한국심리학회지: 건강
The Korean Journal of Health Psychology
2008. Vol. 13, No. 1, 267 - 283

Visuospatial Functioning and Navigation Learning by Patients with Mild Cognitive Impairment in a Virtual City†

Sumi Park.[1] Simon J. Graham[2, 3, 4]
Sandra E. Black.[5] Jang-Han Lee[1‡]
1 Clinical Neuro-Sychology Lab., Department of Psychology, Chung-Ang University, Seoul, Republic of Korea
2 Imaging Research, Sunnybrook & Women's College Health Science Centre, Toronto, ON, Canada
3 Department of Medical Biophysics, University of Toronto, ON, Canada
4 Rotman Research Institute, Baycrest Centre for Geriatric Care, Toronto, ON, Canada
5 Department of Medicine-Neurology, University of Toronto, ON, Canada

We studied the navigation ability and visual functioning of patients with MCI in Virtual Environments (VEs). Forty nineparticipants consisted of elderly adults with/without MCI. Neuropsychological tests (RCFT, BVRT, TMT, and Digit Span), the Groton Maze Learning Test (12 trials), and the VE navigation learning task (6 trials) were performed. As a result, there were significant group differences for the immediate-recall RCFT, the delayed-recall RCFT, and the BVRT, but not for the GMLT. For the VE task, there was a significant difference between the MCI and normal group, and no interactions between groups and trials were found. The VE task was correlated with the RCFT, the BVRT, and the GMLT. The RCFT and the BVRT combined accounted for 45% of VE performance. Thus, we concluded

† This work was supported by grants from the Canadian Foundation for Innovation, the Ontario Premier's Research Excellence Award, and the Ontario Research and Development Challenge Fund, and the Korea Research Foundation Grant funded by the Korea Government (MOEHRD) (KRF-2006-332-H00021). And, this research was partially supported by the Chung-Ang University Excellent Researcher Grant in 2007.
‡ Corresponding Author : Jang-Han Lee, Ph.D., Department of Psychology, Chung-Ang University, 221, Heukseok-dong, Dongjak-gu, Seoul 156-756, Korea, Tel: +82-2-820-5751, Fax: +82-2-816-5124, E-mail: clipsy@cau.ac.kr

that patients with MCI are inferior in VE navigation, and that visual retention/memory play a role in navigation abilities.

Keywords : Mild Cognitive Impairment (MCI), Navigation, Virtual Environments (VEs), Elderly adults

Mild Cognitive Impairment (MCI) is considered as a presage of dementia because it is a transitional stage between normal ageing and dementia (Petersen, Smith, Ivnik, Tangalos, Schaid, Thibodeau, Kokmen, Waring, & Kurland, 1995; Petersen, Smith, Waring,Ivnik, Kokmne, & Tangelos, 1997). However, this is a relatively new concept in the cognitive disease area and has led to controversy about how MCI can best be assessed and defined, because there is insufficient evidence to recommend specific diagnostic tests or cutoff scores that differentiate between normal individuals, patients with MCI and patients with dementia. The current criteria for diagnosing individuals with MCI are the presence of cognitive deficits with no dementia (Clinical Dementia Rating [CDR] of 0.5) (Morris, 1993)and the ability to perform the normal activities of daily living. There is considerable demand for empirical studies on the range and degree of decline in cognitive functioning in individuals with MCI, as well as knowledge about how to assess complex instrumental activities of daily life in patients with MCI. The behavioral symptoms of patients with MCI and whether these symptoms can be used to predict dementia also need to be explored.

Cognitive disorders can lead to deficits in navigation and wayfinding behavior in daily life, as this behavior requires complex cognitive processes. Perception, remembering, updating, orintegrating visual information and the rotational components of movement need to be accurately fulfilled to enable an individual to navigate (Gopal , Klatzky, & Smith, 1989; Mou, & McNamara, 2002; Riecke, van Veen, & Bülthoff, 2002). According to a study by Cammalleri, Gangitano, D'Amelio, Raieli, Raimondo, & Camarda(1996), 90% of patients with severe cognitive disorder were not able to find their way in familiar environments because of problems with visual memory, executive working memory, and visuospatial/attentional functioning.

Patients with MCI also have memory deficits or general cognitive deficits, including deficits in executive functioning and visuospatial functioning. Explicit memory is relevant to spatial, visual and working memory as well as learning (Schacter, & Tulving, 1994). Executive functioning organizes and coordinates cognitive skills and significantly influences the efficacy of memory and other cognitive processes. Executive functioning is responsible for goal-directed behavior and the integration of old and new visual information into navigation activities. Visuospatial functioning, which has a large influence on navigation, involves the cognitive processes of perception, comprehension, and interpretation of visual and spatial information (Morris, 1996). Ritchieand colleagues pointed out the importance of visuospatial functioning in discordance with the presenting criteria of MCI; that is, visuospatial and attentional impairments in patients with MCI have a great effect on a patient's ability to perform the activities of daily living (Ritchie, Artero, & Touchon, 2001). In line with this view, Kasai, Meguro, Hashimoto, Ishizaki, Yamadori, and Mori (2006) have shown that there are deficits in visual processes in patients with MCI. Their study, which involved participants who met the criteria of questionable dementia or MCI with a CDR of 0.5, showed that these participants did not maintain intact learning abilities for encoding and retrieving information from visual and short-term memory, whereas participants with a CDR of 0 did maintain intact learning abilities.

In summary, patients with MCI have deteriorations in memory, visuospatial and visual attentional functioning, and executive functioning, which may affect their wayfinding behavior. To our knowledge, no studies on patients with MCI have examined realistic navigation skills. We hypothesized that elderly patients with MCI have more difficulty learning navigation skills than normal elderly individuals. Additionally, we attempted to ascertain the relationship between spatial functions and navigation skills using several neuropsychological tests and the virtual city task.

To assess spatial memory and navigation learning ability, 2D navigation tasks have generally been carried out; however, these tasks do not represent realistic situations. The Virtual Environment (VE) task, which was developed by systematic and laboratory-based investigations of spatial navigation in humans, has been introduced to supplement the 2D task. VEs enable a given information space to be traversed in different ways by different individuals, using different routes and navigation tools. The VE task involves a viewer-centered perspective where participants perform cognitive functions similar to real-life situations. Nadolne and Stringer have shown that laboratory simulation of wayfinding is related to wayfinding in the real world (Nadolne, & Stringer, 2001). They first suggested that tasks that realistically simulate the spatial environment may have greater ecological validity than traditional psychometric measures. Second, they indicated the need for further validation of ecological simulation tasks. Consistent with these views, this study investigated the ecological validity of, and relationship between, a virtual navigation-learning task, several neuropsychological tests such as the Rey ComplexFigure Test and the Benton Visual Retention Task that measure visuospatial functioning, and a computerized table-top maze-learning test that measures spatial memory and learning in elderly patients with MCI and normal elderly individuals. MCI patients would show deterioration in performance on visuospatial-related neuropsychological tests which covariate with the VE task.

METHOD

Participants

Forty-nine participants with a mean age of 70.66 (7.55) years (range 58-84 years) were recruited from the Sunnybrook & Women's College Health Sciences Center (S&W), in Toronto, Canada. Twenty-two participants were recruited from the Cognitive Neurology Clinic at S&W and classified by the Clinical Dementia Rating (CDR = 0.5). All participants were paid US$50 for attending a 60-minute session. A standardized assessment and investigation protocol was used to rule out secondary causes of cognitive impairment.

There was no difference in the mean age between individuals with MCI (the MCI group) and normal individuals (the normal group), whereas there were significant differences in years of education, the Dementia Rating Scale (DRS) and mini-mental state examination

Table 1. Demographic data for the study participants

	MCI group (n=22)		Normal group (n=27)		
	M	*SD*	*M*	*SD*	*t*
Age	72.14	7.62	69.46	7.41	1.26
CDR	0.5	-	0	-	-
Years of education	13.64	3.96	16.65	3.51	-2.80*
DRS	135.95	5.67	140.27	3.14	-3.12*
MMSE	27.77	1.54	28.58	0.95	-2.13*

*p<0.05

(MMSE) between the MCI group and the normal group (Table 1). Seventeen participants were lost from the study as a result of a computer malfunction, or nausea or dizziness induced by exposure to the VE and being tested using a head-mounted display. The data for these participants were excluded in the subsequent analysis. The final sample size for the navigation trials in the VE was 32 (the MCI group = 9, the normal group = 23). We additionally analyzed years of education, DRS scores, and MMSE scores of final participants andothers who were missed. As a result, participants missed significantly differed from final participants only for the years of education, $t(32) = -2.087$, $p < 0.05$.

Measures

Neuropsychological tests. The neuropsychological measures included in the study were: copy, immediate- and delayed-recall as per the Rey Complex Figure Test (RCFT) (Spreen, & Strauss, 1998); the Benton Visual Retention Test (BVRT) (Benton, 1963) the Trail Making Test (A and B) (Reitan, 1958); Digit Span subtests (forwards and backwards) from the Wechsler Adult Intelligence Scale-Revised

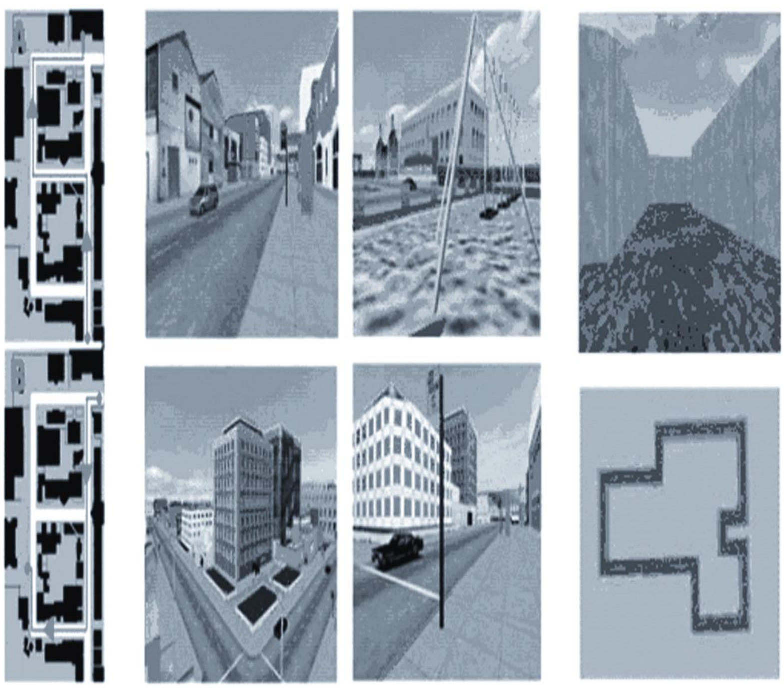

Figure 1. The map of a virtual city used in the navigation-learning task

(Wechsler, 1981); and attention, initiation, construction, conceptualization, and memory in the CDR scale; and the MMSE.

Groton Maze Learning Test. The Groton Maze Learning Test (GMLT) is based on the original hidden-maze learning test developed by Milner(1969). The goal of this test is for a participant to learn how to navigate from a tabletop perspective through a hidden maze and capture a target (flag). The test is a computer-based neuropsychological measure of immediate- and short-term retention of visuospatial information. The participant presses on a touch-screen to reveal the maze under a matrix of tiles. There is a timed component for a chase test in which the participant chases a target on a 10 10 grid of tiles on the computer.

In the pretest practice sessions, a 30s 10 10 form of the timed chase test was used, comprising five learning trials with an intertrial interval of 5 min followed by delayed-recall and reverse trials (navigation of the reverse path). The same components were repeated in the test sessions with 10 learning trials and an intertrial interval of 10 min. The 10 10 chase test included 20 matched alternate forms (28 steps and 11 turns). The presentation order of the forms was randomized for each participant. The "index"scores for the GMLT were obtained for the individual learning trials on the screening and baseline exams by calculating the correct moves per second for each trial: GMLT index = (total number of movements - total number of errors)/time required to complete the trial.

The VE for the navigation-learning task. The virtual city (Figure. 1, adapted from Mraz, Hong, Quintin, Staines, McIlroy, Zakzanis, & Graham (2003)) was viewed by participants on a projection screen with a 6-DOF tracker and a joystick to provide a real-time development environment with a graphical user interface on a PC. This allowed rapid object-oriented design and implementation through built-in support for many peripheral devices and the application of industry standards such as *OpenGL*, *C* and *Visual Basic* (*WorldUp Release 5.0* Engineering Animation, Inc.).

Firstly, participants were trained to move in the virtual space by traversing an elementary maze that consisted of 12 turns over a fixed distance. Subsequently, participants were instructed to navigate as accurately as possible in the virtual city without bumping into objects, to pay attention to "the rules of the road"by staying on the sidewalk, and to pay attention to where various objects in the city were located with respect to each other. A set of three learning trials was performed for one path (Path A), followed by one learning trial for a second path (Path B). Each learning trial consisted of two components: passive viewing of the computer as the appropriate route was shown by video playback, followed by the participant's active navigation to attempt to follow the same route using the joystick. The learning trial for Path B served to indicate the presence of proactive interference when eliciting prompt and free recall of Path A. Each trial was followed by a short-delayed (5 min) and a long-delayed (20 min) recall trial, during which Path A was navigated from memory.

The time required, the distance traveled, and the number of navigation errors (i.e., wrong turns [WTs]) were tabulated for each trial. The "VE index"score was obtained by calculating the mean distance navigated per second with correct movement: VE-index = (Distance-a number of WTs)/time; a = mean distance per one WT).

Procedures

After informed consent (based on approval by the S&W Research Ethics Board) and demographic data had been obtained, participants were tested individually in the following order: (1) the CDR, the DRS, and the MMSE; (2) neuropsychological tests (the RCFT, the Benton Visual Retention Test, the Trail Making Test, and Digit Span subtests) (3) the GMLT (Trials 110, delayed-recall and reverse trials); (4) the VE navigation-learning task (Path A: Trials 13; Path B; short-delayed trial and long-delayed trial); and (5) the Simulator Sickness Questionnaire (SSQ) (Kennedy, Lane, Berbaum, & Lilienthal, 1993) for measuring cyber sickness and side effects of computer-based tasks. Subsequent statistical analysis of the data, reported below, was performed using standard software (SPSS 13.0 version for Windows).

RESULT

Differences between the MCI group and norma l group for neuropsychological tests

The MANCOVA was used to assess differences between the MCI group and the normal group for traditional neuropsychological tests. Years of education were compute as a covariate. Table 2 provides the mean and standard deviation of the traditional neuropsychological tests for each group. For a immediate-recall RCFT, delayed-recall RCFT, and BVRT, there were significant group effects, $F(1, 46) = 10.91$, $p < 0.01$, $F(1, 46) = 4.85$, $p < 0.05$, $F(1, 46) = 4.31$, $p < 0.05$, respectively. These results indicated that the MCI group revealed a lower performance score for the immediate-recall RCFT, delayed-recall RCFT, and BVRT than did the normal group. No significant differences were observed between two groups for the other testsand no significant main effect of omnibus tests.

To assess differences between the two groups for performances in the GMLT excluding years of education as a covariate, we conducted two-way (2 12) repeated measures ANCOVAs. The groups (MCI or normal) were computed as the between-subject factor and the trials (Trials 110, delayed-recall and reversed trials) were computed as the within-subject factor. For the GMLT, there were no significant effects of the groups, trials, or the significant interaction between groupsand trials, $p > .0.5$.Figure 2 show performances of two groups in the GMLT.

Table 2. Means and standard deviations for the MCI group and the normal group

	MCI group			Normal group			
	M	*SD*		*M*	*SD*		*F*
RCFT copy	32.69	4.43		34.27	2.14		.984
RCFT immediate recall	11.21	6.24		18.96	5.89		10.912**
RCFT delayed recall	6.34	18.42		18.50	5.31		4.854*
BVRT	22.73	4.39		24.12	4.23		4.322*
Trails making test A	41.19	11.41		38.85	2.43		.448
Trails making test B	117.38	58.4		98.69	29.43		2.933
Digit span subtest forward	8.86	1.98		8.96	1.69		1.270
Digit span subtest backward	7 .14	2.10		7.12	2.22		2.612

Note. RCFT = Rey Complex Figure Test; BVRT = Benton Visual Retention Test

*p<0.05

**p<0.01

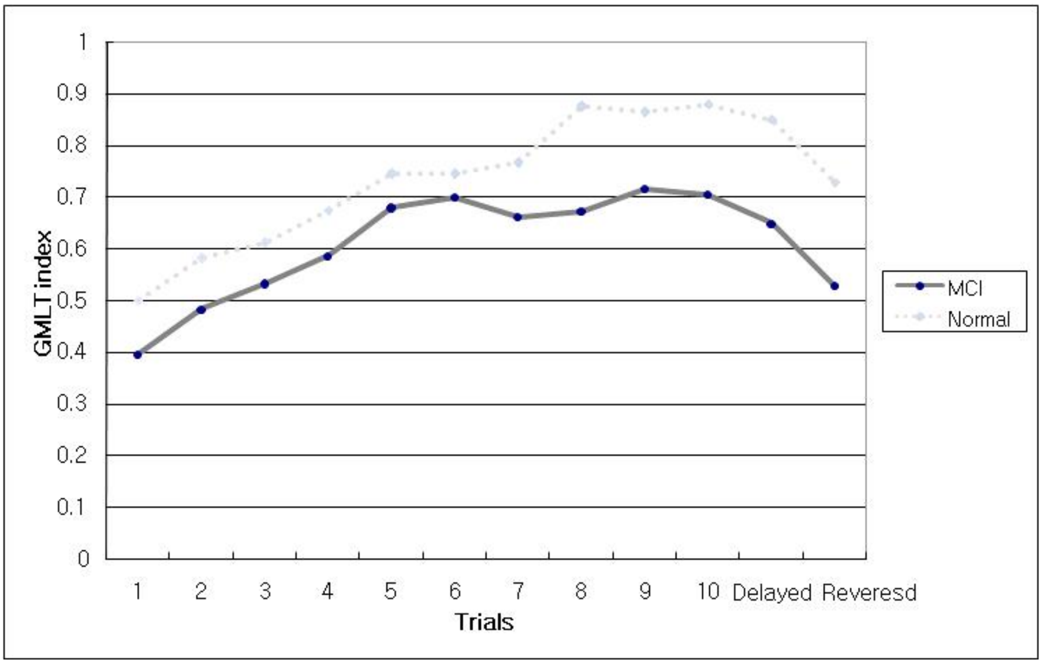

Figure 2.Comparison of the GMLT performance index for the MCI group and the normal group

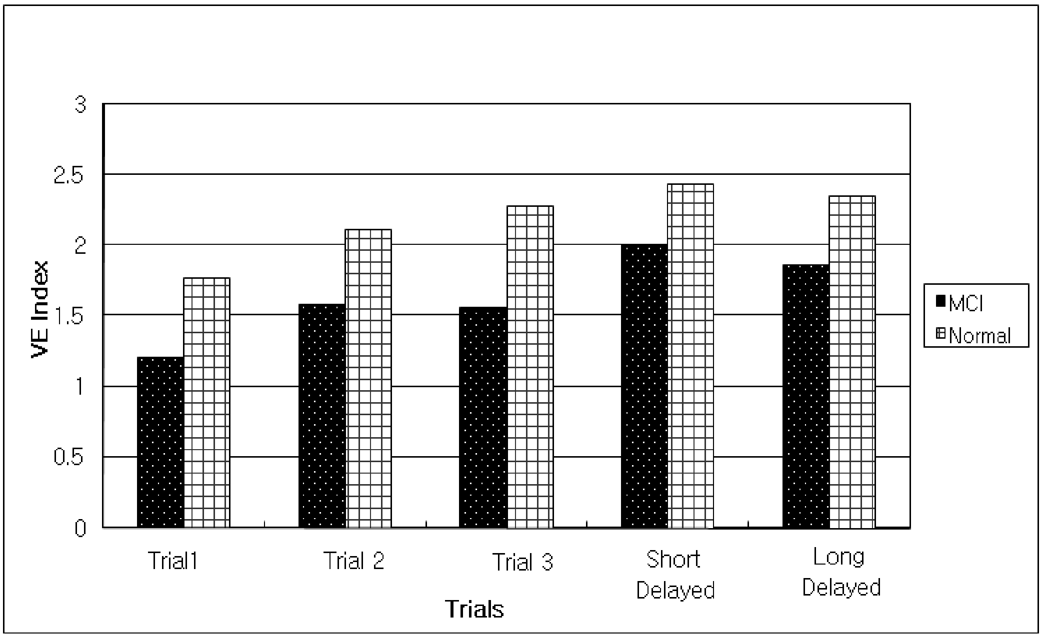

Figure 3. Comparison of the VE navigation index for the MCI group and the normal group

Differences between the MCI group and normal group for the VE task

Two-way (2×5) repeated measures ANCOVAs were computed to assess differences between the MCI and normal groups in VE performances excluding years of education as a covariate. The groups (MCI or normal) were performed as the between-subject factor and the trials (Path A: Trials 13; short-delayed trial; and long-delayed trial) were performed as the within-subject factor. Path B was out of the analysis since it seemed too demanding for the normal group as much as for the MCI group

Table 3. Correlations between VE (Trial 1) and neuropsychological tests

	VE task
RCFT copy	.16
RCFT immediate recall	.50**
RCFT delayed recall	.46**
BVRT	.56**
Trails making test A	.01
Trails making test B	-.31
Digit span subtest forward	.32
Digit span subtest backward	.26

Note. RCFT = Rey Complex Figure Test; BVRT = Benton Visual Retention Test

**p<0.01

Table 4. Correlations between the VE index and GMLT index

		VE Task					
		Trial 1	Trial 2	Trial 3	Path B	Short delayed	Long delayed
GMLT	Trial 1	.16	.27	.55**	.50*	.48*	.38
	Trial 2	.39*	.33	.56**	.54*	.62**	.65**
	Trial 3	.44*	.44*	.58**	.54*	.66**	.74**
	Trial 4	.49**	.40*	.54**	.52*	.52*	.58*
	Trial 5	.57**	.45*	.56**	.54*	.60**	.66**
	Trial 6	.54**	.45*	.55**	.51*	.51*	.61**
	Trial 7	.50**	.43*	.55**	.50*	.56*	.59*
	Trial 8	.51**	.47**	.54**	.45*	.54*	.60**
	Trial 9	.54**	.50**	.57**	.45*	.60**	.65**
	Trial 10	.39*	.33	.33	.32	.39	.45
	Delayed	.56**	.51**	.47**	.35	.60**	.69**
	Reversed	.55**	.50**	.57**	.17	.50*	.60**

* $p < 0.05$

** $p < 0.01$

We first analyzed 2X6 repeated ANCOVAs on the VE task including Path B. As a result, weacquired the significant interaction between groups and trials, $F(1, 18) = 9.68$, $p < 0.05$, and no significant effectsof both the groups and trials. However, these results were possibly derived from Path B which had similar means for both MCI and normal groups unlike to other trials, and could not represent general effects of other trials (means for Path B: the MCI group : $M = 1.45$, $SD = 0.42$, the normal group : $M = 1.56$, $SD = 0.36$). We thus excluded Path B for further analyses. As a result, a significant effect was found in the groups, between-subject factor, $F(1,18) = 8.83$, $p < 0.01$. This result demonstratesthat the ability of the MCI group to perform VE tasks was inferior to the ability of the normal group (Figure 3). Theinteraction between trials and groups and the effect of the trials were not significant for the VE task.

Relationships between the VE task and neuro psychological tests

Pearson's correlation analysis was conducted to investigate the relationships between the VE tasks and neuropsychological tests which consisted of traditional neuropsychological tests and the GMLT. Among VE tasks, only Trial 1 was computed to exclude the learning effect of the VE task and include the pure effect of the VE task on the MCI group and the normal group. Trial 1 of the VE task significantly correlated with the immediate-recall RCFT, the

Table 5. Linear regression analysis using visual memory tests to predict VE navigation performance

	Beta	*t*
RCFT immediate	.444	1.309
RCFR delay	-.097	-.284
BVRT	.479	3.179*

Note. RCFT = Rey Complex Figure Test; BVRT = Benton Visual Retention Test

* < 0.05

delayed-recall RCFT, and the BVRT, $r = 0.50$, $p < 0.05$, $r = 0.46$, $p < 0.05$, and $r = 0.56$, $p < 0.05$, respectively (Table 3). Significant correlations between the GMLT and the VE task were found in most areas, as shown in Table 4. All correlations and regression data below are of both MCI and normal group. We had further analyzed correlations between the VE task and neuropsychological tests of only normal participants, since correlation data could result from enhanced variable by significantly low visouspatial functioning of patients with MCI. Then, we found barely changed data from both MCI and normal groups. Immediate- recall RCFT and BVRT performance of normal group were correlated with the first trial of the VE task, $p < 0.01$, and delayed recall RCFT was marginally correlated with the first trial of the VE task, $p = 0.67$. Furthermore, these three omnibustests performed by normal group accounted for 66.4% of the index of VE task, $p < 0.05$. Thus, we can suggest that our results of correlations show ecological validity of the VE task.

Results for the immediate-recall RCFT, delayed-recall RCFT, and BVRT were entered into a linear regression analysis to investigate the contribution of each test to VE performance for the MCI group; these tests were selected based on their significant correlations with the VE tasks. The GMLT was not included in the regression analysis because of the many trials and learning effects. As a result, three omnibus tests accounted for 45% of the index of the VE task, $F(3,45) = 7.44$, $p < 0.05$. However, only the BVRT significantly contributed to the VE index (Table 5).

DISCUSSION

In this study, we examined the navigation ability of elderly adults with MCI using the VE taskwhich consists of 3D realistic environments. To explore relationships between neuropsychological functioning and the navigation ability, we conducted traditional neuropsychological tests and the GMLT.

Our results demonstrated that the MCI group was less capable of navigating in VEs than the normal group. The MCIgroup also showed inferior functioning for the immediate-recall RCFT, delayed-recall RCFT, and BVRT, but not for the GMLT. Our results secondly showed that the VE task was correlated with the immediate-recall RCFT, delayed-recall RCFT, BVRT, and GMLT confirming the validity of the VE task. Interestingly, although the VR task and GMLT had nonidentical results, there were considerable correlation between the VE task and GMLT. These results can be derived from the sensitivity of the VE task because the VE task consisted of 3D realistic navigation environments supplementing limitations of exiting 2D tasks such as the GMLT. In line with this view, Arthur and colleagues argued that the spatial knowledge aquired using VEs transfers well to subsequent navigation in the real world (Arther, Hancock, & Chrysler, 1997). Thus, individuals with MCI may have difficulties with wayfinding behavior in real life, which is an important part of daily living.

We computed the RCFT for visual memory and the BVRT for visual retention to regression analysis and these tests accounted for 45% of the VE performance. It suggeststhat visual retention and memory play a role in navigation ability. Although the GMLT, which represents visual executive functioning, was not included in the regression analysis because of the many trials and learning effects, it can be considered to predict VE tasks because there was a considerable correlation between the GMLT and the VE task. The GMLT, RCFT, and BVRT represent common ground in visual functions used in navigation.

In this study, retention and processing of body movements, which can influence wayfinding behavior, were not considered because the study focused on cognitive functioning. Another limitation of this study was the lack of statistical comparisons of the differences between the MCI group and normal group in the VE task because of the small sample size that resulted from computer malfunction and simulation sickness (the sample size for the final trial was 6for the MCI group and 12 for the normal group). Therefore, further empirical investigations with larger sample sizes are required to determine cognitive deterioration in individuals with MCI. Regarding to missing participants, there is another explanation that elderly adults confront more difficulties than younger adults in learning and remembering routes through new environments (Kirasic, Allen, & Haggerty , 1992; Newman, & Kaszniak, 2000; and Moffat, Zonderman, & Resnick, 2001). In this study, the VE task, especially Path B, seemed difficult to perform for the normal group as well as the MCI group, resulting in undifferentiated scores in this task for the two groups ($p > 0.05$). To cope with these problems, computer interface programs that are easier and simpler to manipulate for all ages should be developed. Yet, this VE task is future oriented and will be more useful in the future when the present generation, who are skillful at interacting with computer interfaces, are older.

Moreover, we found that the MCIgroup had shorter years of education than the normal group and these years of education affect participating tasks, thus many MCI patients were missed in our study. However, this limitation can represent the real problem of individuals with less education going to cognitive disease. Evans, Hebert, Beckett, Scherr, Albert, Chown, Pilgrim, and Taylor (1997) support our data suggesting that fewer years of formal schooling predict risk of incident clinically diagnosed Alzheimer disease of older persons.

This study has attempted to extend the knowledge of MCI and begin to resolve the many controversies that exist in the clinical field about how MCI can best be assessed and defined. In conclusion, patients with MCI are inferior in VE navigation, and visual retention/memory play a role in navigation abilities. The future empirical studies would be conducted to clarify the diagnosis of MCI and prevent progression to severe cognitive disorder from MCI. This study also suggests that the VE task can contribute to the examination and training of individuals with cognitive deficits, including MCI in future studies.

REFERRENCE

Arthur, E. J., Hancock, P.A., & Chrysler, S. T. (1997). The perception of spatial layout in real and virtual worlds. *Ergonomics, 40*, 69-77.

Benton, A. L. (1963). *The Revised Visual Retention Test*. Iowa City: State University of Iowa.

Cammalleri, R., Gangitano, M., D'Amelio, M., Raieli, V., Raimondo, D., & Camarda, R. (1996). Transient topographical amnesia and cingulate cortex damage: a case report. *Neuropsychologia, 34*, 321-326.

Evans, D. A., Hebert, L. E., Beckett, L. A., Scherr, P.A., Albert, M.S., Chown, M. J., Pilgrim, D. M., & Taylor, J. O. (1997). Education and other measures of socioeconomic status and risk of incident Alzheimer disease in a defined population of older persons. *Archive of Neurology, 54* 1399-1405.

Gopal, S., Klatzky, R. L., & Smith, T. R. (1989). Navigator: A psychologically based model of environmental learning through navigation. *Journal of Environmental Psychology, 9*, 309331.

Kennedy, R., Lane, N., Berbaum, K., & Lilienthal, M. A. (1993). Simulator Sickness Questionnaire (SSQ): A new method for quantifying simulator sickness. *International Journal of Aviation Psychology 3(3)*, 203-220.

Kasai, M., Meguro, K., Hashimoto, R., Ishizaki, J., Yamadori, A., & Mori, E. (2006). Non-verbal learning is impaired in very mild Alzheimer's disease (CDR 0.5): Normative data from the learning version of the ReyOsterrieth Complex Figure Test. *Psychiatry and Clinical Neurosciences, 60*, 139-146

Kirasic, K. C., Allen, G. L., & Haggerty, D. (1992). Age-related differences in adults' macrospatial cognitive processes. *Experimental Aging Research, 18(1)*, 33-39.

Milner, B. (1969). Residual intellectual and memory deficits after head injury. In A. E. Walker, W. F. Caveness, & M. Critchley (Ed.), *The Late Effects of Head Injury* (pp.142-129). Springfield, IL: CC Thomas.

Mraz, R., Hong, J., Quintin, G., Staines, W. R., McIlroy, W. E., Zakzanis, K. K., & Graham, S. J. (2003). A platform for combining virtual reality experiments with functional magnetic resonance imaging. *CyberPsychology & Behavior, 6(4)*, 359-368.

Moffat, S. D., Zonderman, A. B., & Resnick, S. M. (2001). Age differences in spatial memory in a virtual environment navigation task. *Neurobiology of Aging, 22,* 787-796.

Morris, J. C. (1993). The Clinical Dementia Rating (CDR): Current version and scoring rules. *Neurology, 43,* 2412-2414.

Morris, R. G. (1996).Executive functions of the prefrontal cortex Discussion. *Philosophical Transactions of the Royal Society: Biological Sciences, 351,* 1346-1527.

Mou, W., & McNamara, T. P. (2002). Intrinsic frames of reference in spatial memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 162-170.

Nadolne, M. J. & Stringer, A. Y. (2001).Ecologic validity in neuropsychological assessment: prediction of wayfinding. *Journal of the International Neuropsychological Society, , 7* 675-682.

Newman, M., & Kaszniak, A. (2000). Spatial memory and aging: performance on a human analog of the Morris water maze. *Aging, Neuropsychology, and Cognition, 7(2)*86-93.

Petersen, R. C., Smith, G. E., Ivnik, R. J., Tangalos, E. G., Schaid, D. J., Thibodeau, S. N., Kokmen, E., Waring, S. C., & Kurland, L. T. (1995). Apolipoprotein E status as a predictor of the development of Alzheimer's disease in memory-impaired individuals. *Journal of the American Medical Association, 273*1274-1278.

Petersen, R. C., Smith, G. E., Waring, S. C., Ivnik, R. J., Kokmne, E., & Tangelos, E. G. (1997). Aging, memory, and mild cognitive impairment. *International Psychogeriatrics, 9(1),* 65-69.

Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills, 8,* 271-276.

Riecke, B. E., van Veen, H. A. H. C., & Bülthoff, H. H. (2002). Visual homing is possible without landmarks: A path integration study in virtual reality. *Presence: Teleoperators and Virtual Environments, 11,* 443-473.

Ritchie, K., Artero, S., & Touchon, J. (2001). Classification criteria for mild cognitive impairment: a population-based validation study. *Neurology, 56,* 37-42.

Schacter, D. L., & Tulving, E. (1994). What arethe memory systems of 1994? In D. L. Schacter & E. Tulving (Ed.), *Memory Systems* (pp.137). Cambridge, MA: MIT.

Spreen, O., & Strauss, E. A. (1998). *Compendium of Neuropsychological Tests* (2nd ed.). New York: Oxford University.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale-Revised Manual.* San Antonio, TX: The Psychological Corporation.

원고접수일: 2007년 10월 11일
수정원고접수일: 2008년 1월 14일
게재결정일: 2008년 1월 22일

한국심리학회지: 건강
The Korean Journal of Health Psychology
2008. Vol. 13, No. 1, 267 - 283

경도인지장애 환자의 가상환경 내 길찾기 능력 및 시공간 기능 연구

박 수 미　Simon J. Graham　Sandra E. Black　이 장 한
중앙대학교　University of Toronto　중앙대학교

본 연구는 가상환경(VE) 내 길찾기 과제를 통해 경도인지장애(MCI)환자들의 길찾기 능력을 측정하였고, 전통 신경심리검사의 수행을 통해 길찾기 능력을 구성하는 인지기능에 대해 조사하였다. 피험자는 모두 49명으로 정상노인집단 27명과 경도인지장애 환자집단 22명으로 구성되었다. 피험자는 간이정신집단검사를 수행한 후, Rey Complex Figure Test(RCFT), Benton Visual Retention(BVRT), Trail-Making Test(A형과 B형), 그리고 성인용 웩슬러 지능검사의 하위검사인 숫자외우기(바로/거꾸로)를 수행하였다. 이와 함께 2차원공간에서의 미로학습검사인 Groton Maze Learning Test(GMLT)(12회기)를 마친 후, VE 길찾기 과제(6회기)를 수행하였다. VE과제 점수에는 소요시간, 총 이동거리, 오류를 범한 횟수가 측정되었다. 그 결과, 신경심리검사에 대한 두 집단의 유의미한 차이가 RCFT와 BVRT에서 발견되었으며, GMLT에서는 집단과 회기의 유의미한 주 효과 및 상호작용이 나타나지 않았다. 반면 VE 과제에서는 집단간 유의미한 차이가 나타났으며, 회기와 집단간의 상호작용은 나타나지 않았다. 즉, MCI 집단의 길찾기 학습이 정상집단보다 느리게 이루어졌다. VE과제와 시공간 기능을 측정하는 RCFT, BVRT, 및 GMLT사이에서 상관이 발견되었으며, RCFT와 BVRT는 가상환경 내 길찾기 행동에 대한 45%의 설명력을 지니고 있었다. 따라서 본 연구의 결과는 MCI환자의 가상환경 내 길찾기 능력이 정상인에 비하여 떨어지며, MCI환자의 시공간기억기능 결함이 이와 같은 길찾기 능력저하에 주요한 역할을 한다는 점을 시사한다.

주요어 : 경도인지장애(MCI),길찾기 능력, 가상환경(VE),노인