learning games which are based on traditional presentation of linear material interspersed with segments of game play. In essence, the connection between the material to be learned and the game play experience must be seamless. Otherwise, the system may not only fail to exploit the advantages of learning games, but may actually inhibit the ability and motivation of users to learn the material. This study has also identified few significant variations between a hearing population and deaf children with regards to the effectiveness of CAI and game-based learning. It can therefore be concluded that, insofar as the present study explored the interaction between learners and learning games, deaf children and their hearing counterparts have responded similarly to these types of CAI. Learning games represent a potentially useful technology for the classroom, but the design of such games must be carefully tailored to provide an experience that is engaging and motivating in order to avoid the effects observed in the present study.

Contributors

Jennifer J. Vogel, MS, is currently on the research faculty at Florida State University studying reading skill acquisition in children with significant cognitive impairments. She also has a research lab at the University of Central Florida called HANDS, where she conducts the majority of her research with deaf children. Specifically, her interests focus on using computer-based programs for special education populations for learning.

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Jan Cannon-Bowers, PhD, is an associate professor of digital media at the University of Central Florida. She is also a senior research scientist at the university's Institute for Simulation and Training, and is the founding director of UCF's new Center for Dynamic Media. She has more than 15 years of experience conducting research into learning and performance in complex systems. She is currently principal investigator on several efforts aimed at applying technology to K–12 education and workforce development, including a grant from the National Science Foundation to investigate synthetic learning environments.

Clint Bowers, PhD, is the associate dean of research, academic promotion, and technology for the College of Arts and Sciences at the University of Central Florida. He is also a professor of digital media at that school. Bowers is a fellow of the American Psychological Association and a past president of the organization's Division of Applied and Experimental Psychology. He serves on several editorial boards, including Human Factors and The Journal of Psychology: Interdisciplinary and Applied. Bowers has been involved in several efforts to apply and evaluate technology in learning and decision support system design, with diverse populations.

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