신경재활치료과학 제1권 제1호
Therapeutic Science for Neurorehabilitation
Vol. 1, No. 1, 2012.

Virtual Reality in Cognitive Rehabilitation

Park, Inn-Jee[*], O.D., Park, Heung-Seok[**], M.S., O.T., Kim, Tae-Hoon[***], M.P.H., O.T.

[*]Dept. of Opthalmic Optics, Kaya University

[**]Dept. of Rehabilitation Medicine, Samsung Medical Center

[***]Dept. of Occupational Therapy, Kaya University

Abstract

Introduction : This study reviews the main areas of cognitive rehabilitation including executive dysfunction, memory dysfunction, perceptual dysfunction, attention deficit, and dysfunctions in activities of daily living in order to apply to the adaptation of occupational therapy.

Body : Cognition programs based on the virtual reality are being used not only to evaluate but to train the overall components of human' s cognition. Because the cognitive program is concentrating on the real environment, it is known to bring a remarkable transitional effect to the actual environment, compared to the basic computer-based evaluation and training. Applying virtual reality to the rehabilitation program can develop and advance the high technology and can result in a major effect on the innovative treatment technology.

Conclusions : In this process, virtual reality is expected to be researched more in the near future. Particularly in the cognitive realm, it is imperative for researchers to pay attention to the improved transitional effect of the virtual reality toward the actual environment, rather than the already existing method of evaluations. Therefore, application of the virtual reality for the cognitive training should be researched for various types of subjects in the diverse aspects of congnitive function. Application of the virtual reality in the cognitive function has its unlimited potential, thus the rehabilitation program integrated with not only evaluation but training and education is expected extensively in the future.

Key words : Cognition, Rehabilitation, Virtual reality

Ⅰ. Introduction

Virtual Reality has been discussed to have a great potential in explaining the concepts of impairment, disability, and handicap in the context of WHO model (Rose, Attree, & Johnson, 1996).

교신저자 : 김태훈 (ot@kaya.ac.kr)
|| 접수일: 2012. 6. 10 ||심사일: 2012. 6. 17
|| 게재승인일: 2012. 6. 30

Brain damage decreases the ability for humans to reciprocate with the physical environment, hence leads to environment impoverishment according to Grealy (Grealy, Johnson, & Rushton, 1999). Virtual Reality focuses on the individual patient, provides proper opportunities and enables to interact with the environment directly through the HMD (Head Mounted Display) method (Tanaka, Ifukube, Sugihara, & Izumi, 2010).

The benefit of utilizing virtual reality in the area of cognitive rehabilitation is to practice and train situations that can occur in the real life as well as in the imaginary circumstances (Renison, Ponsford, Testa, Richardson, & Brownfield, 2012). Besides, the virtual reality has a feed-back-like pattern and quality to easily control senses, the level of difficulty, and requisites to generate a reaction depending on the user's degree of damage (Griffin et al., 2011). Unlike many traditional evaluation and training, the virtual reality can provide detailed measurement of the performance and accurate revival on user's task performance (Kim, Chun, Kim, & Park, 2011).

This study reviews the main areas of cognitive rehabilitation including executive dysfunction, memory dysfunction, perceptual dysfunction, attention deficit, and dysfunctions in activities of daily living in order to apply to the adaptation of occupational therapy.

Ⅱ. Body

1. Virtual Reality in Executive Dysfunction

The term, executive dysfunction, explains the existence of damage to prioritize the order of behaviors, which includes planning, strategy development, and mental flexibility (Shallice, 1991). Pugnetti et al. (1995) used the immersive virtual reality system to create a virtual reality to evaluate a test which is equivalent to Wisconsin Card Classification Test. This system contains the effective strategy to find the exit in the fastest time in a virtual building. Users of the system can move freely to the direction they choose, by using a joystick, and can open the doors when their virtual key contacts the door knob. Virtual environment is composed of 32 different types of rooms and each door is connected to the hallway which is adjacent to another room, and the last door is connected to the exit. The clue to find the exit door can be obtained via the entrance door and vice versa, the clue to the entrance door can be applied to the exit door.

Morris et al. (2002) used the method of "selecting furniture for removing" in the environment of bungalow to evaluate the strategy formation and rule breaking. 35 patients who have damage to the frontal lobe of their brain and a control group whose age and IQ correspond to the comparison group participated in this research. All participants were allowed to move around/transfer themselves around the bungalow and participate in this experiment; however, patients with frontal lobe damage have shown to use an ineffective strategy to find the exit door. Compared to the control group, the patients showed the rule breaking in this bungalow environment. This study suggested the usefulness of virtual reality as a tool to evaluate human's ecological executive function.

2. Virtual Reality in Memory Dysfunction

Andrews et al. (1995) performed a research to evaluate the memory function. This study compared incidental memory regarding the objects on the computer screen in five situations. The situations include 1) four rooms of virtual environments, 2) four fixed screens without any background, 3) four fixed screens and a cursor that a participant has to move, 4) four fixed pictures in a virtual space, and 5) four fixed pictures in a virtual room and a cursor that a participant has to move. The pattern recognition was at the lowest when the participant hits an object in a virtual environment. Researchers concluded participants became confused when they reciprocated with the virtual environment, and their incidental memory was easily influenced by their distraction. Also, researchers pointed out that interactive condition is expressed better than patients' real life memory, as real life does not occur in the form of consecutive fixed computer screens.

Mathias et al. (2003) had patients with traumatic brain damage to perform a task on the memory function by applying the HMD office scenario. In this scenario, patients are subject to remember objects located near the office after exploring it in their fixed sitting position. The task could actually be applied to the residual visual memory function unless limitation exists to the attention capacity.

Brooks, Attree, Rose, Clifford, & Leadbetter. (1999a) performed two different experiments regarding objects and spatial memory; one was to investigate spatial memory difference between the active participants and passive participants and the other was in regards to patients' object memory and memory of the objects' location. The virtual circumstance consisted of four rooms adjacent to each other and each room had some virtual objects. Two groups were able to see the same scene on their computer screen. Active participants had to explore the virtual rooms by using the joystick. On the other hand, passive participants are not allowed to control their behaviors in the study. The active participants remembered the arrangement of the virtual environment better than the passive participants. On the contrary, no difference was found in the active and passive participants regarding object memory and the location of the objects. The researchers explained the factor influencing the active participants' improved performance in the memory of spatial arrangement was their ability of actual movement through the rooms. The authors summarized that the active participants encoded the spatial placement of the virtual environment into their brain, hence demonstrated the enhanced ability on their recollection.

Brooks et al. (1999b) performed a study in the patients who have amnesia in order to find a way around the hospital by using a PC virtual environment. Participants were hospitalized for two months before the training session, however, still were not able to find directions around the hospital. They could not find 10 simple directions where they regularly navigated through before this training session. Furthermore, out of

10 directions, two roads were trained via the virtual reality and evaluation was done on all 10 roads by the blindfolded examiners. Three weeks later, participants were able to find the two trained directions, but not the remaining 8. Then, another training session was done on one of the remaining eight roads in the virtual reality and another session was performed on the actual road around the hospital. Two weeks later, the participants were able to find the direction trained in the virtual reality besides the 2 roads that were trained in the past. However, they were not able to find the direction to the hospital learned on the actual road.

3. Virtual Reality in Perceptual Dysfunction

Three perceptual functions exist in the premise of human's independent life: spatial relation and disorientation, visualization, and kinesthetic imagery (ability to decide one's spatial location of the objects in relation to the physical location) (Michael, Guilford, Fruchter, & Zimmerman, 1957). Virtual environment skills can develop, express, and control dynamic three-dimensional objects as well as the environment, in a consistent pattern. In addition, the virtual environmental skills have the unique value to target spatial ability because it is possible to delicately measure the stimuli and human's interactive performance (Rizzo, Buckwalter, & Van der Zaag, 2002).

A number of researches have been using a screen-based virtual environment to evaluate and train spatial ability (Rizzo, Buckwalter, & Van der Zaag, 2002). For instance, there is a relationship between the ability of place learning in the virtual environment and the matter of finding directions for patients with traumatic brain injury (Skelton, Bukach, Laurance, Thomas, & Jacobs, 2000). Another study has used the immersive audio method to provide an auditory clue and supplement the environmental information for people who have visual impairment (Berka & Slavik, 1998; Cooper & Taylor, 1998).

In a research using this technology to develop computer games for children who are visually impaired, children can actually find directions by utilizing an auditory clue and actually reciprocating with the virtual environment (Lumbreras & Sánchez, 2000).

4. Virtual Reality in Attention Dysfunction

Problems regarding concentration are common in children with ADHD (Attention Deficit Hyperactivity Disorder). In addition, it is referred not only as the major obstacle after traumatic brain injury occurred but also as the common symptoms in dementia (Sohlberg & Mateer, 1987).

Cho et al. (2002) performed two different types of cognition training to twenty six teenagers who committed crime and were in the juvenile detention center. All of the participants had a hard time to study and they were inattentive, impulsive, hyperactive and distracted. Even though they were not diagnosed as ADHD, 30 percent of them had symptoms of ADHD. The participants were divided into three groups randomly, such as control group of 9 participants, virtual reality group of 8 participants and non-virtual reality group of 9 participants. The virtual and non-virtual reality groups were trained 8 times for 2 weeks and each training lasted for 20 minutes. However, the control group did not get any special treatment. The task of cognitive training by using the virtual reality was comparison training of virtual reality and continuous attention training of virtual reality. The task of comparison training was to strengthen focused attention and selective attention of the participants. It was performed by showing the cylinder and quadrangular prism to the participants and let them choose if those subjects were the same or different. Sustaining task was to improve the sustained attention of the participants. The task was experimented by using alphabet number on the desk and let the participants to push the button when the number zero shows up after certain number except for number 8.

5. Virtual Reality in Activities of Daily Living

Driving is one of the most challenging handicaps which are seen in patients who have brain injury. Clinicians generally provide a task to determine if patients with brain injury can drive or not although their decisions are inevitably subjective, and each clinician can have a different judgment and standard. Liu, Miyazaki and Watson (1999) experimented a PC-based simulation-driving device composed of HMD, wheels, breaks, accelerators on 17 patients with traumatic brain injury. The researchers also had 17 people with the corresponding demographics including the age, sex, and intelligence level as a control group. The performance measurement included speed, steering, putting the break as well as changing lanes. In this study, the control group performed better than the comparison group on most of the criteria. The driving simulation training can provide an opportunity for patients with brain damage to practice in various environments if they are driving for the first time after their brain damage The training can motivate a number of patients to improve their driving skills, and relieve the boredom at the rehabilitation center because of the significance of being capable to drive.

Another concept, street crossing is a skill which facilitates independence in daily living and also can be practiced at the rehab center safely. McComas, MacKey and Pivak (2002) evaluated 95 students at one school from suburb and at another school from the inner city, in a virtual street crossing circumstance. Students from the suburban school demonstrated a smooth transition to their real life; however, the students from the inner city did not show any transition to their life in their street crossing skill. On another experiment, Strickland, Marcus, Mesibov and Hogan (1996) implemented a street crossing method on two children with schizophrenia by using the HMD method at their virtual/imaginary environment. Both children adapted well to the HMD method, were able to select objects, and their eyes moved along with the moving cars. The street crossing was suggested to patients with unilateral neglect, and the patients performed better at the virtual reality than the actual street crossing, compared to the computerized visual scanning training according to Katz et al. (2005).

On another experiment, Mowafy and Pollack (1995) designed a training session for students with learning disability to travel through the HMD–based virtual environment and one of the settings was the virtual bus ride. The virtual trip started from a bus stop near the participant's house and ends at their workplace, which requires an ability to know how to transfer buses. The participants and their teachers enjoyed the virtual bus trip, and the students were able to learn how to ride buses because they could control their speed and content in the virtual learning setting.

Another research reviewed two other studies regarding evaluation and arrangement of virtual city design on a user group composed of 15 patients with learning disability and facilitator (Brown, Kerr, & Bayon, 1998). The user group suggested what they desired to build in the virtual city, what they wanted to learn, and the methods that needed to be designed. The virtual city was consisted of houses, grocery stores, coffee shops, and public transportations. The measurement of this study focused on the efficacy of the virtual environment and also examined the participants' learning skills according to Cobb, Neale and Reynolds (1998). The virtual town provided patients with learning disability an opportunity to approach to the learning environment smoothly/easily and motivate their learning desire.

Furthermore, functional activities including cooking and food–preparing in the independent daily living was trained in the virtual environment. For instance, Christiansen et al. (1998) selected 30 patients with traumatic brain injury. The researchers observed and evaluated the patients preparing soup from a canned soup at the virtual kitchen by using the HMD method, which requires 30 small steps. Additionally, a screen–based virtual kitchen was used for 24 students who have a learning disability to prepare fish, meat, vegetables, and fruits in a virtual kitchen setting. The purpose of this study was to evaluate the process of preparation of food/cooking, awareness of risks, and a fire drill at the kitchen. (Brooks, Rose, Attree, & Elliot–Square, 2002). The virtual training has shown to be as effective as the real–life training and even more efficient than learning from the textbooks.

Ⅲ. Conclusion

Cognition programs based on the virtual reality are being used not only to evaluate but to train the overall components of human's cognition. Because the cognitive program is concentrating on the real environment, it is known to bring a remarkable transitions effect to the real/actual environment, compared to the basic computer–based evaluation and training. Applying virtual reality to the rehabilitation program can develop and advance the high technology and can result in a major effect on the innovative treatment technology. In this process, virtual reality is expected to be researched more in the near future. Particularly in the cognitive realm, it is imperative for researchers to pay attention to the improved transitional effect of the virtual reality toward the actual environment, rather than the already existing method of evaluations. Therefore, application of the virtual reality for the cognitive training should be researched for various types of subjects in the diverse aspects of cognition function. Application of the virtual reality in the cognitive function has its unlimited potential, thus the rehabilitation program integrated with not only evaluation but training and education is expected extensively in the future.

참고문헌

Andrews, T., Rose, F., Leadbetter, A., Attree, E., & Painter, J. (1995). The use of virtual reality in the assessment of cognitive ability. In I. P. Porrero, & R. P. Bellacasa (Eds.), *Proceedings of the 2nd TIDE Congress* (pp. 276-279). Amsterdam: IOS Press.

Berka, R., & Slavik, P. (1998). Virtual reality for blind users. In P. Sharkey, D. Rose, & J. I. Lindstrom, *Proceedings of the 2nd European Conference on Disability, Virtual Reality & Associated Technologies* (pp. 89-98). Sweden: Skovde.

Brooks, B. M., Attree, E. A., Rose, F. D., Clifford, B. R., & Leadbetter, A. G. (1999a). The specificity of memory enhancement during interaction with a virtual environment. *Memory*, 7, 65-78.

Brooks, B. M., McNeil, J. E., Rose, F. D., Greenwood, R. J., Attree, E. A., & Leadbetter, A. G. (1999b). Route learning in a case of amnesia: a preliminary investigation into the efficacy of training in a virtual environment. *Neuropsychological Rehabilitation*, 9, 63-76.

Brooks, B. M., Rose, F. D., Attree, E. A., & Elliot-Square, A. (2002). An evaluation of the efficacy of training people with learning disabilities in a virtual environment. *Disability and Rehabilitation, 24*(11), 622-626.

Brooks, B. M., Rose, F. D., Potter, J., Jayawardena, S., & Morling, A. (2004). Assessing stroke patients' prospective memory using virtual reality. *Brain Injury, 18*(4), 391-401.

Brown, D. J., Kerr, S. J., & Bayon, V. (1998). The development of the Virtual City: A user-centered approach. In P. Sharkey, D. Rose, & J. I. Lindström(eds.), *Proceedings of the 2nd European Conference on Disability, Virtual Reality & Associated Technologies* (pp. 11-15). Sweden: Skovde.

Cho, B. H., Ku, J. H., Jang, D. P., Kim, S. B., Lee, Y. H., Kim, I. Y., et al. (2002). The effect of virtual reality cognitive training for attention enhancement. *Cyber Psychology and Behavior, 5*(2), 129-137.

Christiansen, C., Abreu, B., Ottenbacher, K., Huffman, K., Masel, B., & Culpepper, R. (1998). Task performance in virtual environments used for cognitive rehabilitation after traumatic brain injury. *Archives of Physical Medicine and Rehabilitation, 79*(8), 888-892.

Cobb, S. V. G., Neale, H. R., & Reynold, H. (1998). Evaluation of virtual learning environments. In P. Sharkey, D. Rose, & J. I. Lindström (eds.), *Proceedings of the 2nd European Conference on Disability, Virtual Reality & Associated Technologies*(pp. 17-23), Sweden: Skovde.

Grealy, M. A., Johnson, D. A., & Rushton, S. K. (1999). Improving cognitive function after brain injury: The use of exercise and virtual reality. *Archives of Physical Medicine and Rehabilitation, 80*(6), 661-667.

Griffin, H. J., Greenlaw, R., Limousin, P., Bhatia, K., Quinn, N. P., & Jahanshahi, M. (2011). The effect of real and virtual visual cues on walking in parkinson's disease. *Journal of Neurology, 258*(6), 991-1000.

Katz, N., Ring, H., Naveh, Y., Kizony, R., Feintuch, U., & Weiss, P. L. (2005). Interactive virtual environment training for safe street crossing of right hemi-sphere stroke patients with unilateral spatial neglect. *Disability and Rehabilitation, 27*(20), 1235-1243.

Kim, B. R., Chun, M. H., Kim, L. S., & Park, J. Y. (2011). Effect of virtual reality on cognition in stroke patients. *Annals of Rehabilitation Medicine, 35*(4), 450-459.

Levin, H. S., Eiseaberg, H. M., & Benton, A. L. (1991). Higher-order cognitive im-pairments and frontal lobe lesions in man. In T. Shallice, & P, Burgess. *Frontal lobe function and dysfunction,* (pp. 125-138). Oxford: Oxford University Press.

Lumbreras, M., & Sánchez, J. (2000). Usability and cognitive impact of the interaction with 3D virtual interactive acoustic envi-ronments by blind children. In P. Sharkey, A. Cesarani, L. Pugnetti et al. (eds.), *Proceedings of the 3rd International Conference on Disability, Virtual Reality and Associated Technologies*(pp. 129-136). Sardinia, Alghero: Springer Press

Liu, L., Miyazaki, M., & Watson, B. (1999). Norms and validity of the DriVR: A vir-tual reality driving assessment for per-sons with head injuries. *CyberPsychology and Behavior, 2*(1), 53-67.

Mathias, R. J., Schultheis, M. T., & Rizzo, A. A. (2003). Learning and memory in a virtual office environment. In G. Burdea, D. Thalmann, & J. A. Lewis (Eds.), *Proceedings of the 2nd International Workshop in Virtual Rehabilitation*(pp. 48-54). NJ, Piscataway: Rutgers University.

McComas, J., MacKay, M., & Pivak, J. (2002). Effectiveness of virtual reality for teach-ing pedestrian safety. *CyberPsychology and Behavior, 5*(1), 185-190.

Michael, W. B., Guilford, J. P., Fruchter, B., & Zimmerman, W. S. (1957). The Description of Spatial-Visualization Abilities. *Educational and Psychological Measurement, 17*(2), 185.

Morris, R. G., Kotitsa, M., Bramham, J., Brooks, B., & Rose, F. D. (2002a). Virtual reality investigation of strategy formation, rule breaking and prospective memory in patients with focal prefrontal neuro-surgical lesions. In: Sharkey, P., L▯nyi, C.S., & Standen, P. (eds.), *Proceedings of* *the 4th International Conference on Disability, Virtual Reality & Associated Technologies* (pp. 101-108). Veszprm, Hungary.

Mowafy, L., & Pollack, J. (1995). Train to travel ability. *Journal of the British Computer Society Disability Group, 15*(1), 18-20.

Pugnetti, L., Mendozzi, L., Motta, A., Cattaneo, A., Barbieri, E., & Brancotti, A. (1995). Evaluation and retraining of adults' cognitive impairments: Which role for virtual reality technology? *Computers in Biology and Medicine, 25*(2), 213-227.

Renison, B., Ponsford, J., Testa, R., Richardson, B., & Brownfield, K. (2012). The ecological and construct validity of a newly developed measure of executive function: The virtual library task. *Journal of Intenational Neuropsychological Society, 18*(3), 440-450.

Rizzo, A. A., Buckwalter, J. G., & Van der Zaag, M. C. (2002). Virtual environment application for neuropsychological assessment and rehabilitation. In K. Stanney (ed.), *Handbook of virtual environments*. Mahwah, NJ: Earlbaum.

Rose, F., Attree, E., & Johnson, D. (1996). Virtual reality: An assistive technology in neurological rehabilitation. *Current Opinion in Neurology, 9*(6), 461.

Skelton, R. W., Bukach, C. M., Laurance, H. E., Thomas, K. G., & Jacobs, J. W. (2000). Humans with traumatic brain injuries show place-learning deficits in computer-generated virtual space. *Journal of Clinical Experimental Neuropsychology, 22*(2), 157-175.

Sohlberg, M. M., & Mateer, C. A. (1987). Effectiveness of an attention-training program. *Journal of Clinical Experimental Neuropsychology, 9*(2), 117-130.

Strickland, D., Marcus, L. M., Mesibov, G. B., & Hogan, K. (1996). Brief report: Two case studies using virtual reality as a learning tool for autistic children. *Journal of Autism and Developmental Disorder, 26*(6), 651-659.

Tanaka, T., Ifukube, T., Sugihara, S., & Izumi, T. (2010). A case study of new assessment and training of unilateral spatial neglect in stroke patients: Effect of visual image transformation and visual stimulation by using a Head Mounted Display system (HMD). *Journal of Neuroengineering and Rehabilitation, 7,* 20.

국문초록

인지재활 영역에서 가상현실

박인지[*], 박흥석[**], 김태훈[***]
[*]가야대학교 안경광학과
[**]서울삼성병원 재활의학과
[***]가야대학교 작업치료학과

서론 : 본 연구는 인지재활의 주요영역인 실행 장애, 기억력 장애, 지각 장애, 주의력 장애, 일상생활활동 영역에서의 가상현실의 적용 사례를 문헌고찰 함으로써, 작업치료 적용을 위한 기초자료로 활용하고자 한다.

본론 : 가상현실을 바탕으로 한 인지프로그램은 평가 뿐 만이 아니라 전반적인 인지 요소의 훈련용으로 사용되어지고 있다. 가상현실을 이용한 인지 프로그램은 실제 환경에서의 평가이자 훈련이기에 기존 컴퓨터에 기초한 평가 및 훈련과 비교하여 실제 환경으로 전이효과가 큰 것으로 밝혀지고 있다. 가상현실의 재활 프로그램에 적용은 최신 기술의 발전과 더불어 보다 큰 발전을 가져올 것으로 예상되며, 이는 곧 혁신적인 치료 기술의 발전을 가져 올 수 있다. 이 과정에 가상현실은 미래에 보다 많이 연구되어질 것으로 예상되며, 특히 인지영역에서 가상현실은 기존의 평가들 보다 향상된 실제 환경으로의 전이효과에 주목할 필요가 있다.

결론 : 인지영역에서 가상현실의 적용은 무한한 잠재력을 가지고 있으며, 평가 뿐 만 아니라 훈련이 통합된 재활 프로그램으로 활용도가 광범위 할 것으로 기대된다.

주제어 : 가상현실, 인지, 재활