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Cognition, Behaviour and Driving

26 June 2015, Athens
Amphitheater NIMTS



Driving behaviour, elderly and Mild Cognitive Impairment



Stella Fragkiadaki

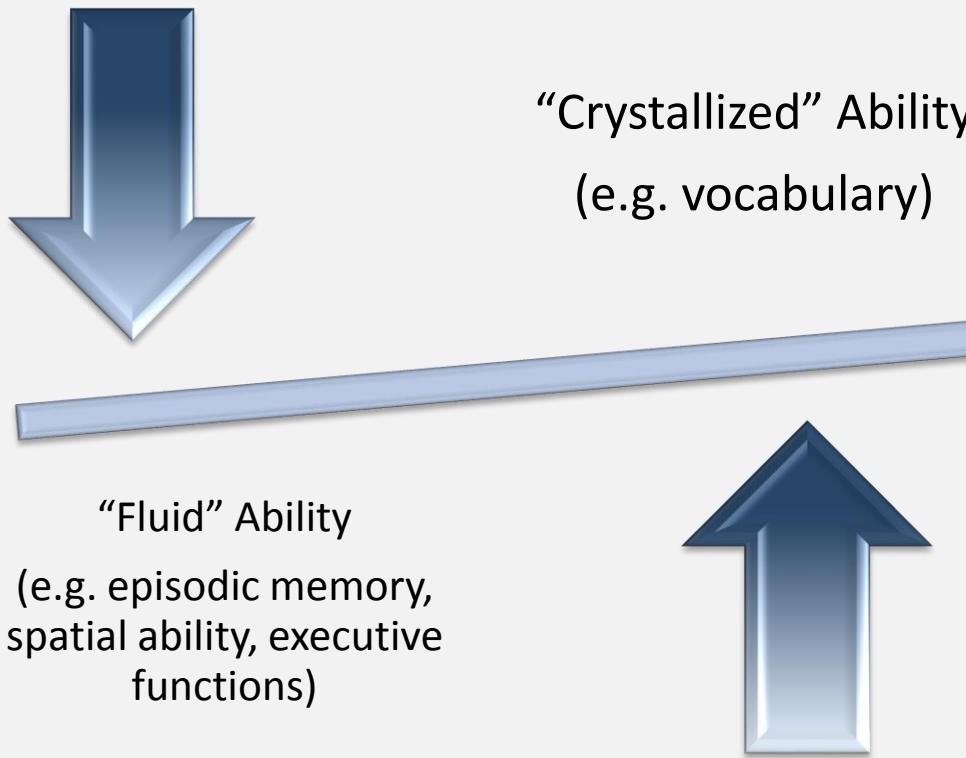
MSc Clinical Neuropsychology

2nd Department of Neurology, “Attikon”

University General Hospital

Athens, 26 June 2015

Is cognitive decline a normal feature of ageing?



(Lindeboom & Weinstein, 2004)

Cognitive decline associated with age

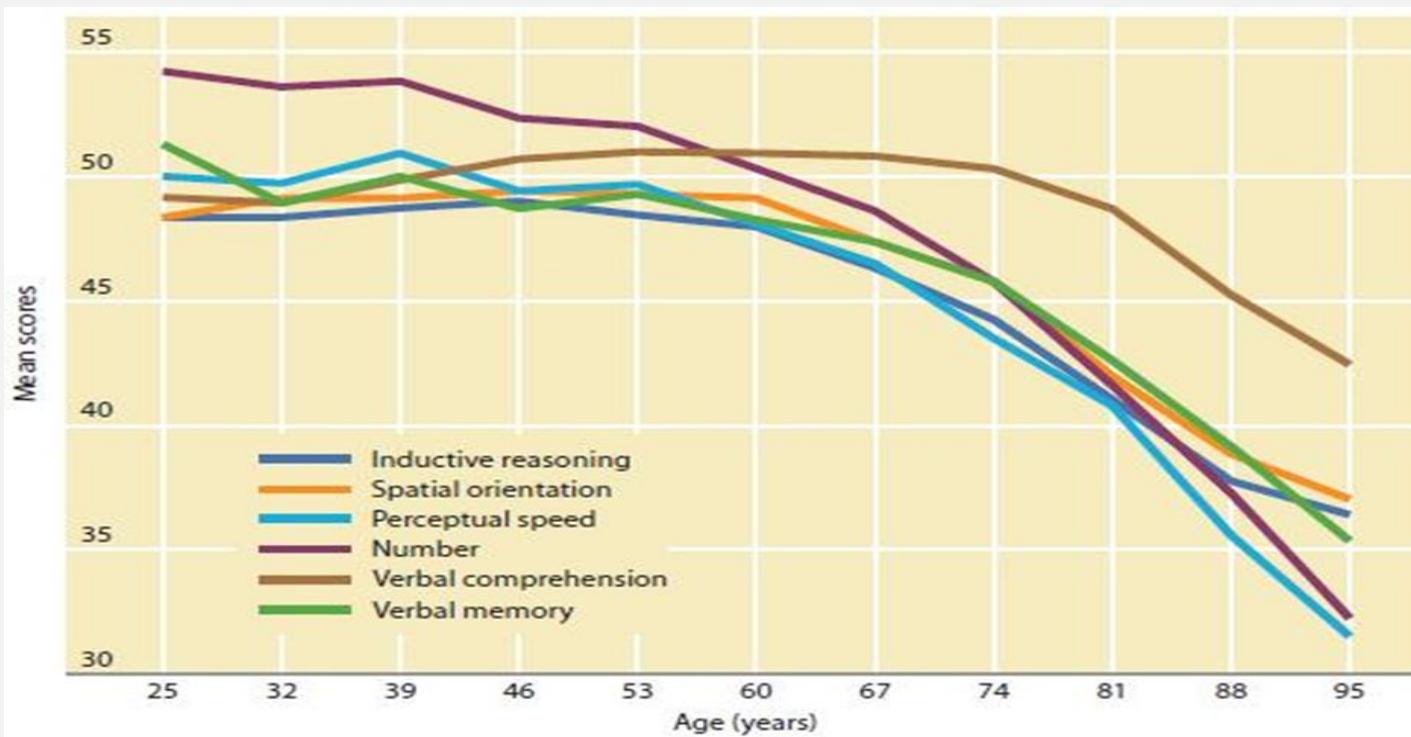
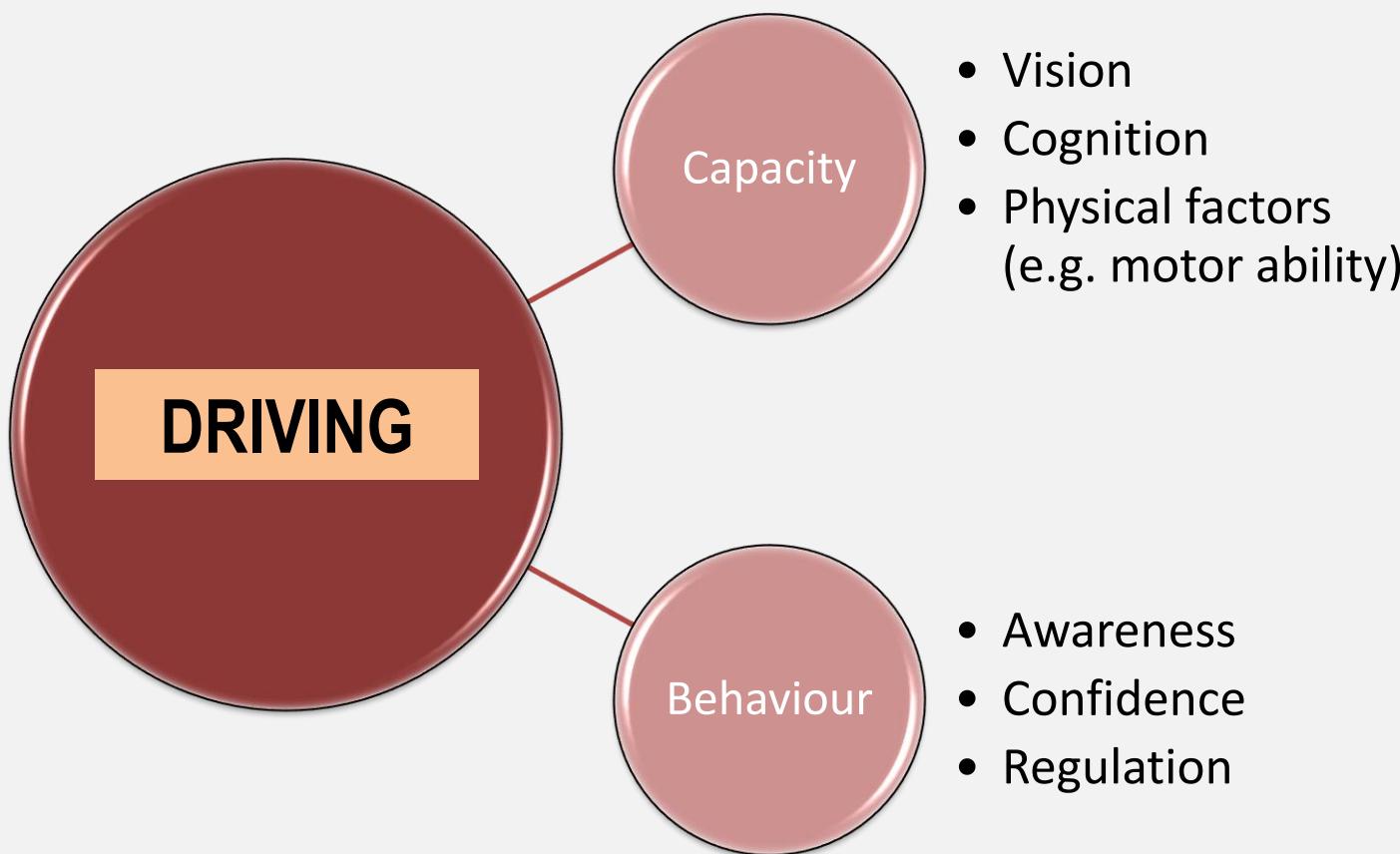


FIGURE 15.4
LONGITUDINAL CHANGES IN SIX
INTELLECTUAL ABILITIES FROM AGE 25 TO
AGE 95

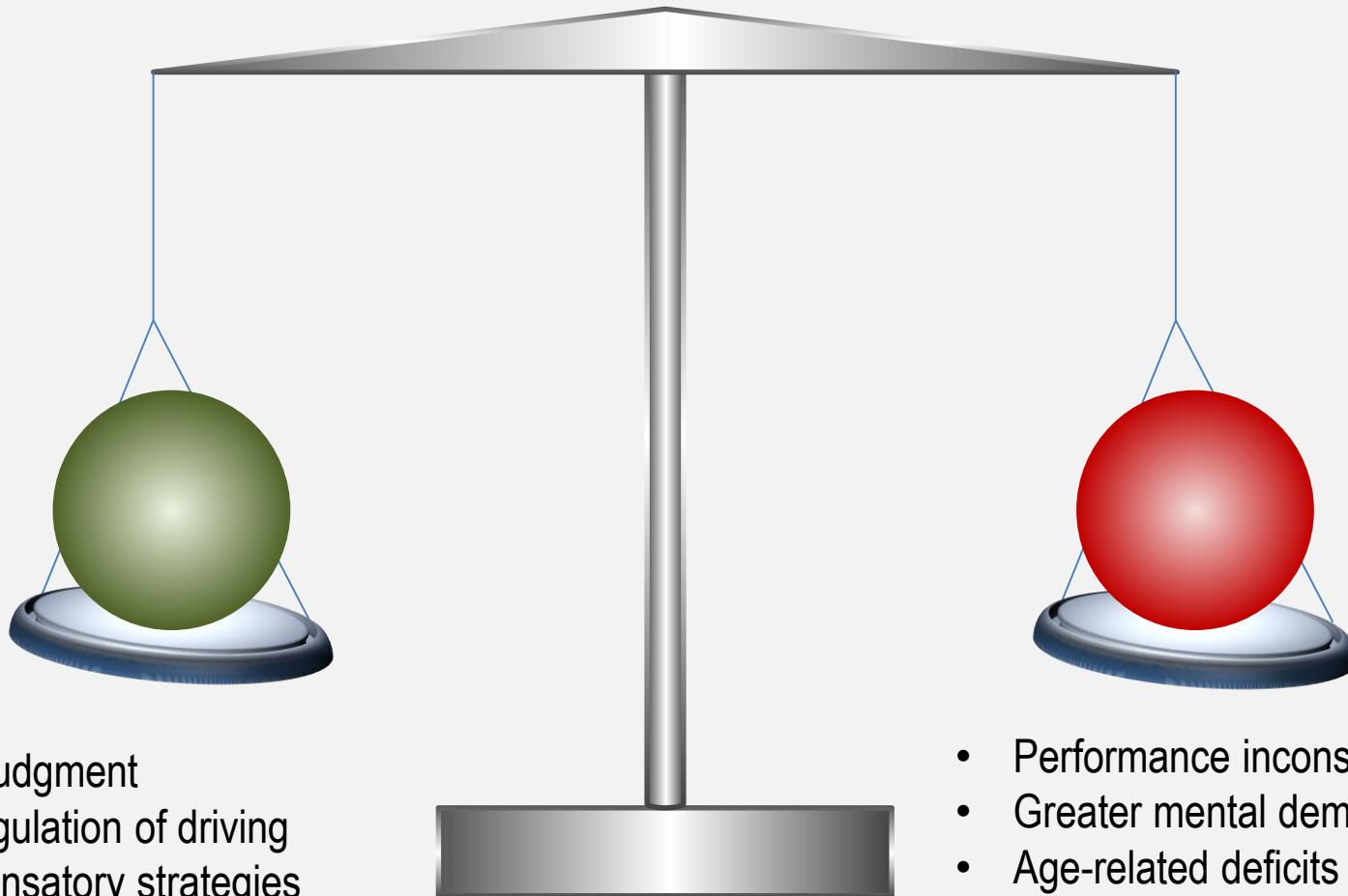
Source: Adapted from Schaie, K.W. (2012).
Developmental Influences on Adult Intelligence:
The Seattle Longitudinal Study (2nd ed.), Fig. 5.8.
New York: Oxford University Press.

Driving capacity and behaviour



(Anstey et al., 2005; Wonga, Smith & Sullivan, 2012)

Driving performance in normal ageing



(Bunce et al., 2012; Meng et al., 2012)

Participants

- 40 patients diagnosed with MCI (26 males)
- 40 control participants (19 males)

	MCI	Controls	p
	Mean (\pm SD)	Mean (\pm SD)	
Age	64,6 (\pm 6,8)	61,75 (\pm 8,1)	0,092
Education	12,89 (\pm 3,88)	14,76 (\pm 3,55)	0,032

Inclusion Criteria

- Valid driving license
- CDR \leq 0,5
- Active drivers
- No history of psychiatric disorder
- No disease of the Central Nervous System
- Without important motor disorder
- Without experience of dizziness or nausea while driving either as driver or as passenger
- Without any alcohol or drug addiction
- Without important eye disorder

Methodology

Neuropsychological Battery

- **General Cognitive Status**
 - Mini Mental State Examination (MMSE)
 - Montreal Cognitive Assessment (MoCA)
- **Attention**
 - Trail Making (part A) (TMT-A)
 - Driving Scenes Test
 - Useful Field of View (UFOV)
 - Spatial Span – Forward
- **Memory**
 - Hopkins Verbal Learning Test – Revised (HVLT-R)
 - Brief Visuospatial Memory Test – Revised (BVMT-R)
- **Verbal Fluency**
 - Semantic
 - Phonemic
- **Visuospatial Perception**
 - Judgment of Line Orientation (JLO)
 - Embedded Figures Test
- **Psychomotor Vigilance**
 - Symbol Digit Modalities Test –Written / Oral (SDMT)
- **Executive Functions**
 - Frontal Assessment Battery (FAB)
 - Clock Drawing Test (CDT)
 - Letter Number Sequencing LNS)
 - Trail Making Test (Part B)(TMT-B)
 - Spatial Span Backwards
 - Psychomotor Vigilance Test
 - Comprehensive Trail Making Test (CTMT)
 - Spatial Addition

Driving Assessment variables

- **Longitudinal Parameters**
 - Average Speed
 - Variation of Speed
 - Headway average
 - Variation of Headway
- **Lateral Parameters**
 - Lateral Position
 - Variation of Lateral position
 - Wheel position average
 - Variation of wheel position
- **General Parameters**
 - Hits of side bars
 - Outside road lanes
 - Sudden brakes
 - Speed limit violations
- **Unexpected Incidents Parameters**
 - Reaction time
 - Accident Probability



Results of Neuropsychological Assessment I

	Controls (mean ±SD)	MCI (mean ±SD)	Sig.
General Cognitive Status			
MMSE (of 30)	29,26 ($\pm 0,89$)	28,16 ($\pm 1,77$)	p=0,001**
MoCA (of 30)	26,11 ($\pm 2,4$)	23,18 ($\pm 2,95$)	p<0,001**
Attention			
TMT_A (in sec.)	43,02 ($\pm 13,36$)	55,67 ($\pm 19,23$)	p=0,001**
Driving Scenes (of 70)	49,23 ($\pm 10,35$)	38,72 ($\pm 8,21$)	p<0,001**
UFOV (in µsec.)	2141,71 ($\pm 1109,85$)	2976,41 ($\pm 1245,01$)	p=0,005**
Spatial Span – F (of 16)	7,5 ($\pm 1,81$)	6,17 ($\pm 2,10$)	p=0,410 (n.s.)
Memory			
HVLT-R (of 36)	23,86 ($\pm 4,24$)	19,43 ($\pm 4,98$)	p<0,001**
HVLT delayed (of 12)	7,36 ($\pm 2,64$)	4,20 ($\pm 3,19$)	p<0,001**
BVMT-R total (of 36)	24,05 ($\pm 7,65$)	18,41 ($\pm 8,95$)	p=0,004**
BVMT delayed (of 12)	9,71 ($\pm 2,58$)	7,15 ($\pm 3,75$)	p=0,001**

Results of Neuropsychological Assessment II

Verbal Fluency			
Semantic (N in 1 min.)	20,71 ($\pm 4,86$)	18,05 ($\pm 4,82$)	p=0,019*
Phonemic (N in 1 min.)	12,57 ($\pm 3,87$)	11,74 ($\pm 3,97$)	p=0,353 (n.s.)
Visuospatial Perception			
JLO (of 20)	16,68 ($\pm 2,69$)	14,76 ($\pm 3,91$)	p=0,015*
Psychomotor Vigilance			
SDMT_W (of 110)	44,42 ($\pm 8,98$)	32,23 ($\pm 10,6$)	p<0,001**
SDMT_O (of 110)	49,23 ($\pm 10,35$)	35,61 ($\pm 12,17$)	p<0,001**
Executive Functions			
FAB (of 18)	16,29 ($\pm 1,69$)	14,13 ($\pm 2,97$)	p<0,001**
CDT (of 7)	6,76 ($\pm 0,59$)	6,51 ($\pm 1,25$)	p=0,261 (n.s.)
LNS (of 21)	10,13 ($\pm 2,2$)	8,02 (± 3)	p=0,001**
TMT_B (in sec.)	83,89 ($\pm 39,39$)	144,89 ($\pm 74,91$)	p<0,001**
Spatial Span_B (of 16)	7,28 ($\pm 1,69$)	6,17 ($\pm 2,10$)	p=0,019*
Vigilance Test (in msec.)	328,52 (± 40)	359,15 (± 97)	p=0,099 (n.s.)

Driving Profile in the MCI group

Rural area / no distraction	MCI (mean ±SD)	Controls (mean±SD)	p
Longitudinal Parameters			
Average Speed	39,78 ($\pm 7,24$)	43 ($\pm 7,8$)	0,083
Speed variation	11,24 ($\pm 3,19$)	11,96($\pm 3,71$)	0,396
Headway average	514, 28 ($\pm 135,06$)	460,57 ($\pm 126,56$)	0,097
Headway variation	221,05 ($\pm 72,97$)	200,39 ($\pm 66,13$)	0,228
Lateral Parameters			
Lateral position	1,51 ($\pm 0,12$)	1,48 ($\pm 0,11$)	0,263
Lateral variation	0,26 ($\pm 0,04$)	0,27 ($\pm 0,06$)	0,637
Wheel average	-1,81 ($\pm 0,44$)	-1,84 ($\pm 0,82$)	0,835
Wheel variation	16,59 ($\pm 1,62$)	17,04 ($\pm 1,92$)	0,299
General Parameters			
Hits of side bars	0,375 ($\pm 0,83$)	0,722 ($\pm 1,48$)	0,233
Outside road lanes	0	0,056 ($\pm 0,33$)	0,324
Sudden brakes	1,41 ($\pm 1,24$)	1,97 ($\pm 1,25$)	0,066
Speed limit violation	0,031 ($\pm 0,17$)	0,139 ($\pm 0,42$)	0,170
Unexpected Incidents Parameters			
Reaction time	1945, 14 ($\pm 547,24$)	1613,91 ($\pm 393,33$)	0,007*
Accident Probability	0,18 ($\pm 0,39$)	0,25 ($\pm 0,51$)	0,531

Driving Profile in the MCI group

<u>Urban area / no distraction</u>	MCI (mean ±SD)	Controls (mean ±SD)	p
Longitudinal Parameters			
Average Speed	28,52 (±4,12)	30,36 (±6,33)	0,218
Speed variation	11,27 (±2,39)	11,67 (±2,89)	0,592
Headway average	109,81 (±18,59)	118,20 (±34,01)	0,271
Headway variation	58,08 (±7,69)	53,14 (±9,93)	0,050*
Lateral Parameters			
Lateral position	3,29 (±0,60)	2,92 (±0,63)	0,038*
Lateral variation	1,86 (±0,49)	1,51 (±0,58)	0,021*
Wheel average	6,96 (±1,34)	6,91 (±1,55)	0,886
Wheel variation	23,91 (±5,81)	24,49 (±8,66)	0,777
General Parameters			
Outside road lanes	0,120 (±0,33)	0,185 (±0,48)	0,571
Sudden brakes	1,28 (±1,56)	1,81 (±2,13)	0,306
Speed limit violation	0,04 (±0,20)	0,037 (±0,19)	0,957
Unexpected Incidents Parameters			
Reaction time	1357,44 (187,86)	1372,32 (±407,06)	0,874
Accident Probability	0,33 (±0,48)	0,13 (±0,34)	0,103

Driving Profile in the MCI group

Rural area / conversation	MCI (mean ±SD)	Controls (mean ±SD)	p
Longitudinal Parameters			
Average Speed	38,53 ($\pm 7,31$)	45,52 ($\pm 8,39$)	0,001**
Speed variation	11,19 ($\pm 2,98$)	12,49 ($\pm 3,43$)	0,119
Headway average	531,16 ($\pm 136,21$)	442,42 ($\pm 139,75$)	0,014*
Headway variation	216,97 ($\pm 80,65$)	176,51 ($\pm 64,43$)	0,031*
Lateral Parameters			
Lateral position	1,47 ($\pm 0,15$)	1,46 ($\pm 0,12$)	0,848
Lateral variation	0,28 ($\pm 0,05$)	0,28 ($\pm 0,06$)	0,703
Wheel average	-2,19 ($\pm 0,80$)	-2,16 ($\pm 0,43$)	0,882
Wheel variation	16,57 ($\pm 2,77$)	18,38 ($\pm 1,68$)	0,002**
General Parameters			
Hits of side bars	0,529 ($\pm 0,78$)	0,586 ($\pm 0,98$)	0,803
Outside road lanes	0	0,034 ($\pm 0,18$)	0,326
Sudden brakes	1,44 ($\pm 1,07$)	1,89 ($\pm 1,21$)	0,122
Speed limit violation	0,059 ($\pm 0,34$)	0,310 ($\pm 0,54$)	0,090
Unexpected Incidents Parameters			
Reaction time	1890,54 ($\pm 482,46$)	1658,15 ($\pm 791,82$)	0,177
Accident Probability	0,15 ($\pm 0,36$)	0,31 ($\pm 0,54$)	0,188

Driving Profile in the MCI group

<u>Urban area / conversation</u>	MCI (mean \pm SD)	Controls (mean \pm SD)	p
Longitudinal Parameters			
Average Speed	27,74 (\pm 3,46)	30,01 (\pm 5,33)	0,095
Speed variation	10,21 (\pm 2,74)	12,02 (\pm 3,05)	0,052
Headway average	134,82 (\pm 0,48)	110,59 (\pm 27,31)	0,357
Headway variation	68,49 (\pm 59,44)	55,23 (\pm 8,03)	0,322
Lateral Parameters			
Lateral position	3,19 (\pm 0,66)	3,12 (\pm 0,62)	0,707
Lateral variation	1,81 (\pm 0,48)	1,62 (\pm 0,64)	0,283
Wheel average	7,19 (\pm 2,61)	8,08 (\pm 0,81)	0,146
Wheel variation	23,07 (\pm 4,99)	22,87 (\pm 3,71)	0,878
General Parameters			
Sudden brakes	1,14 (\pm 1,35)	1,66 (\pm 1,34)	0,200
Speed limit violation	0	0,083 (\pm 0,28)	0,162
Unexpected Incidents Parameters			
Reaction time	1773,92 (\pm 539,29)	1490,43 (\pm 471,43)	0,084
Accident Probability	0,053 9 \pm 0,22	0,045 (\pm 0,21)	0,918

Driving Profile in the MCI group

Rural area / mobile	MCI (mean ±SD)	Controls (mean ±SD)	p
Longitudinal Parameters			
Average Speed	35,80 ($\pm 6,54$)	40,48 ($\pm 6,89$)	0,042*
Speed variation	10,32 ($\pm 3,34$)	10,98 ($\pm 3,22$)	0,552
Headway average	629,42 ($\pm 71,61$)	547,82 ($\pm 107,38$)	0,013*
Headway variation	325,96 ($\pm 60,61$)	277,05 ($\pm 87,64$)	0,063
Lateral Parameters			
Lateral position	1,55 ($\pm 0,13$)	1,50 ($\pm 0,13$)	0,204
Lateral variation	0,25 ($\pm 0,04$)	0,29 ($\pm 0,05$)	0,051
Wheel average	-2,48 ($\pm 0,83$)	-2,44 ($\pm 0,58$)	0,860
Wheel variation	16,61 ($\pm 1,81$)	17,34 ($\pm 2,01$)	0,251
General Parameters			
Hits of side bars	0,250 ($\pm 0,44$)	0,765 ($\pm 1,75$)	0,254
Outside road lanes	0	0,06 ($\pm 0,24$)	0,332
Sudden brakes	1,350 ($\pm 1,04$)	1,294 ($\pm 0,91$)	0,863
Speed limit violation	0	0,12 ($\pm 0,48$)	0,332
Unexpected Incidents Parameters			
Reaction time	2518,50 ($\pm 974,11$)	1873,94 ($\pm 551,29$)	0,017*
Accident Probability	0,650 ($\pm 0,74$)	0,118 ($\pm 0,33$)	0,008**

Driving Profile in the MCI group

<u>Urban area /mobile</u>	MCI (mean ±SD)	Controls (mean ±SD)	p
Longitudinal Parameters			
Average Speed	25,84 ($\pm 4,12$)	32,55 ($\pm 5,27$)	0,008**
Speed variation	10,31 ($\pm 1,92$)	12,26 ($\pm 2,04$)	0,058
Headway average	133,26 ($\pm 17,46$)	109,06 ($\pm 24,37$)	0,027*
Headway variation	60,16 ($\pm 9,96$)	50,14 ($\pm 9,69$)	0,040*
Lateral Parameters			
Lateral position	3,25 ($\pm 0,74$)	3,16 ($\pm 0,71$)	0,794
Lateral variation	1,89 ($\pm 0,45$)	1,52 ($\pm 0,62$)	0,162
Headway variation	60,16 ($\pm 9,96$)	50,14 ($\pm 9,69$)	0,040*
Wheel average	6,84 ($\pm 0,87$)	8,29 ($\pm 1,52$)	0,027*
Wheel variation	22,41 ($\pm 3,31$)	21,92 ($\pm 2,01$)	0,704
General Parameters			
Outside road lanes	0,100 ($\pm 0,31$)	0,111 ($\pm 0,33$)	0,942
Sudden brakes	1,10 ($\pm 1,37$)	1,11 ($\pm 1,26$)	0,986
Speed limit violation	0	0,111 (0,33)	0,347
Unexpected Incidents Parameters			
Reaction time	1521,80 ($\pm 261,29$)	1832,61 ($\pm 579,41$)	0,167
Accident Probability	0,100 ($\pm 0,31$)	0,111 ($\pm 0,33$)	0,942

Summary of driving profile in the MCI group

RURAL AREA

No distraction

- Reaction time (\uparrow)

Conversation

- Average Speed (\downarrow)
- Headway average (\uparrow)
- Wheel variation (\uparrow)

Mobile

- Average speed (\downarrow)
- Headway average (\uparrow)
- Accident probability (\uparrow)
- Reaction time (\uparrow)

URBAN AREA

No distraction

- Lateral position (\uparrow)
- Variation of lateral position (\uparrow)
- Headway variation (\uparrow)

Conversation

- No differences with control participants

Mobile

- Average speed (\downarrow)
- Headway average (\uparrow)
- Headway variation (\uparrow)
- Wheel average (\uparrow)

Driving performance in MCI



Driving Ability



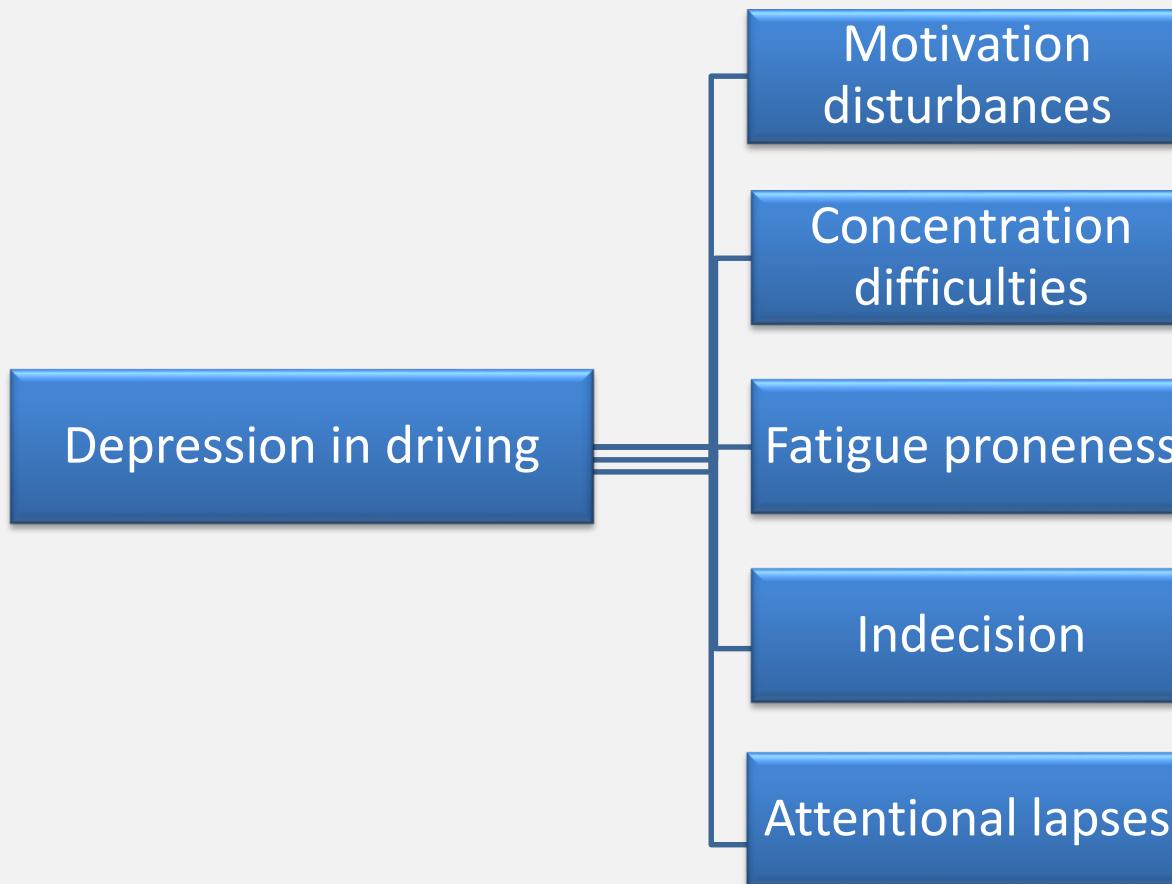
Driving Ability

- Wadley et al., 2009
 - 15 MCI patients, on-road assessment, “not-optimal” performance
- Devlin et al., 2012
 - 14 MCI patients, simulator assessment, poorer performance but trends did not reach statistical significance
- Jeong et al., 2012
 - 169 MCI patients
 - Self-rated questionnaires
 - No differences in history of crashes, but situational avoidance
- Snellgrove et al., 2005
 - 115 MCI patients, on-road assessment, 50% of MCI patients failed the driving test
- Kawano et al., 2012
 - 12 aMCI patients, simulator assessment, clear differences in driving ability
- O' Connor et al., 2010
 - 2.335 participants, Driving Habits Questionnaire, faster rates of decline for driving frequency and difficulty

Driving Errors in MCI

- Left-head turns
 - Lane control
- (Wadley et al., 2009)
- Mean time to collision
- (Frittelli et al., 2009)
- Qualitative judgments
 - Reaction time
 - Ability to control speed
- (Duchek et al., 2003, Devlin et al., 2012)
- “Pedal confusion” (inappropriate motor response such as pressing the accelerator instead of the brake pedal)
- (Snellgrove, 2005)

Relationship between driving behaviour and depression



(Bulmash et al., 2006; Hilton et al., 2009; Wingen et al., 2006)

Association of depressive symptoms with driving behavior in the MCI population has not yet been investigated

The PHQ-9 Questionnaire

- Depressive symptoms questionnaire
 - Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2002)
 - It is based on the diagnostic criteria for major depression according to the **DSM-IV**(Diagnostic and Statistical Manual Fourth Edition)
 - Questions:
 - Little interest or pleasure
 - Low mood
 - Sleep disturbance
 - Loss of energy
 - Poor appetite or overeating
 - Feelings of failure or guilt
 - Concentration difficulties
 - Psychomotor disturbance
 - Suicidal thoughts

Scoring (0-27)

- 0 (not at all)
- 1 (several days)
- 2 (half the days)
- 3 (every day)

	MCI		Controls		<i>p</i>
	Mean	SD	Mean	SD	
PHQ-9	4,58	4,02	3,31	4,14	<u>0,339</u>

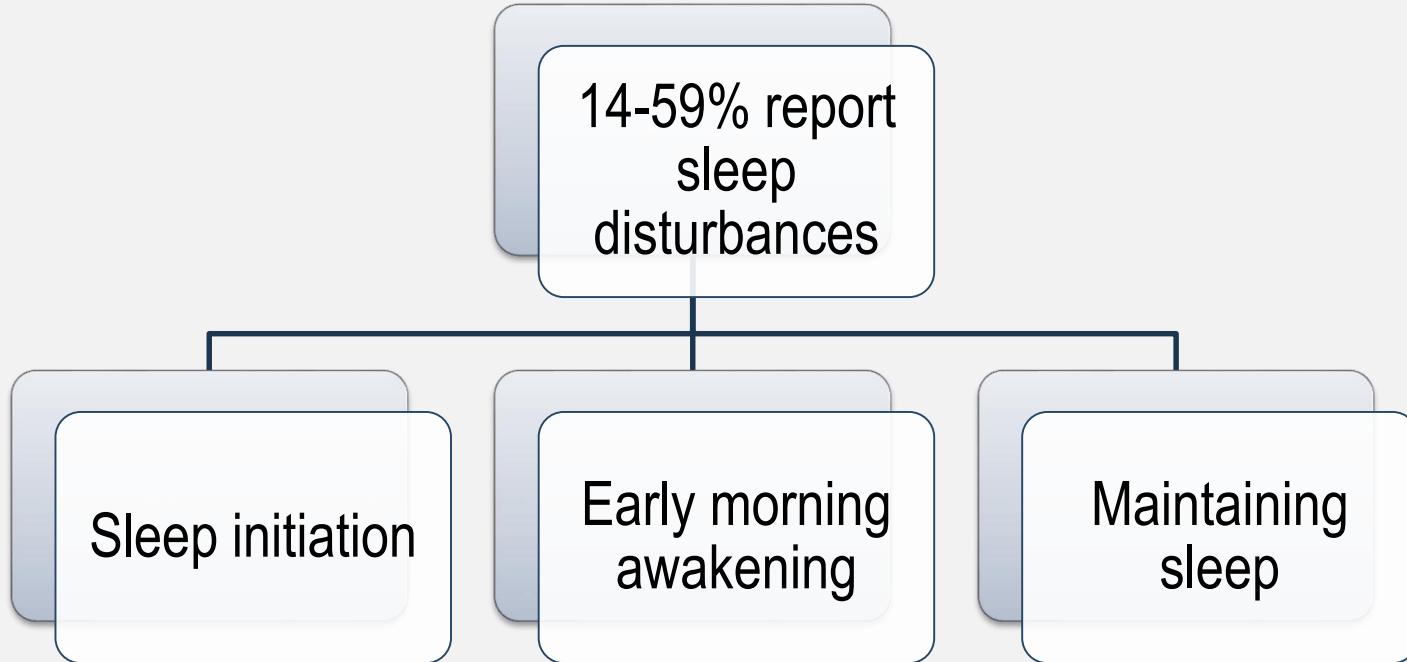
Correlation of PHQ-9 with driving variables

Driving Variables	Patient Health Care Questionnaire (PHQ-9)			
	MCI		Controls	
	r	p	r	p
Lateral position	-.087	.686	.274	.304
Lateral position variation	.723	<.001**	-.248	.354
Average speed variation	.329	.116	-.028	.918
Average speed	.570	.004**	-.166	.540
Headway average	-.569	.004**	.248	.355
Headway variation	-.564	.004**	.264	.323
Reaction time	.177	.409	.287	.281
Number of crashes	.584	.003**	.206	.444
Hits of side bars	.425	.039*	-.226	.400
Engine stops	-.043	.841	.183	.497
Speed limit violations	.499	.013*	.411	.114
Wheel average	-.434	.034*	-.139	.608
Wheel variation	.341	.102	-.302	.256

Predictive value of PHQ-9

Unique contribution of PHQ-9 on predicting various indexes of driving performance after controlling for the role of neuropsychological measures and sleep disturbances

Outcome measure	PHQ-9 contribution			
	β	<i>t</i>	<i>p</i>	<i>R</i> ² Overall
<i>Model</i>				
Lateral Position Variation	.60	2.89	.011*	.635
Average Speed	.62	2.52	.023*	.490
Average Headway	-.61	2.43	.028*	.468
Headway Variation	-.59	2.34	.034*	.463
No. of Crashes	.70	2.84	.012*	.485
Hits of Side Bars	.39	2.11	.052	.705
Speed Limit Violation	.61	2.84	.012*	.613
Average Wheel Position	-.59	2.50	.025*	.524

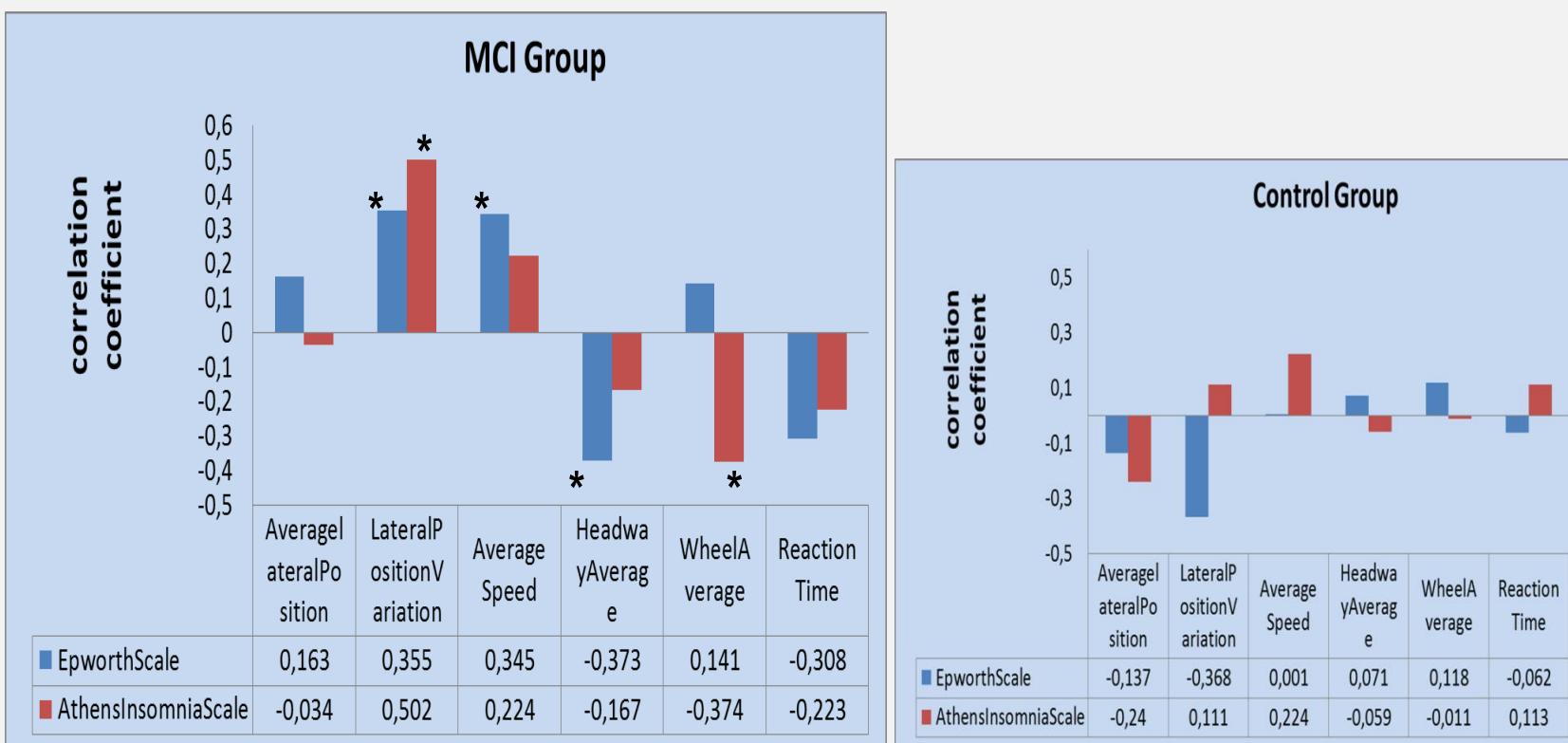


(Beaulieu-Bonneau S. & Hudon C, 2009; Dlugaj et al., 2014)

Questionnaires

- Sleeping abnormalities questionnaires
 - Epworth sleepiness scale
 - Athens insomnia scale

	MCI		Controls		p
	Mean	SD	Mean	SD	
Epworth	5,97	2,98	5,23	4,04	0,440
Athens	4,21	3,72	3,19	2,99	0,261



Predictors of driving performance in individuals with MCI



Results (Average Speed)

Outcome: Driving Speed

Predictors:

(1st level) general cognitive functioning (MMSE)

(2nd level) balance and movement coordination (**Tandem Walking**, $\beta=-.63$, $p=.007$)

The model explained 55.9% of the variance in average driving speed

$R^2=.559$, $F(2,13)=8.25$, $p=.005$.

- In the cognitively intact group the same regression model did not contribute to the prediction of average driving speed

$R^2=.166$, $F(2,11)=1.10$, $p=.368$

Normal Group (*Mean*=43.62, *SD*=7.33) vs MCI Group(*Mean*=42.24, *SD*=7.46)
 $t(28)=.51$, $p=.614$

Results (Number of Crashes)

Outcome: Number of Crashes

Predictors:

(1st level) general cognitive functioning (**MMSE**)

(2nd level) visuospatial memory (**BVMT_Recognition**, $\beta=-.40$, $p=.056$) and speed of **attention** (UFV_1, $\beta=.48$, $p=.027$)

The model explained 77.3% of the variance in number of crashes

$R^2=.773$, $F(3,10)=11.35$, $p=.001$

- In the cognitively intact group the same regression model did not contribute to the prediction of number of crashes

$R^2=.279$, $F(3,10)=1.29$, $p=.330$

Normal Group (*Mean*=.43, *SD*=.65) vs MCI Group(*Mean*=.56, *SD*=.81)
 $t(28)=.49$, $p=.25$

Results (Reaction Time)

Outcome: Reaction Time

Predictors:

(1st level) general cognitive functioning (**MMSE**)
(2nd level) **information processing speed** (SDMT, $\beta=-.60$, $p=.014$) and balance and movement coordination (Tandem Walking_RNC, $\beta=.54$, $p=.007$)

The model explained 73.2% of the variance in reaction time

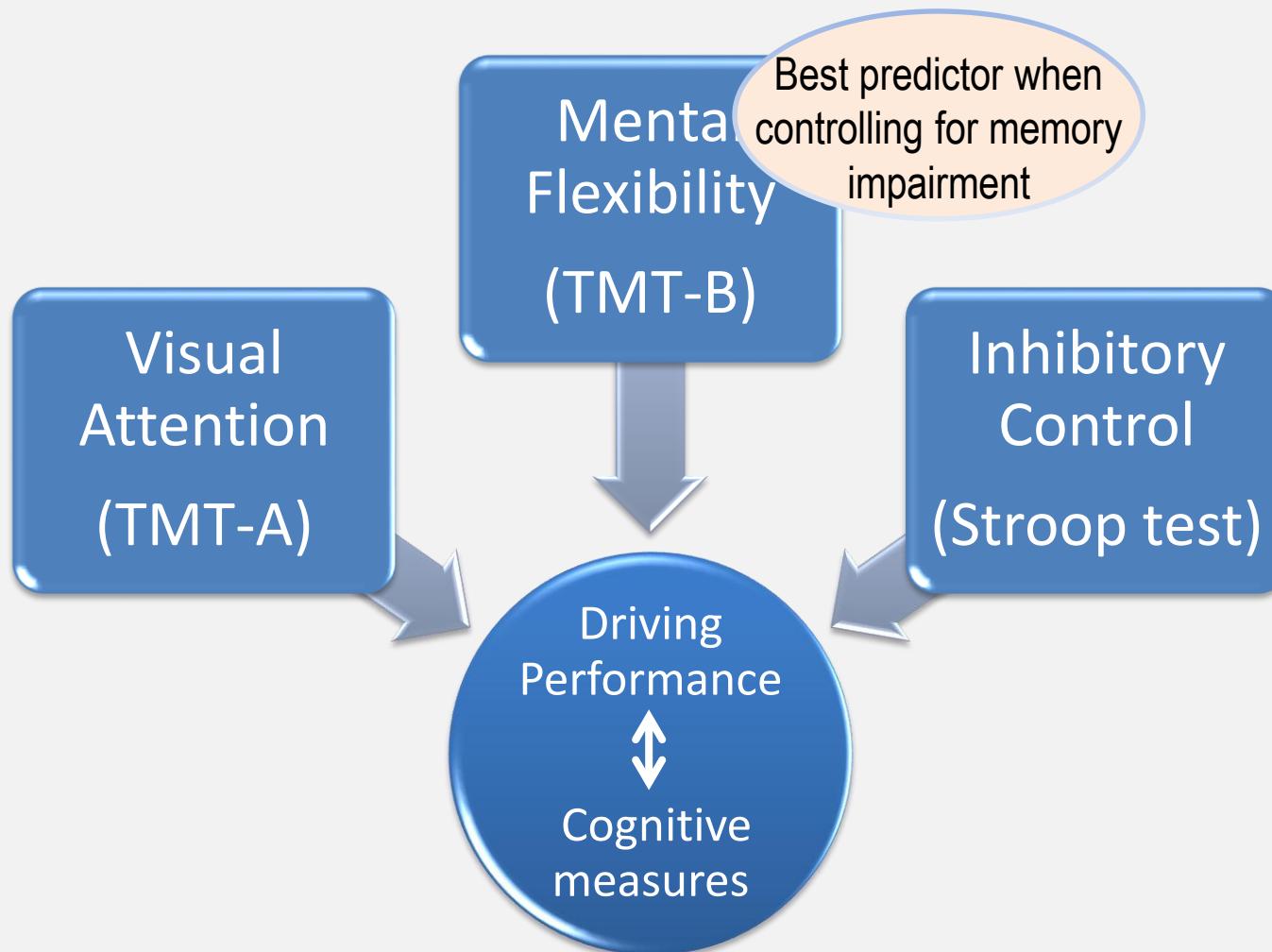
$$R^2 = .732, F(3,12)=10.92, p=.001$$

- In the cognitively intact group the same regression model did not contribute to the prediction of reaction time

$$R^2=.119, F(3,10)=.45, p=.772$$

Normal Group (*Mean*=1.78, *SD*=.28) vs MCI Group (*Mean*=1.89, *SD*=.46)
 $t(28)=.80, p=.43$

Predictors of driving ability in the MCI



(Kawano et al., 2012)

Conclusions

- It seems that driving performance in the MCI group is reduced in comparison to cognitively intact individuals
- Depressive symptoms and sleep abnormalities have a significant effect on driving performance in MCI
- These findings should be taken into account in the medical management of MCI patients



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Driving behaviour, elderly and Mild Cognitive Impairment



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