

Children's Transfer of Spatial Learning from Virtual Reality to Real Environments

JOAN McCOMAS, Ph.D., JAYNE PIVIK, M.A., and MARC LAFLAMME, B.Sc.

ABSTRACT

Spatial abilities in children have been shown to be related to activity in the environment, particularly to walking and other forms of active locomotion. The objective of this study is to investigate whether virtual reality (VR) can assist children in transferring spatial learning to a real environment. Children (six and seven-yr-old participants) were asked to find ten objects hidden around a room and to try not to visit the same location more than once. Examination of the percentage of correct choices and the visit of first error showed improvement as a result of training. There were initial differences between children trained on the computer compared to those trained in the real environment. However, after three practice trials, children with the VR training were comparable to children trained in the real space. The implications for utilizing a VR environment for enhancing spatial abilities for children with mobility difficulties is discussed.

ALTHOUGH THE USE OF THREE-DIMENSIONAL computer animation and virtual reality (VR) is becoming more widespread, there is little concrete evidence to demonstrate whether transfer of learning to real space is actually occurring in children practicing spatial skills in VR. Though this question is important in demonstrating the usefulness of VR as a training tool, it has particular importance for children with disabilities. It has been suggested that VR may become a meaningful resource for people with disabilities by providing them with experiences that would not normally be possible because of physical limitations.¹⁻³ VR is defined as an immersive and interactive three-dimensional (3D) computer experience occurring in real time.⁴ In other words, VR applications use 3D computer graphics, give the user a sense of im-

mersion, and respond interactively to the user's movements in the virtual environment (VE).

VR and training applications

In addition to the potential for improving spatial skills using VR, other practical training applications have included industrial and military training,⁵ firefighter training,⁶ medical and rehabilitation training,⁷ and architectural and urban planning.⁸ VR can assist in training by providing an opportunity for practice where that opportunity may be difficult or impossible to achieve first-hand. The underlying principle for the use of VR for training is the opportunity for simulated learning, experience, and practice to be transferred to the real world. Using a simulated environment, VR can assist in real-world situations which are either too costly, too dangerous or too difficult to experience. For example, VR can allow individuals with physical disabilities and mobility problems the opportunity for experiences and sen-

Rehabilitation Sciences Virtual Reality Lab, School of Rehabilitation Sciences, University of Ottawa, Ottawa, Canada K1H 8M5.

sations not available to them in the real world, as well as provide an environment conducive to rehabilitation training.¹ Other benefits may include the opportunity for control and practice that would instill a sense of skill and confidence, an environment free of physical and social hazards,³ and training that is stimulating and interesting.⁹

Spatial abilities and active exploration

The active, immersive and simulative nature of VR lends itself to the investigation of training opportunities for improving spatial knowledge and skills. Theoretically, the acquisition of spatial knowledge in children has been related to active exploration of the environment, particularly to walking and other forms of locomotion.¹⁰ Siegal and White¹¹ suggest that locomotion (walking) is an essential condition for the construction of spatial representations, since it provides direct sensorimotor information about landmarks and routes. There is evidence that children who actively explore an environment, by moving in it or by manipulating objects, perform better on tests of spatial knowledge than children who just watch. For example, Feldman and Acredolo¹² found that young children permitted to actively explore an environment were better at remembering the location of an event than those who were passively led. Hazen¹³ concluded that after active exploration, three-year-old children better understood spatial relationships. Recently, in a study of six- and seven-year-old children, with and without physical mobility difficulties, McComas, Dulberg and Latter¹⁴ trained children in a memory location task. They found that children who actively moved to find the pieces during training, as opposed to being pushed passively in a wheelchair, performed better on a subsequent test of the task. The factorial design allowed the researchers to examine the influence of choice and movement during training. When these factors were teased apart, active movement was the important factor for spatial memory.

Spatial abilities and computer interfaces

Children with mobility impairments often have more difficulty with spatial tasks than children without disabilities.^{15,16} Aside from

the possible effects of neurological damage, children with mobility impairments often lack the opportunity for self-governed exploration, which may account for their limited spatial awareness.¹⁷ The notion that computers can be used to help children with physical disabilities acquire spatial knowledge and skills not otherwise accessible in real space is appealing. Conditions considered necessary for influencing spatial abilities with computer environments include: the opportunity for repeated practice, physical and mental manipulation of two-dimensional (2D) and three-dimensional (3D) objects, the coordination of horizontal and vertical axes,¹⁸ the coordination of perspectives, induction activities, and parallel processing.¹⁹ Evidence of the effect of repeated practice on improving children's spatial cognition with computer games that involved visual perception and discrimination of 3D objects at differing speeds, distances, and orientations was noted by McClurg and Chaillé.²⁰ Early studies by Dorval and Pépin²¹ and Gagnon²² examined the impact of computer training on adults' spatial abilities, finding that undergraduate students who were trained in video games scored higher on subsequent measures of spatial abilities than those without training.

Transfer of training from VR to real space

As VR has increased in accessibility and attention, researchers have begun to investigate its effect on spatial skills and knowledge, and whether spatial learning can transfer from the computer to the real world. There is some evidence that spatial learning occurs through exploration of VR environments. Péruch, Vercher and Gauthier²³ compared active and passive exploration of 3D computer-simulated environments and found that active hand sensorimotor activity via joystick manipulation had a positive influence on spatial performance in a simulated environment. Regian, Shebilske and Monk⁹ found that spatial learning occurred when subjects were trained on a virtual console or on a maze task (navigating several rooms) in VR. As well, research focusing on route navigation training found that VR was as effective as the more familiar blueprint format typically used by fire rescue personnel.⁶

Although these studies have shown that spatial knowledge may be acquired while working in VR, there is a paucity of research examining the transfer of spatial knowledge from computers to real environments. Essentially, can training in VR improve spatial skills in the real world? Regian, Shebilske and Monk⁹ suggest the potential of simulation-based learning for spatial skills, since VR preserves the visual-spatial characteristics of the simulated world and provides a connection between the individual's motor actions and resulting effects. In one study, Wilson, Foreman and Tlauka¹⁷ tested severely disabled children's knowledge of a real environment and found that spatial learning from VR to real space occurred at a level better than chance. They compared the children's performance for finding objects in a real environment, following simulated VR training, to the best guess of college-aged students. However, Kozak and his colleagues⁵ found that real-world training resulted in better performance than VR training on a motor task where cans had to quickly be placed at target locations. The problems affecting transfer of learning in this study may have been due to the motor nature of the task, which resulted in computer interface problems as well as a lack of sensory feedback.⁵

Other factors that may limit the effectiveness of VR training for increasing spatial skills, besides a possible discrepancy between interface reaction, feedback and real-life movement, include: (1) the artificial nature of VR which offers mostly visual feedback;^{5,17} (2) the different properties or characteristics of a virtual environment compared to those of the real world (e.g., gravity);⁵ and, (3) the level of the individual's spatial capabilities, which may impede new knowledge/skill acquisition.¹⁷

With the overall goal of developing and refining a VR tool that will help children with physical disabilities, the present study attempts to first examine how spatial learning is transferred from a virtual environment to a real environment. Specifically, baseline data was collected on children without disabilities who trained in a VR spatial task that simulated the task in real space. It was hypothesized that the children in the computer-simulated training group would: (1) demonstrate learning of a

spatial task, and (2) perform similarly to children who had real-space training. The task was designed to allow children with physical disabilities to participate in future studies.

METHODS

Subjects

Thirty-eight children, 16 boys and 22 girls, participated in the study. Composed of children from Grades 1 (52.6%) and 2 (47.4%), 20 subjects were six years old, 17 were seven years old, and one was eight years old ($M = 6.5$, $SD = .56$). The children were recruited from an urban school with a population of approximately 100 children in Grades 1 and 2.

Setting and Materials

Children were assigned to either a real environment training condition or a computer desktop VR training condition that simulated the real space. Typically, desktop VR utilizes a personal computer, where the virtual environment is displayed on a conventional computer monitor and movement within the environment is effected through either a mouse, a keyboard, or a joystick. For the real environment training condition, the children were tested in a large school classroom (7.32 m \times 7.32 m) that was cleared of movable furniture. Landmarks such as poster boards, windows, blackboards, the teacher's desk, and a reading area were clearly visible. Ten 1.5-m high, identical cardboard clowns, secured on wooden frames, were arranged at equal distances to form a 4.8-m diameter circle. Attached to each clown was an identical bag for holding a piece of a puzzle. For each trial, the child had to visit each clown to retrieve the ten puzzle pieces that made up one large wooden puzzle. A similar task was first described by Foreman and his colleagues²⁴ and later used by McComas, Dulberg and Latter¹⁴ to study the effects of choice and movement on children's memory for locations visited.

In an adjacent cloakroom, a computer station, consisting of an IBM-compatible 233-MHZ Pentium computer with a 17" Viewsonic 17 PS MGA monitor, was set up on a small

table. A child-sized wheelchair served as the chair in front of the computer monitor. The virtual environment (VE) used for this study was modelled as closely as possible to the real environment. The VE included landmarks such as shelves, blackboards, posters, tables, two windows (with moving clouds), a clock, an EXIT sign, and a door. The VE also contained ten clowns, arranged as described in the real environment, as well as fluorescent lighting and a cloakroom. The clowns were scanned into 3D Studio Max, retouched, then imported into the VE and were, therefore, almost identical to the clowns used in real space. The child was informed that one puzzle piece could be found in each red bag being held by the clowns.

Children moved through the VE in a virtual wheelchair, but only the armrests could be seen on the computer screen. The video monitor was placed at eye level, approximately 50 cm in front of the child. Following pilot work, it was decided that the arrow keys on the keyboard should be used to manoeuvre through the VE, as opposed to using a mouse or joystick, and that the space bar should be used to retrieve the puzzle pieces from the clowns. The UP arrow key was used to move forward, and the DOWN arrow key was used to move backward. The side arrows were used to rotate to the right or left. Sound was added to the program to give feedback on success. A pleasant rising chime was heard when the child visited a clown for the first time. On subsequent visits to the *same* clown, the child was "warped" back to the middle, indicating an error. A different sound indicated that the child had successfully returned to the centre of the classroom between visits.

The computer program was created as a level of the computer game Quake (IdSoftware, Orem, UT, 1996). The school classroom was created with a Quake Editor called Worldcraft. The clown cutouts and wheelchair arms were created using 3-D Studio Max and then imported into Quake Model Editor (qME). This program allowed the models to be retouched and saved in a Quake-compatible format. The textures (for the walls, floor, etc.) were created/retouched in Adobe Photoshop 4.0 and then imported into qART. This program was used to create bitmaps for the textures and to

save them in a Quake-compatible format for use by the level editor. The code that allowed the user to interact with the clowns/environment was compiled for Quake using the Quake C Compiler (QCC).

Certain modifications were made to the default settings in the Quake Options Menu. The Quake display was set to a width of 640 pixels, a height of 480 pixels and a resolution of 24 BPP (bits per pixel). The "Always Run" function was turned off and the "Screen Brightness" was kept at the minimum setting. A score indicating the number of puzzle pieces found was presented on an information bar at the bottom of the screen. The child's name was entered by using the NAME command in the Quake Console and, thus, appeared in the information bar along with the running score. All information pertaining to a child's session (i.e., number of trials, number of visits, puzzle pieces found, clowns visited and total time) were automatically recorded into the "qconsole.log" file, which was renamed according to subject number and cleared after each session.

Procedure

Information letters and consent forms were distributed to all children in Grades 1 and 2 at a local primary school in the week previous to the testing period. Group membership was determined by counter-balancing to either the real environment or the computer-simulated environment. Two children were tested simultaneously, one in the real environment and the other using the computer-simulated environment, with one researcher working with each child in adjacent rooms. The 30-min testing session consisted of three learning trials and a final test trial in the real environment. Thus, the children tested in the real environment had four trials in the real environment, whereas the computer-simulation group had three trials on the computer and a final test trial in the real environment.

For both conditions, the child was informed that the goal of the task was to find all ten puzzle pieces, that there was only one piece hidden at each clown, and that they should try not to return to a clown already visited. After visiting the clown, the child was instructed to re-

turn to the centre mark and, for the real environment, place the puzzle piece in a bag held by the experimenter, then close their eyes and very briefly turn themselves around. The reason for the turning was to reduce the possibility of choosing successive adjacent clowns. In the computer program, following a return to the centre, the program randomly turned the subject in a different direction. Completion of the trial consisted of the retrieval of all ten puzzle pieces or 14 visits, whichever came first. In the real environment, after 14 trials, the child was asked to walk around the room and retrieve the rest of the puzzle pieces from the clowns. The child was then asked to put the puzzle together while the experimenter placed new puzzle pieces in the bags for the next trial. In the computer-simulated environment, a score was visible at the bottom of the screen, informing the child of how many puzzle pieces had been retrieved. After 14 trials, the program ended and gave the child his/her final score. Between computer trials, the child was asked to complete wooden puzzles similar to those used in the real environment. During the trials, the experimenter recorded the location of the visit (e.g., clown #1), and whether a puzzle piece was found in the bag. By definition, a correct choice was a visit to a clown (or location) that had not been previously visited on that trial. An error was defined as a repeat visit to a particular location.

The dependent measures recorded for this study included the: (1) total percentage correct (number correct/number of visits \times 100), and (2) visit of first error (trial number that the first error occurred). Higher scores on the measures reflect better performance. Logically, the probability of making a correct choice by chance alone decreases as the number of correct visits increases. Over the entire trial, the total percentage correct measure identifies how well a child performs on this task. Similarly, an error made earlier in the trial, when the probability of making a correct choice is higher, would be considered a greater error than one made later in the trial. So, a child making their first error on Visit 8 would be performing better than a child making their first error on Visit 2.

RESULTS

All 38 children who had agreed to participate in the task and who had parental consent, completed the testing. The task appeared to be interesting and motivating for the children. In the computer training environment, the children were given an orientation of approximately 2 min in order to acquaint the child to movement within the computer environment using the arrow keys. Both conditions took approximately 30 min to complete, with no discernible time difference between the two groups.

Measures of the dependent variables (total percentage correct and visit of first error) were analyzed using a 2 group by 2 trial repeated measures analysis of variance. SPSS/PC for Windows version 6.1.3 was used for the analyses. Wilk's criterion indicated a significant main effect for group for the total percentage correct (CTOT), $F(1,35) = 6.18, p < .01$ (Fig. 1). Examination of the univariate analyses of variance indicated a statistically significant difference between the computer-trained and the real-space trained group on the first trial, $F(1,36) = 10.8, p < .01$, with no significant differences between groups on trial 4, $F(1,36) = .54, p = .466$. Thus, for trial 1, scores were significantly better for children in the real environment ($M = 71.0, SD = 12.6$) compared to those children using the computer-simulated environment ($M = 59.1, SD = 9.6$). However, after three trials on the computer-trained environment, children then tested in the real environment did not show statistically different scores than children trained in the real environment.

There was also a significant main effect for time across trials 1 and 4 for both dependent measures; CTOT, $F(1,36) = 16.24, p < .001$, and ERR (visit of first error), $F(1,36) = 14.43, p < .001$ (Fig. 2). In both cases, the children's scores improved over time. The means for the dependent variables for the two groups on trials 1 and 4 are shown in Table 1. In a secondary analysis, grade level and gender were included as additional factors in the MANOVAs. Including these factors did not alter the pattern of results. There were no significant three-way or two-way interactions.

To examine the impact of computer training

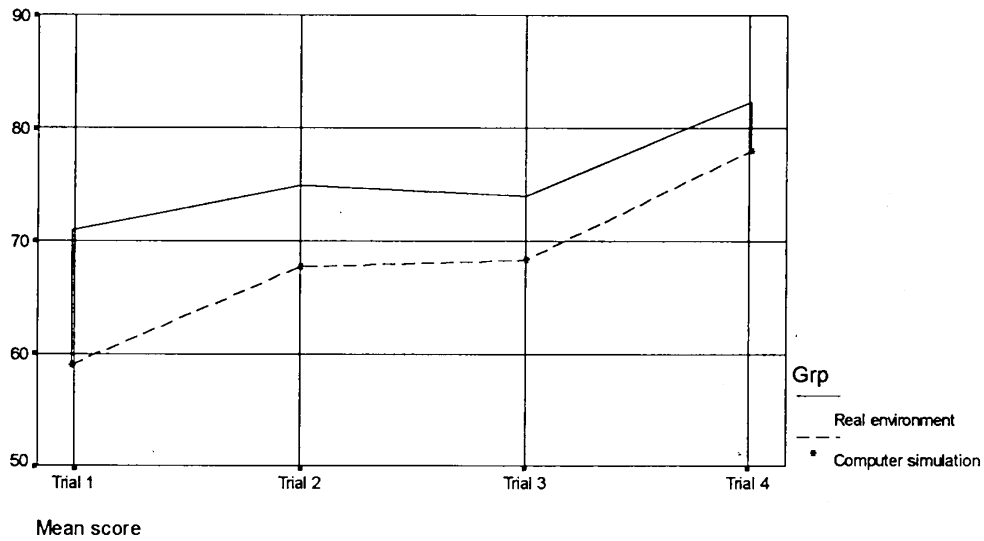


FIG. 1. Percentage of correct scores over trials.

compared to no experience on the task, the baseline data of the children tested in the real environment (trial 1) were compared to the final test scores of the children trained in the computer-simulated environment, using one-way analysis of variance. There were no differences between groups on the CTOT scores, $F(1,36) = 1.7, p = .199$; however, there were statistically significant differences noted for the visit of first error, $F(1,36) = 4.65, p < .05$. Children who had computer training made their first error later in the trial than children with

no experience ($M = 8.42, SD = 2.63$ and $M = 6.79, SD = 1.98$, respectively).

DISCUSSION

Children who participated in this study clearly improved with training in this spatial task. Further, after three trials in the VR program, both groups obtained comparable scores in the real environment test. This demonstration of the transfer of learning of a spatial task

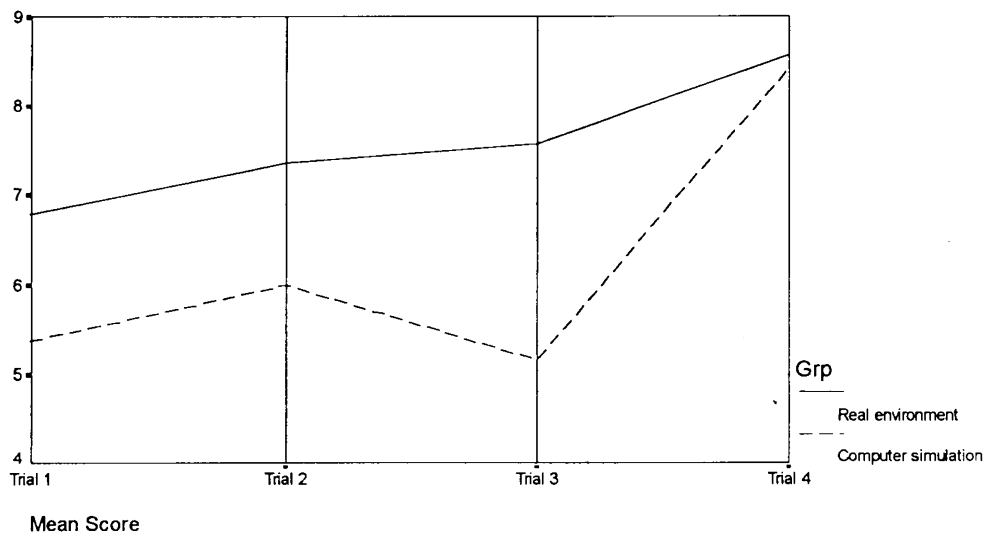


FIG. 2. Visit of first error over trials.

TABLE 1. DESCRIPTIVE STATISTICS, BY TRIAL AND TRAINING GROUP

		<i>Real-trained</i>		<i>Computer-trained</i>	
		<i>Trial 1</i> (n = 19)	<i>Trial 4</i> (n = 19)	<i>Trial 1</i> (n = 19)	<i>Trial 4</i> (n = 19)
Percentage correct	Mean	71.0	82.4	59.1	78.0
	SD	12.6	16.8	9.6	19.7
Visit of 1st error	Mean	6.8	8.2	5.4	8.4
	SD	2.0	2.9	2.2	2.6

from a VR to a real environment has implications for the use of VR as tool for providing children with spatial experiences. This study also suggests that VR may be a valid method for providing spatial experiences to children with mobility difficulties who are unable to explore the spatial relationships of objects in their environment to the same extent as children without physical disabilities. These results support those of Wilson, Foreman and Tlauka¹⁷ who also found that VR training transferred spatial knowledge to real-space environments.

It is interesting to note that training in this spatial task occurred in a VE that was not totally immersive (i.e., desktop VR). Although the VE had many of the landmarks of the real space, it was not a completely realistic simulation of the real space. One noted disadvantage of VR is its current level of surrealism and the interaction properties that differ from a real environment. Although high realism and identical physical properties may be important for the training of a motor skill,⁵ or for treatment of anxiety disorders,²⁵ it appears that, for learning a spatial task, desktop VR provides adequate information. The landmark information in VR may cue the child to use the same information when they are asked to perform a task in a real space. Anecdotally, the children tested in the VE initially chose clowns in a somewhat random order, before realizing that they had to keep track of where they had visited by using such strategies as "I have been to the clown in front of the window so I will not go there again." It seems plausible that, along with landmark information, the sensorimotor activity from movement within the VE was important. Active movement allowed the child to experi-

ence a changing visual array important for route information.

Rizzo and his colleagues²⁶ have posited 13 advantages of VR for cognitive and functional assessment and rehabilitation. One important aspect they mention is the introduction of "gaming" factors to enhance motivation. In the present study, this was an important factor for keeping the children involved with the task. Pilot testing of various factors related to the VE revealed that the children preferred the movement through the environment to be relatively smooth and not slower than a normal walking pace. Also, they would get frustrated if they became lodged behind objects, if the collision detection was not realistic, or if the movement was not effortless and precise.

In future studies, it will be important to look at the performance of children with mobility difficulties of this task. The implications for VR as a tool to assist in the development of spatial knowledge is important for all children, but as active movement experience is one factor that improves performance on spatial tasks, it appears primordial that the transfer of training from VR to real environments in this population be further examined.

ACKNOWLEDGMENTS

The authors thank the children who participated in this study, the teachers who assisted, and particularly Lucille Pummer, the principal of Corpus Christi School; Eileen McGregor of the Ottawa Life Sciences Technology Park; Ken Billings and Ross Bellinger of Fifth Dimension; and Judith MacNeill, Judy Lynch, and Paul Mc-

Comas. This project was funded by the Industry Canada Tri-Council Technology Partnerships Program and the University of Ottawa, University-Industry Fund.

REFERENCES

- Greenleaf, W.J., and Tovar, M.A. (1994). Augmenting reality in rehabilitation medicine. *Artificial Intelligence in Medicine*, 6, 289–299.
- Kuhlen, T., and Dohle, C. (1995). Virtual reality for physically disabled people. *Computers in Biology and Medicine*, 25(2), 205–211.
- Wilson, P.N., Foreman, N., and Stanton, D. (1997). Virtual reality, disability and rehabilitation. *Disability and Rehabilitation*, 19(6), 213–220.
- Pimentel, K., and Teixeira, K. (1995). *Virtual reality: Through the new looking glass*. Toronto: McGraw-Hill.
- Kozak, J.J., Hancock, P.A., Arthur, E.J., and Chrysler, S.T. (1993). Transfer of training from virtual reality. *Ergonomics*, 36(7), 777–784.
- Bliss, J.P., Tidwell, P.D., and Guest, M.A. (1997). The effectiveness of virtual reality for administering spatial navigation training to firefighters. *Presence* 6(1), 73–86.
- Satava, R.M. (1995). Medical applications of virtual reality. *Journal of Medical Systems*, 19(3), 275–280.
- Pantelidis, V.S. (1993). Virtual reality in the classroom. *Educational Technology*, 33, 23–27.
- Regian, J.W., Shebilske, W.L., and Monk, J.M. (1992). Virtual reality: An instructional medium for visual-spatial tasks. *Journal of Communication*, 42(4), 136–149.
- Cohen, S., and Cohen, R. (1982). Distance estimates of children as a function of type of activity in the environment. *Child Development*, 53(3), 834–837.
- Siegal, A.W., and White, S.H. (1975). The development of spatial representations of large-scale environments. In H.W. Reese (Ed.), *Advances in child development and behavior vol. 10*. New York: Academic Press.
- Feldman, A., and Acredolo, L. (1979). The effect of active versus passive exploration on memory for spatial location in children. *Child Development*, 50, 698–704.
- Hazen, N.L. (1982). Spatial exploration and spatial knowledge: Individual and developmental differences in very young children. *Child Development*, 53, 826–833.
- McComas, J., Dulberg, C., and Latter, J. (1997). Children's memory for locations visited: Importance of movement and choice. *Journal of Motor Behavior*, 29(3), 223–229.
- Foreman, N., Orencas, C., Nicholas, E., and Morton, P. (1989). Spatial awareness in seven to 11-year-old physically handicapped children in mainstream schools. *European Journal of Special Needs Education*, 4, 171–179.
- Simms, B. (1987). The route leaning ability of young people with spina bifida and hydrocephalus and their able-bodied peers. *Zeitschrift für Kinderchirurgie*, 42, 53–56.
- Wilson, P.N., Foreman, N., and Tlauka, M. (1996). Transfer of spatial information from a virtual to a real environment in physically disabled children. *Disability and Rehabilitation*, 18(12), 633–637.
- Lowery, B.R., and Knirk, F.G. (1982). Micro-computer video games and spatial visualization acquisition. *Journal of Educational Technology Systems*, 11(2), 155–166.
- Greenfield, P.M. (1984). *Mind and media: The effects of television, video games and computers*. Stanford: Harvard University Press.
- McClurg, P.A., and Chaillé, C. (1987). Computer games: Environments for developing spatial cognition? *Journal of Educational Computing Research*, 3(1), 95–111.
- Dorval, M., and Pépin, M. (1986). Effect of playing a video game on a measure of spatial visualization. *Perceptual Motor Skills*, 62, 159–162.
- Gagnon, D. (1985). Videogames and spatial skills: An exploratory study. *Educational Communication and Technology Journal*, 33(4), 263–275.
- Péruch, P., Vercher, J.-L., and Gauthier, G.M. (1995). Acquisition of spatial knowledge through visual exploration of simulated environments. *Ecological Psychology*, 7(1), 1–20.
- Foreman, N., Gillett, R., and Jones, S. (1994). Choice autonomy and memory for spatial locations in six-year-old children. *British Journal of Psychology*, 85, 17–27.
- Wiederhold, B.K., and Wiederhold, M.D. (1998). A review of virtual reality as a psychotherapeutic tool. *CyberPsychology & Behavior*, 1(1), 45–52.
- Rizzo, A.A., Buckwalter, J.G., Neumann, U., Kesselman, C., and Thiebaut, M. (1998). Basic issues in the application of virtual reality for the assessment and rehabilitation of cognitive impairments and functional disabilities. *CyberPsychology & Behavior*, 1(1), 59–78.

Address reprint requests to:

Dr. Joan McComas, Director,

Physiotherapy Program

University of Ottawa,

School of Rehabilitation Sciences

451 Smyth Road, Ottawa, Ontario, Canada,

K1H 8M5

E-mail: jmccoma@uottawa.ca

This article has been cited by:

1. Sing-Fai Tam, David Wai-Kwong Man, Yuk-Piu Chan, Pan-Ching Sze, Chi-Ming Wong. 2005. Evaluation of a Computer-Assisted, 2-D Virtual Reality System for Training People With Intellectual Disabilities on How to Shop. *Rehabilitation Psychology* 50:3, 285-291. [[CrossRef](#)]
2. Nigel Foreman , George Sandamas , David Newson . 2004. Distance Underestimation in Virtual Space Is Sensitive to Gender But Not Activity-Passivity or Mode of InteractionDistance Underestimation in Virtual Space Is Sensitive to Gender But Not Activity-Passivity or Mode of Interaction. *CyberPsychology Behavior* 7:4, 451-457. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
3. Stacey Miller , Denise Reid . 2003. Doing Play: Competency, Control, and ExpressionDoing Play: Competency, Control, and Expression. *CyberPsychology Behavior* 6:6, 623-632. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
4. Kathleen A. Flannery , Rena Walles . 2003. How Does Schema Theory Apply to Real versus Virtual Memories?How Does Schema Theory Apply to Real versus Virtual Memories?. *CyberPsychology Behavior* 6:2, 151-159. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
5. Nigel Foreman, Danaë Stanton, Paul Wilson, Hester Duffy. 2003. Spatial knowledge of a real school environment acquired from virtual or physical models by able-bodied children and children with physical disabilities. *Journal of Experimental Psychology: Applied* 9:2, 67-74. [[CrossRef](#)]
6. Ivan L. Beale . 2002. An Evaluation Model for Psychoeducational Interventions Using Interactive MultimediaAn Evaluation Model for Psychoeducational Interventions Using Interactive Multimedia. *CyberPsychology Behavior* 5:6, 565-580. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
7. Denise Reid . 2002. Virtual Reality and the Person-Environment ExperienceVirtual Reality and the Person-Environment Experience. *CyberPsychology Behavior* 5:6, 559-564. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
8. J.S. McGee , C. van der Zaag , J.G. Buckwalter , M. Thieboux , A. Van Rooyen , U. Neumann , D. Sisemore , A.A. Rizzo . 2000. Issues for the Assessment of Visuospatial Skills in Older Adults Using Virtual Environment TechnologyIssues for the Assessment of Visuospatial Skills in Older Adults Using Virtual Environment Technology. *CyberPsychology Behavior* 3:3, 469-482. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
9. A.A. Rizzo , J.G. Buckwalter , T. Bowerly , C. Van Der Zaag , L. Humphrey , U. Neumann , C. Chua , C. Kyriakakis , A. Van Rooyen , D. Sisemore . 2000. The Virtual Classroom: A Virtual Reality Environment for the Assessment and Rehabilitation of Attention DeficitsThe Virtual Classroom: A Virtual Reality Environment for the Assessment and Rehabilitation of Attention Deficits. *CyberPsychology Behavior* 3:3, 483-499. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]
10. P. LARSON, A.A. RIZZO, J.G. BUCKWALTER, A. VAN ROOYEN, K. KRATZ, U. NEUMANN, C. KESSELMAN, M. THIEBAUX, C. VAN DER ZAAG. 1999. Gender Issues in the Use of Virtual EnvironmentsGender Issues in the Use of Virtual Environments. *CyberPsychology Behavior* 2:2, 113-123. [[Abstract](#)] [[PDF](#)] [[PDF Plus](#)]