Spatial Ability and Navigation Learning in a Virtual City

Jang-Han Lee, Ph.D., Richard Mraz, P.Eng., Konstantine K. Zakzanis, Ph.D., C.Psych., Peter J. Snyder, Ph.D., In Y. Kim, Ph.D., Sun I. Kim, Ph.D., Sandra E. Black, M.D.,
Simon J. Graham, Ph.D., P.Eng.

Department of Biomedical Engineering, Hanyang University, Seoul, Korea
Imaging Research, Sunnybrook & Women's College Health Sciences Centre, Toronto, Canada
Division of Life Sciences, University of Toronto, Canada
Department of Psychology, University of Connecticut, Groton, CT, USA
Department of Neurology, University of Toronto, Canada
Department of Medical Biophysics, University of Toronto, Canada

한양대학교
HANYANG UNIVERSITY

SUNNYBROOK & WOMEN'S
Sunnybrook & Women's College Health Sciences Centre

Motivation

- Ongoing development of an ecologically valid navigation task in VR
- Neuroimaging study identifying brain regions implicated in navigation
- Identification of the components of navigation – memory and executive function (movement)
- Task performance in different populations (eg patients with Alzheimer's Disease or precursor states; or sex)
- Relationships to traditional, and newer computerized neuropsychological measures

Participants

- total N= 42; age 70.4 +/ 7.8, range 58-84
- 18 diagnosed with probable Mild Cognitive Impairment
  - Structured interview, neuropsych tests, clinical exam
  - Subjective memory complaint >= 1 std. devn. below age norms (acquisition or delayed recall of CVLT)
  - MMSE >= 24; CDR >= 0.5
- 16 completed VR task (hardware faults, cybersickness)

	Normal	MCI
Neuropsychological & maze learning test VE navigation learning task	24 9	18 7
Age MMSE	69.36±7.80 28.50±0.93	71.89±7.68 28.11±1.45

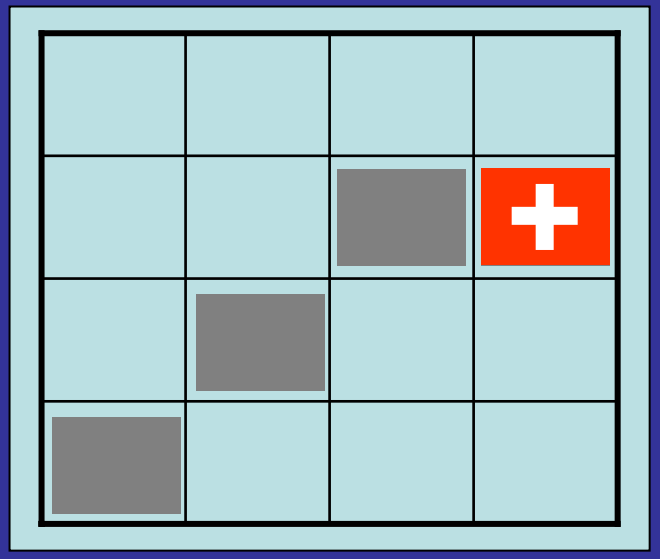
Measures

Standard Neuropsychological Tests

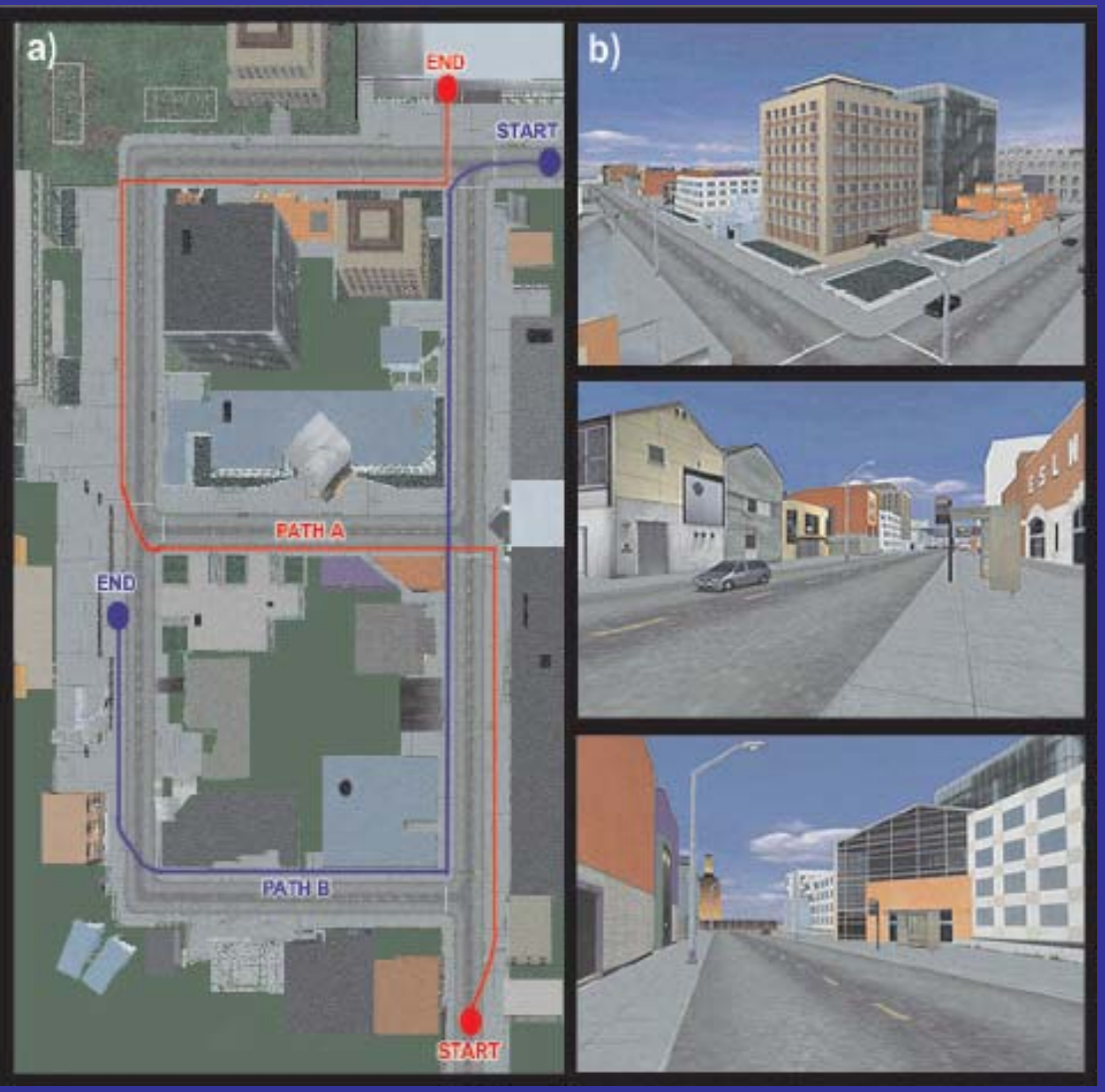
- Rey Visual Memory Test (copy, immediate & delayed recall)
- Benton Visual Retention Test
- Trail Making Test (A&B)
- Digit Span Test (forwards, backwards)
- Dementia Rating Scale, MMSE

Maze Learning Test

- Derived from Milner's (1969)
- Computer touch-screen
- MMSE < 26 = 4 by 4
- MMSE >= 26 = 10 by 10
  (28 steps, 11 turns)
- 10 learning trials, 10 min. inter-trial interval
- reverse trial



VE Navigation Learning Task



Learning

- ***passive*** by video playback

- ***active*** by joystick
- 3 trials Path A, then Path B
- instructed to pay attention to visual features of VE

Recall

- short(5 min)&long(20 min) Path A by memory

Behavioural Measures: distance travelled, time to completion, simulator sickness questionnaire

Test Performance of Normal and MCI Groups

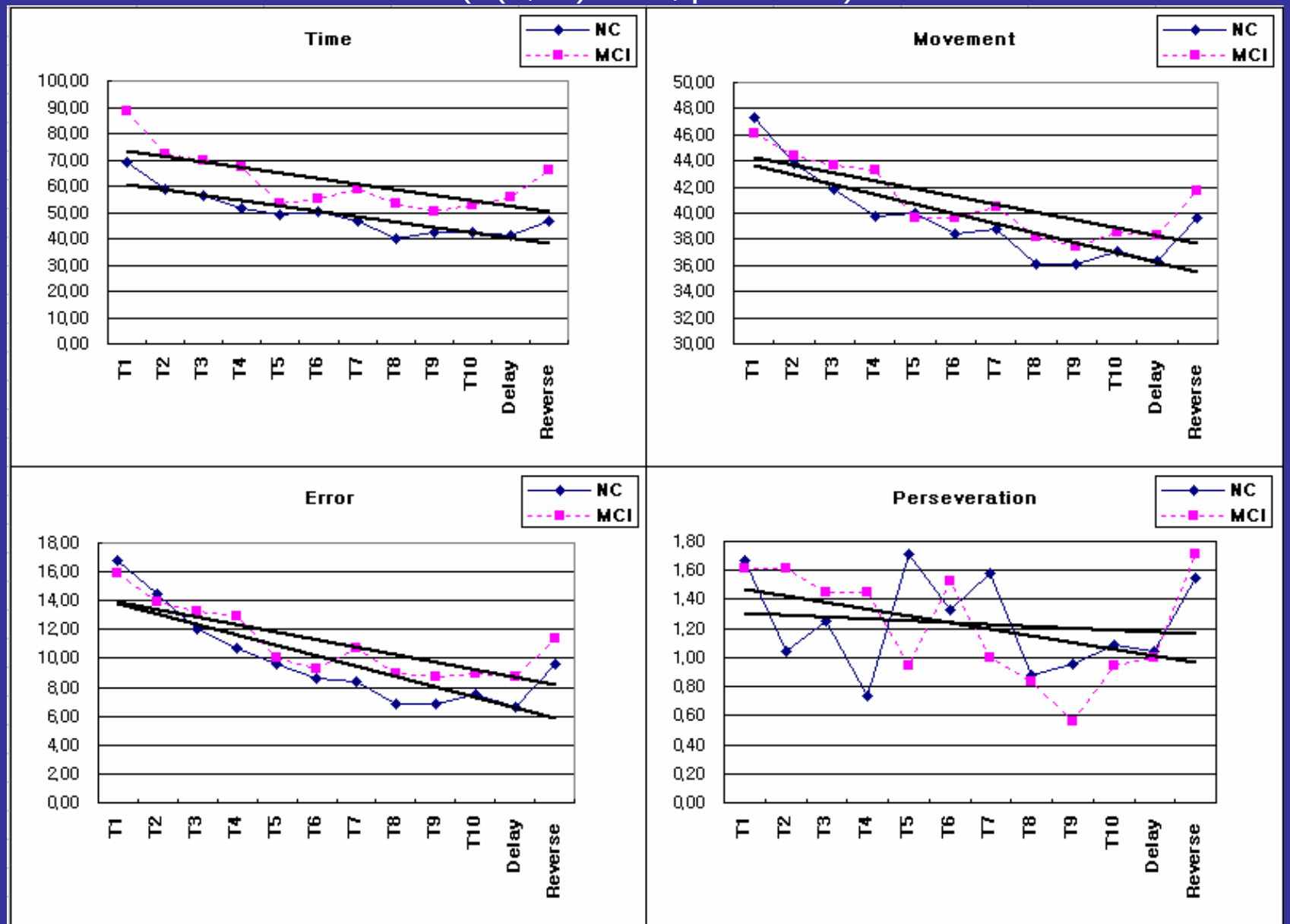
	Variables	Normal	MCI	*t*
maze learning test	Trial2_rule break	0.26±0.45	0.83±1.04	-2.372*
	Delay time	41.05±14.36	55.95±23.81	-2.52*
	Reverse time	46.95±16.57	65.98±25.51	-2.82**
Neuropsych tests	DRS total	140.00±3.12	137.28±4.82	2.22*
	DRS initiation	36.67±0.64	35.33±2.40	2.61**
	Rey Immediate Recall	18.94±6.13	11.33±6.39	3.90**
	Rey Delayed Recall	18.58±5.53	10.62±5.93	4.41**
	Memory index	52.56±11.00	37.77±11.68	4.14**

*p<0.05; **p<0.01

Maze Learning Test Results

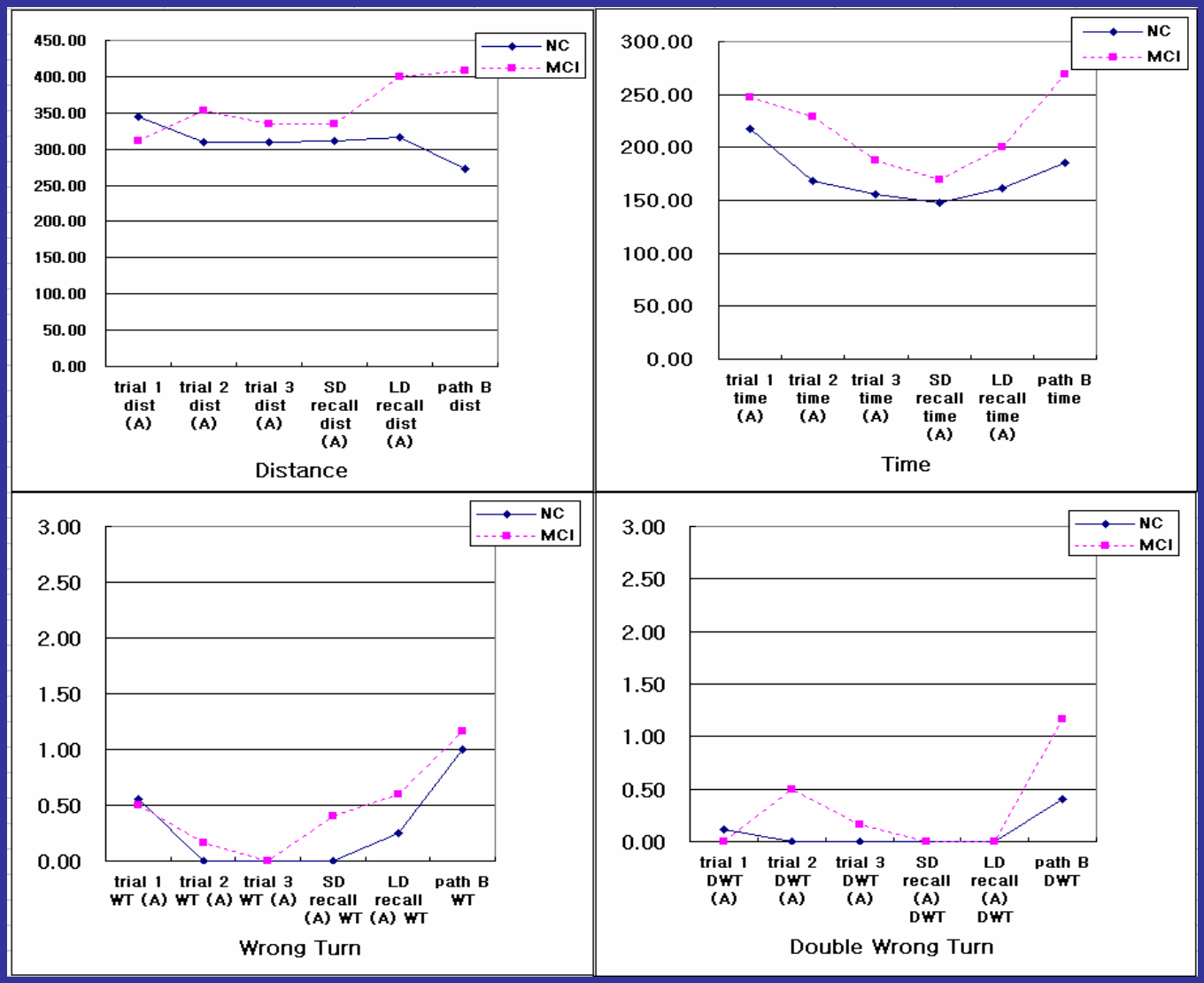
Representative Main Effect of Trials on Time

($F(1,37) = 85$, $p < 0.001$)

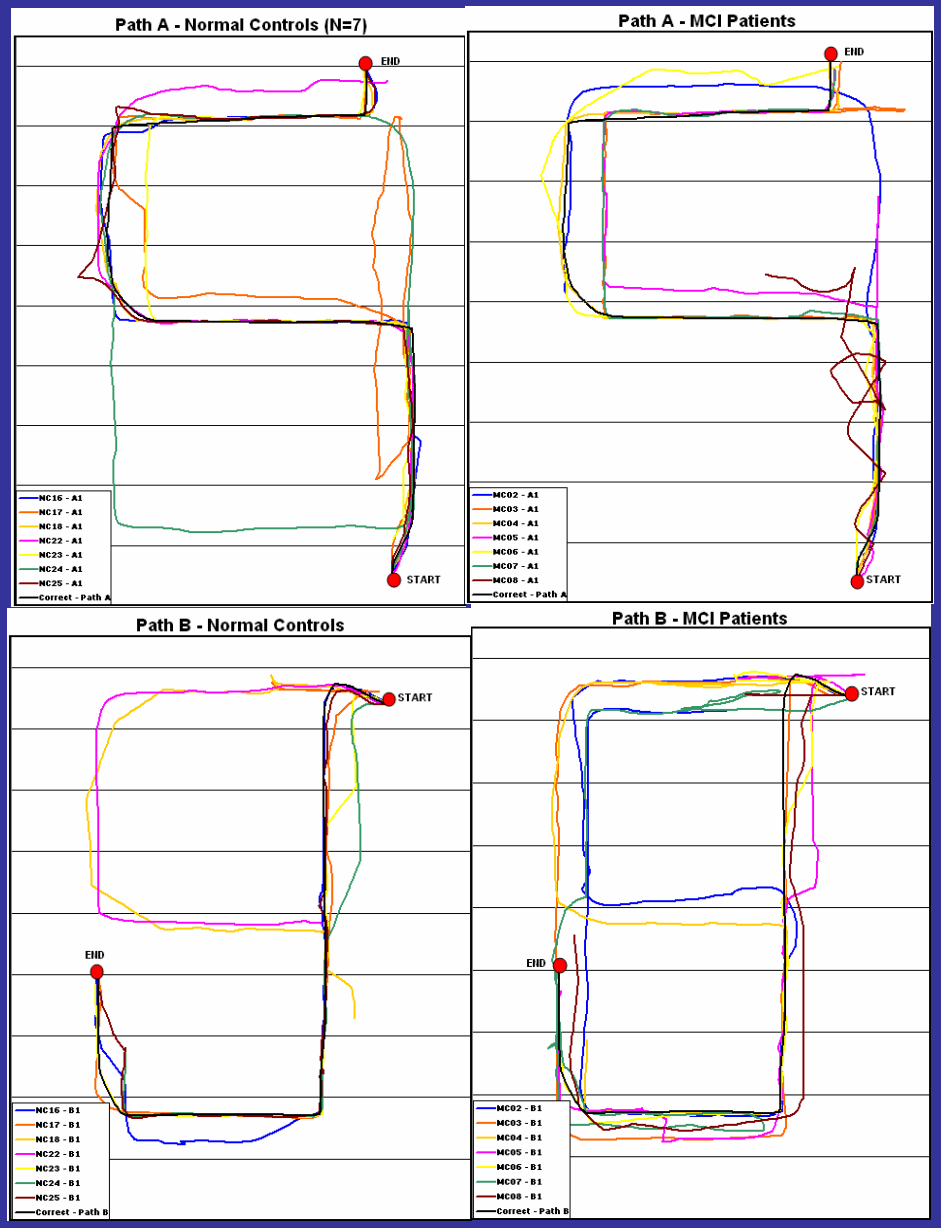


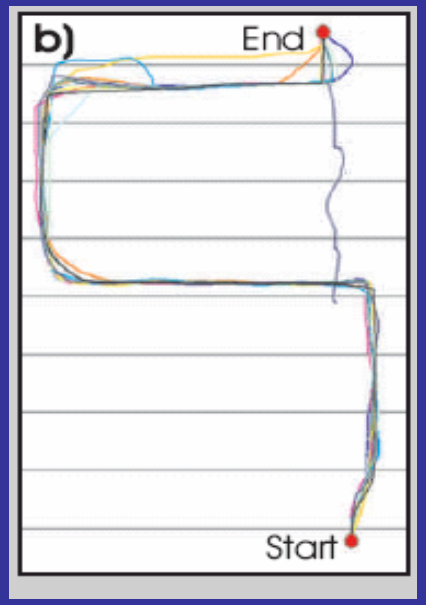
VE Test Results

Main Effect of Trials on
Time ($F(1,12) = 13$, $p < 0.01$) and on
Number of Wrong Turns ($F(1,12) = 8$, $p < 0.05$)



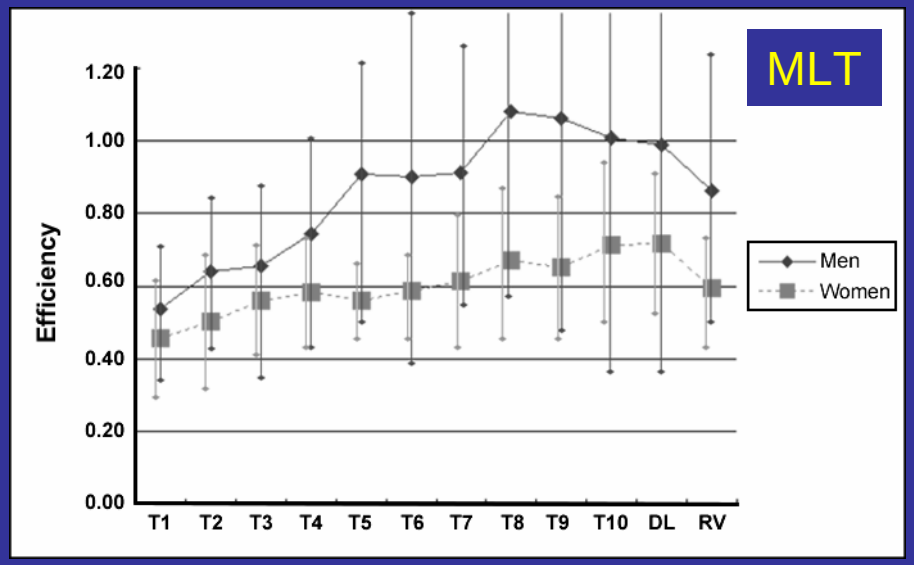
Navigation Differences: VE Task

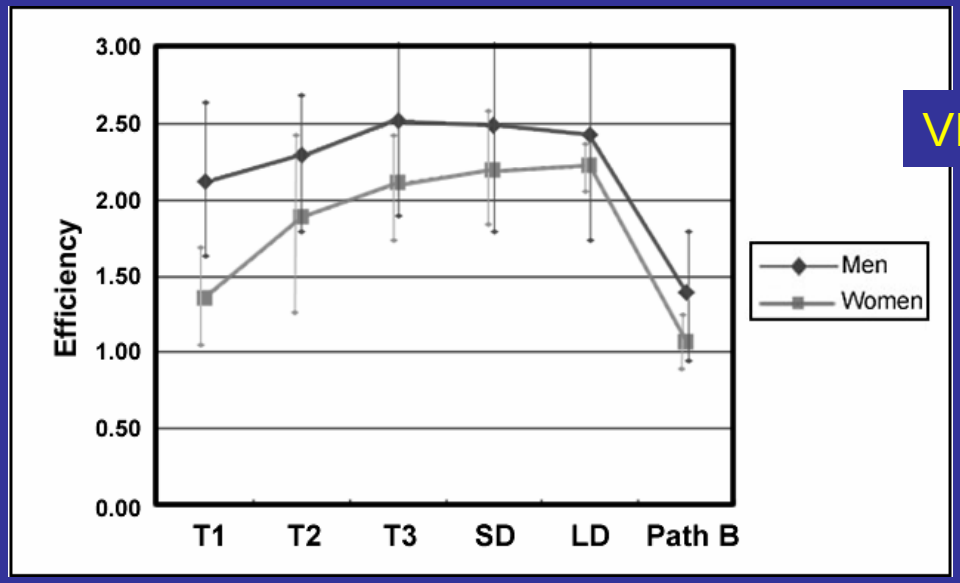




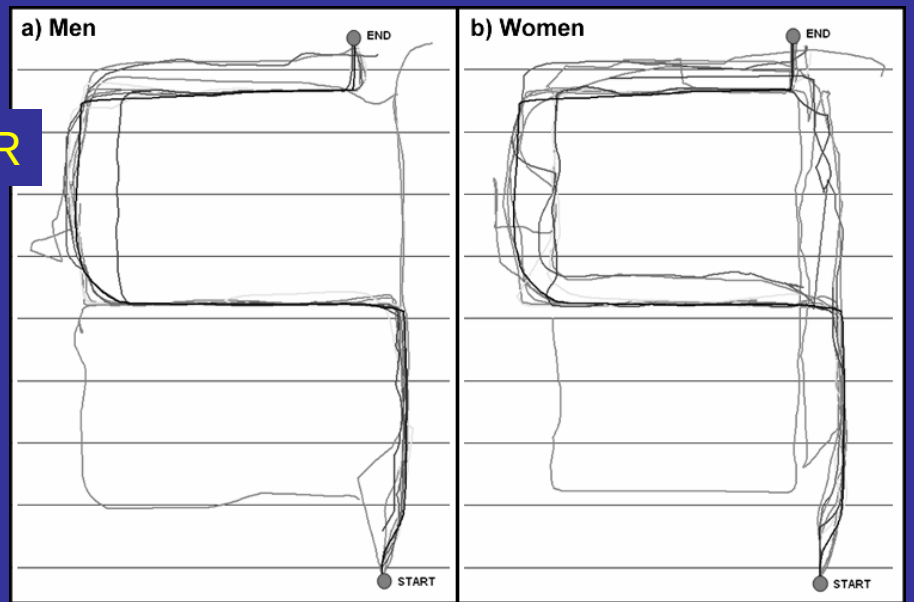
fMRI study

Sex Differences





VR



Pearson Correlations between Memory Index and Learning Tests

		Time	Movement	Error	Perseveration	Rule break
maze learning test	Trial 1	-0.25	0.03	0.07	-0.13	0.00
	Trial 2	-0.34*	-0.35*	-0.22	-0.46**	-0.51**
	Trial 3	-0.45**	-0.44**	-0.38**	-0.36*	-0.57**
	Trial 4	-0.36*	-0.41**	-0.35*	-0.32*	-0.42**
	Trial 5	-0.36*	-0.31*	-0.38*	-0.09	-0.16
	Trial 6	-0.35*	-0.40**	-0.40**	-0.21	-0.20
	Trial 7	-0.45**	-0.41**	-0.46**	-0.19	-0.36*
	Trial 8	-0.47**	-0.49**	-0.46**	-0.34*	-0.39**
	Trial 9	-0.33*	-0.35*	-0.46**	0.01	-0.07
	Trial 10	-0.42**	-0.41**	-0.48**	-0.10	-0.16
	Delay	-0.40**	-0.37*	-0.43**	-0.06	-0.10
	Reverse	-0.53**	-0.36*	-0.44**	-0.13	-0.10
VE navigation learning task		Time	Distance	Wrong Turn	Double WT	
	Trial 1	-0.41*	-0.02	-0.29	0.17	
	Trial 2	-0.14	0.12	0.09	0.03	
	Trial 3	-0.39	0.00	0.13	0.10	
	Path B	-0.26	0.01	0.05	-0.12	
	Short	-0.37	-0.25	-0.34	0.08	
	Delay	-0.51*	-0.37	-0.28		
	Long Delay					

*p<0.05; **p<0.01

Factor analysis: Memory Index = 0.934 * (Rey delayed recall) + 0.904 * (Rey immediate recall) + 0.611 * (forward digit span) + 0.530 * (DRS memory)

Pearson Correlations between VE Measures and Neuropsychological Tests

	VE navigation	VE movement	VE memory
VE movement	0.94**		
VE memory	0.58*	0.32	
Memory index	-0.24	-0.13	-0.55*
Rey immediate recall	-0.25	-0.12	-0.60**
Rey delayed recall	-0.21	-0.05	-0.54*
Trail-making A	0.35	0.46**	0.08
Trail-making A error	0.49	0.41*	0.08
Trail-making B error	0.58	0.47**	0.23

*p<0.05; **p<0.01

VE Memory Index = long delay time + trial 1 time

VE Movement Index = 0.87 * (wrong turn) + 0.73 * (distance travelled) + 0.60 * (double wrong turn)

VE Navigation Index = VE Memory Index + VE Movement Index

Conclusions

- Measures of spatial memory and movement (executive function) during navigational learning in a VE are correlated with conventional neuropsychological tests, and the Maze Learning Test
- VE Memory index was related to the Rey tests
- VE Movement index was related to the Trail tests
- Sex differences were observable for the MLT and VE Task
- The VE test is a good intermediate between conventional and computerized behavioural assessment, and evaluation in the real world
- Quantifying behaviour in VEs remains an issue

Acknowledgments

Pfizer

CIHR IRSC

Ontario
Ontario Research and Development Challenge Fund

Canada Foundation for Innovation
Fondation canadienne pour l'innovation