THE VALUE OF MINI MENTAL STATE EXAMINATION (MMSE) AND MONTREAL COGNITIVE ASSESSMENT (MoCA) IN THE PREDICTION OF FITNESS TO DRIVE IN PATIENTS WITH MILD COGNITIVE IMPAIRMENT (MCI) AND MILD ALZHEIMER'S DISEASE (AD)

Ion N. Beratis, PhD Research Associate
Behavioral Neurology and Neuropsychology Unit, 2nd Department of Neurology,
National and Kapodistrian University of Athens, "Attikon" University Hospital,
1 Rimini Str, 12462 Haidari, Athens, Greece, Tel: +302105832466;
Email: ionas96@hotmail.com

Evangelia Stanitsa, Research Assistant
Behavioral Neurology and Neuropsychology Unit, 2nd Department of Neurology,
National and Kapodistrian University of Athens, "Attikon" University Hospital,
1 Rimini Str, 12462 Haidari, Athens, Greece, Tel: +302105832466;
Email: eva.st.92@gmail.com

Dionysia Kontaxopoulou, Research Assistant
Behavioral Neurology and Neuropsychology Unit, 2nd Department of Neurology,
National and Kapodistrian University of Athens, "Attikon" University Hospital,
1 Rimini Str, 12462 Haidari, Athens, Greece, Tel: +302105832466;
Email: d.kontaxopoulou@hotmail.com

Stella Fragkiadaki, Research Assistant
Behavioral Neurology and Neuropsychology Unit, 2nd Department of Neurology,
National and Kapodistrian University of Athens, "Attikon" University Hospital,
1 Rimini Str, 12462 Haidari, Athens, Greece, Tel: +302105832466;
Email: st.fragkiadaki@gmail.com

Panagiota Kontari, Research Assistant
Behavioral Neurology and Neuropsychology Unit, 2nd Department of Neurology,
National and Kapodistrian University of Athens, "Attikon" University Hospital,
1 Rimini Str, 12462 Haidari, Athens, Greece, Tel: +302105832466;
Email: teta.kont@gmail.com

Dimosthenis Pavlou, PhD Research Associate, Corresponding Author
National Technical University of Athens,
Department of Transportation Planning and Engineering
5 Heroon Polytechniou Str, GR-15773 Athens, Greece, Tel: (+30)2107722210;
Email: dpavlou@central.ntua.gr

Panagiotis Papantoniou, PhD Research Associate
National Technical University of Athens,
Department of Transportation Planning and Engineering
5 Heroon Polytechniou Str, GR-15773 Athens, Greece, Tel: (+30)2107723167;
Email: ppapant@central.ntua.gr

Alexandra Economou, Associate Professor
National and Kapodistrian University of Athens,
School of Philosophy, Department of Psychology
Zografos University Campus, GR-15784, Athens, Greece, Tel: +302107277589;
Email: aoikono@psych.uoa.gr

George Yannis, Professor
National Technical University of Athens,
Department of Transportation Planning and Engineering
5 Heroon Polytechniou Str, GR-15773 Athens, Greece, Tel: (+30)2107721326;
Email: geyannis@central.ntua.gr

Sokratis G. Papageorgiou, Associate Professor
Behavioral Neurology and Neuropsychology Unit, 2nd Department of Neurology,
National and Kapodistrian University of Athens, "Attikon" University Hospital,
1 Rimini Str, 12462 Haidari, Athens, Greece, Tel: +302105832466;
Email: sokpapa@med.uoa.gr

Word count: 5,488 words

Submitted: 30 July 2017

ABSTRACT
Montreal Cognitive Assessment (MoCA) and Mini Mental Examination (MMSE) are commonly used cognitive screening instruments. Although MMSE has been previously associated with driving fitness, MoCA has not been widely explored in that perspective. The aim of the study was to explore whether significant correlations would be present between the aforementioned tests and specific driving indexes in patients with amnestic Mild Cognitive Impairment (aMCI), mild Alzheimer's disease (mAD) and healthy individuals. Forty-four aMCI patients (69.1±8.9 years), 23 mAD patients (73.7±6.8 years), and 30 healthy individuals (65.9±5.7 years) were assessed in rural and urban areas through the use of a driving simulator. Both tests were significantly associated with accident probability and reaction time in both driving conditions in aMCI patients, while MoCA was also significantly correlated with speed limit violations in the rural area. In mAD patients, both tests indicated a significant correlation with headway distance in the rural area and accident probability in the urban area. MoCA also showed a significant correlation with average speed in rural area. No association with any of the driving indexes was reported for the healthy individuals. Both measures of general cognitive functioning, with a relative advantage of the MoCA, appear to be associated with crucial indexes related to driving fitness in patients with aMCI and mild AD. Nonetheless, it is recommended that these measures should not be used independently but instead as elements of a broader evaluation when taking decisions related to driving fitness in drivers belonging to the specific clinical groups.

Keywords: Montreal Cognitive Assessment, Mini Mental State Examination, driving ability, driving simulator, Mild Cognitive Impairment, Alzheimer's Disease

INTRODUCTION

Driving is a highly complex task that requires a combination of physical and mental skills *(1)*. According to previous studies, decline in cognitive functions due to neurodegenerative diseases influences in a critical way the ability to operate a vehicle safely *(2)*. Alzheimer's disease (AD), is the most frequent neurodegenerative disease causing dementia. Mild Cognitive Impairment (MCI), is an intermediate state between dementia and normal cognition in the elderly *(3)* that most commonly progresses to AD.

Numerous studies have investigated the driving performance of patients with AD using on-road evaluations and simulator driving experiments, revealing a significant impairment on various driving indexes, such as accident probability, reaction time, maintaining proper speed and taking left turns *(2, 4, 5, 6, 7, 8)*. However, patients at the earlier stages of the disease, may maintain their driving fitness *(4, 9, 10, 11, 12)*. Apart from driving experience, several factors assist in differentiating between safe drivers and those at risk: sex, disease severity and duration, self and family assessment, performance in on road evaluations and driving simulators, as well as neuropsychological measures *(4)*.

Although previous research has focused on driving ability of patients with dementia, fewer studies have assessed driving fitness of patients with MCI *(2, 13, 14, 15)*. To date, no consensus has been reached by studies assessing the driving safety of MCI patients both in driving simulator experiments and in on road tests. Although some studies report impaired driving ability of patients with MCI in comparison to cognitively intact individuals *(16, 17, 18)*, a respected number of studies, does not indicate statistically significant differences, suggesting that overall driving performance of MCI patients is within the normal range. However, most researchers agree that although MCI patients do not drive consistently worse than the healthy elderly, they tend to make more driving errors and present trends towards impaired driving performance in comparison to cognitively intact elderly drivers. In most studies, those trends fail to reach statistical significance but nonetheless raise concerns regarding the potential driving safety of individuals with mild cognitive impairments *(7, 15, 17, 19)*.

Given the fact that driving requires multiple cognitive skills, namely attention, speed of processing and visuospatial perception, clinicians should consider multiple factors when evaluating driving competency of patients. Diagnosis of dementia per se should not be the reason of withdrawing a patient's driving privileges. A useful guideline for clinicians, in order to make accurate and valid recommendations, is the utilization of a personalized approach taking into account the individual's driving performance along with the level of cognitive and functional impairment *(4, 20, 21)*.

In line with a personalized approach concept, neuropsychological assessment is a potentially reliable and cost-effective means for identifying at risk drivers. Despite the inconsistency of findings from past studies that have examined the correlation between cognitive domains and driving ability, there is strong evidence that cognitive performance is highly associated with driving fitness *(5, 18)*. Thus, a combination of neuropsychological, and neurological measures along with a detailed evaluation of driving performance through on road or driving simulator assessments, should be used to identify older drivers at risk *(22)*.

One of the most frequently administered neuropsychological instruments for screening dementia is the Mini Mental State Examination (MMSE) *(23)*. Multiple studies have examined the utility of MMSE as a predictor of driving ability among individuals with dementia, but have revealed contradictory results. Some researchers have indicated a significant association of MMSE performance and driving ability *(19, 20, 23, 24)*, while others did not identify any associations between those measures *(25, 26, 27, 28, 29, 30)*. A significant distinction, however, should be made regarding the nature of the samples that were utilized by studies that have found significant correlations with the MMSE in comparison to the studies that do not identify such correlations. The majority of the samples examined in the studies that detect significant associations included individuals with cognitive disorders (e.g. patients with AD), while the majority of the samples in the studies which do not verify those results included participants from the general population. Thus, it appears that the MMSE is associated at a greater extent with various indexes of driving fitness when applied in clinical populations because of the greater variability that exists on the test performance patterns as compared to the case of cognitively healthy individuals that commonly achieve maximum scores on the specific instrument.

Another widely used cognitive screening tool is the Montreal Cognitive Assessment (MoCA) *(31)*. MoCA is a highly sensitive tool for the identification of milder forms of cognitive impairment, has excellent test-retest reliability *(31, 32, 33, 34, 35)* and is less prone to ceiling effects than MMSE *(36, 37)*. According to Esser et at. *(38)*, MoCA could be utilized by clinicians as a useful screening tool for identifying whether a driving assessment is necessary for individuals self-reporting concerns about their driving ability.

To our knowledge, only one study has directly compared the MMSE and the MoCA regarding their capacity to predict unsafe driving behavior. Hollis et al. *(25)* compared MMSE and MoCA in predicting driving risk in individuals with and without cognitive impairment by using a standardized on-road evaluation. According to this study, in the case of cognitively healthy individuals none of the two aforementioned screening tests could serve as an effective indicator of driving performance. On the other hand, regarding participants who were classified under the cognitively impaired spectrum, the results showed that both tests could serve as significant predictors of unsafe driving behavior, indicating however an advantage of the MoCA test which yielded stronger associations with driving performance than the MMSE. However, it should be noted, that the clinical sample of this study was heterogeneous and the classification regarding the presence or absence of cognitive impairment was based on the reason of referral without applying a detailed neuropsychological evaluation as indicated by the most recent diagnostic criteria.

The aim of the present study was to investigate the strength of the association of two routine cognitive screening tools, namely MMSE and MoCA, with fitness to drive related-measures in individuals diagnosed with MCI and mild AD according to well-established diagnostic criteria *(3, 39)*. This factor renders originality to the current work, because previous relevant research comparing MMSE and MoCA *(25)* has assessed the role of cognitive impairment in a more general way without using strict criteria and detailed neuropsychological testing. Based on accumulated findings of previous research works, significant associations were expected to be observed between these two cognitive measures and various driving indexes. Additionally, given the important role of executive functioning on driving behavior *(40)*, we hypothesized that the MoCA test, due to its greater executive load as compared to the MMSE *(41)*, would be more effective for identifying associations with the fitness to drive related-measures that were applied in the current study.

METHODOLOGY

Paticipants

The current study included 44 patients with amnestic MCI (aMCI; mean age=69.1, SD=8.9), 23 patients with mild AD (mean age= 73.7, SD=6.8) and 30 cognitively intact individuals (mean age=65.9, SD=5.7). All participants underwent a comprehensive neurological and neuropsychological assessment. Diagnosis of MCI was based on the Petersen and Morris criteria

(2005) along with a score of ≤0.5 in the Clinical Dementia Rating Scale (CDR) *(42)*. Additionally, by applying the same criteria *(3)*, all MCI patients were classified as of the amnestic subtype. Diagnosis of mild AD was based on the McKhann et al. criteria *(39)* along with a score≤1 in the CDR. In order to participate in the study, additional strict criteria were required: a) a valid driving license, b) participants should be active drivers: driving at least once a week, driving at least 10km/week and count more than 2500km of driving, all three conditions within the last year, c) participants should be experienced drivers: more than three years licensed driving experience, d) no history of psychosis e) no significant motor or visual disorders f) no complaints of dizziness or nausea while in a moving vehicle, neither as a driver nor as a passenger, g) no record of traffic accidents, h) no evidence for alcohol or drug addiction. The clinical groups consisted of consecutive visitors of the Cognitive Disorders/Dementia Unit of the 2nd Department of Neurology at NKUA "Attikon" University General Hospital in Athens. The control group included family members or informants that visited our Unit during the data collection period of the study. The participation to the study was voluntary and informed consent was obtained from all the individuals that were included in the sample. Participants were informed about the nature and the phases of the study. They were ensured that their background information would remain confidential and would be used only for research purposes, and that they had the right to cease the procedure at any time. The current study was approved by the ethical committee of "Attikon" University General Hospital.

Procedure

The collection of data was divided in two Phases. During Phase-A, all the participants underwent a thorough neurological, neuropsychological and ophthalmological assessment. MMSE and MoCA were administered as a measures of the neuropsychological assessment. Both tests are brief, well accepted cognitive screening instruments that are used to evaluate the general cognitive ability. MMSE contains 30 items (maximum score: 30 points). Five cognitive functions are briefly assessed: a) orientation (time and space: 5 points each), b) memory (learning and delayed recall: 3 points each), c) attention (5 points), d) language (8 points), and e) constructional skills (1 point). MoCA is also a 30 points neuropsychological tool. Five specific cognitive domains are evaluated: a) attention/executive function: Trail Making Test (1 point), digit span (2 points), target detection (1 point), verbal fluency (1 point), abstraction (2 points) and serial seven subtraction (3 points), b) visuospatial ability: Clock Drawing (3 points) and copying a cube (1 point), c) language: object naming (3 points) and sentence repetition (2 points), d) memory: delayed recall of 5 previously presented words (5 points) and e) orientation: orientation questions (6 points).

In Phase-B, the driving simulator experiment was conducted. First, there was a 5-10 minutes practice session aiming to familiarize the participants with the simulation environment. Then, two driving sessions followed, with an overall duration of approximately 20 minutes. Each session represented a distinct driving surrounding, one taking place at an urban environment and the other taking place at a rural environment. The urban driving condition comprised of a total driving distance of 1.7 km, a dual carriageway at its bigger part, separated by guardrails, with 3.5m lane width and a speed limit of 60 km/h.

The rural driving condition consisted of a 2.1km driving route, two lanes with 3m width, no gradient inclination and mild horizontal carves and a speed limit of 70km/h. In both sessions traffic volume was moderate (average volume Q=300 vehicles per hour) and two unexpected incidents occurred on the roadway: in the urban environment there was a sudden appearance of a child chasing a ball or a vehicle leaving a parking position, while in the rural environment the unexpected appearance of an animal (donkey or deer). However, these incidents were scheduled at fixed points along the way. Phase-B, took place at the Department of Transportation Planning and Engineering of the National Technical University of Athens. The driving simulator was a Foerst FPF, validated against a real world environment *(43)*.

The indexes assessed for the current study from the driving simulator experiment were: a) the average speed in kilometers per hour, b) the lateral position of the vehicle (distance from the central road axis in meters), c) the headway distance with the preceding vehicle (mean headway in meters), d) the reaction time at the unexpected incidents (in milliseconds), e) the number of speed limit violations, and e) the accident probability.

RESULTS

The descriptive characteristics of the participants are presented in the Table 1. A One-way Analysis of Variance (ANOVA) was conducted in order to investigate possible differences between mild AD patients, aMCI patients and cognitively intact individuals in terms of age, years of education, performance on MMSE and MoCA as well as scores on the Geriatric Depression Scale (GDS) and the Functional Assessment Questionnaire (FAQ) (Table 1).

TABLE 1 Comparisons between aMCI and AD patients in demographic characteristics, MMSE, MoCA, GDS and FAQ

	HC (N=30)		MCI (N=44)		AD (N=23)		ANOVA		Post hoc comparisons with Bonferroni correction
	Mean	SD	Mean	SD	Mean	SD	*F*	*P*	
Age	65.9	5.7	69.1	8.8	73.1	6.3	5.97	.004	AD>HC**
Education	15.1	3.3	13.2	3.9	10.8	4.3	6.65	.002	AD<HC*
MMSE	29.3	.80	27.6	2.0	22.3	4.5	49.2	.000	AD<HC**, AD<MCI**, MCI< HC*
MoCA	26.2	1.8	22.4	3.3	15.7	5.3	56.8	.000	AD<HC**, AD<MCI**, MCI< HC**
GDS	2.1	2.5	2.3	2.0	2.7	1.8	.52	.597	
FAQ	.09	.30	.97	1.5	5.1	4.1	21.7	.000	AD<HC**, AD<MCI**

**p= .05, **p<.001*

Significant differences were observed between the control group and the mild AD group in the variables of age and educational level. Regarding the MMSE scores, significant differences were found between the three groups, where the group of patients with AD appeared to perform worse from all the other groups examined, while the aMCI patients had also a lower performance in comparison to cognitively intact individuals. Regarding performance in the MoCA test, significant differences were also found between the three groups, where mild AD patients had the worst performance, followed by the patients with aMCI and lastly by the cognitively intact individuals. Considering the FAQ, significant differences were observed between mild AD patients with both MCI patients and healthy elderly. More specifically, mild AD patients demonstrated significantly lower scores in the specific scale reporting functionality impairments. In GDS, non-significant differences were observed between the three groups.

Pearson r correlations were carried out in order to assess the association between the MMSE and MoCA performance with driving indexes for each group. The results for the cognitively intact individuals are presented in Table 2, whereas the correlations of the aMCI and the mild AD patients are presented in Tables 3 & 4 respectively.

TABLE 2 Correlations between MMSE, MoCA and Driving Indexes in cognitively intact individuals

Driving Indexes	Rural Area				Urban Area			
	MMSE		MoCA		MMSE		MoCA	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*
Average speed	.03	.86	-.11	.61	-.11	.63	-.17	.48
Lateral position	-.06	.77	-.20	.33	.02	.94	-.32	.18
Headway distance	-.02	.93	-.05	.79	.18	.45	.38	.10
Reaction time	-.04	.83	.09	.66	-.05	.86	.01	.97
Accident probability	-.29	.14	-.32	.12	.18	.45	-.15	.59
Speed limit violations	-.30	.13	-.20	.33	-	-	-	-

**p=.05. **p<.001*

TABLE 3 Correlations between MMSE, MoCA and Driving Indexes in aMCI patients

Driving Indexes	Rural Area				Urban Area			
	MMSE		MoCA		MMSE		MoCA	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*
Average speed	.01	.94	-.05	.77	-.01	.96	.09	.61
Lateral position	-.10	.55	-.33	.055	.22	.22	.18	.32
Headway distance	.02	.91	.04	.83	-.16	.38	.01	.94
Reaction time	-.33	.045*	-.42	.01*	-.78	.000**	-.47	.02*
Accident probability	-.34	.041*	-.046	.006*	-.56	.003*	-.47	.02*
Speed limit violations	-.23	.18	-.39	.02*	.20	.27	.34	.059

**p=.05. **p<.001*

TABLE 4 Correlations between MMSE, MoCA and Driving Indexes in mild AD patients

Driving Indexes	Rural Area				Urban Area			
	MMSE		MoCA		MMSE		MoCA	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*	*r*	*p-value*
Average speed	.41	.09	.48	.044*	.29	.26	.34	.21
Lateral position	.22	.37	.06	.79	.21	.43	-.04	.88
Headway distance	-.53	.024*	-.57	.014*	-.28	.29	-.26	.32
Reaction time	.07	.77	-.09	.69	-.16	.59	-.13	.68
Accident probability	.21	.39	.13	.61	-.54	.03*	-.53	.037*
Speed limit violations[a]	-	-	-	-	-	-	-	-

**p=.05. **p<.001*

No significant correlations were found between the MMSE, MoCA and the driving indexes in the group of cognitively intact individuals (Table 2). As regards aMCI patients, MMSE scores were significantly correlated with reaction time and the accident probability in both rural and urban environments, while non-significant correlations were observed in the remaining driving indices in neither rural nor urban areas (Table 3).

In the same group, performance in MoCA was also significantly correlated with reaction time and accident probability in both urban and rural areas (Table 3). Moreover, MoCA was significantly correlated with speed limit violations in the rural environment. No other significant correlations were observed between the MoCA performance and the rest of the driving indexes namely average speed, lateral position, headway distance in rural and urban areas as well as speed limit violations in the urban area.

Regarding the group of mild AD patients, MMSE performance significantly correlated with headway distance in the rural environment and with accident probability in the urban environment (Table 4). In addition, MoCA performance was significantly correlated with headway distance and average speed in the rural environment as well as with accident probability in the urban environment (Table 4). Non-significant correlations were observed between MMSE, MoCA and the rest of the driving indexes in the group of mild AD patients. No speed limit violations were observed in both rural and urban areas in the group of patients with mild AD.

DISCUSSION

The objective of the present study was to investigate in patients with aMCI and mild AD the magnitude of the associations that exist between two popular measures of general cognitive state, namely MMSE and MoCA, with a variety of indexes related to driving fitness that were obtained from a driving simulation experiment. In addition, a second goal of the current work was to explore whether the MoCA test would present stronger overall associations with driving performance than the most widely used MMSE. According to our knowledge, this study was the first that compared the magnitude of the associations of the MoCA and the MMSE with various driving indexes in a group of drivers with a clinical diagnosis of aMCI and mild AD that was based on well-established criteria *(3, 39)*. In the only previous work that investigated MoCA in comparison to MMSE regarding their associations with driving indexes in patients with cognitive impairment *(25)*, the sample was heterogeneous belonging to various neurological disorders and did not comprise a homogeneous clinical sample as in the case of the current study. In addition, the diagnosis of cognitive impairment was mainly based on the reason of referral without applying a detailed neuropsychological battery.

The driving evaluation for collecting information from distinct driving environments included both a rural and an urban scenario for the assessment of the following driving indexes: average speed, lateral position of the vehicle, head way distance, reaction time, accident probability and speed limit violations. According to our findings, both MMSE and MoCA were associated with crucial driving indexes that have an integral link with overall driving fitness. This pattern of findings is in line with previous research supporting the capacity of both *MMSE (19, 20, 22, 24, 27, 44)* and MoCA *(25, 38)* to provide meaningful information regarding the driving performance of clinical samples.

In particular for patients with aMCI, both neuropsychological instruments were associated with reaction time to unexpected incidents that occurred in both the rural and the urban driving scenario. In addition, performance on the MMSE and MoCA was significantly related with accident probability in both driving environments. Reaction time and accident probability are critical indexes regarding the safe operation of the vehicle and, therefore, the aforementioned associations could facilitate the effort for identifying those patients with problematic or questionable driving skills. Notably, the specific aforementioned associations regarding MMSE for patients with MCI have not been observed in previous studies, according to our knowledge. This was, also, the first study that observed in patients with aMCI the specific associations regarding the case of MoCA. In addition, in the group of drivers with aMCI the MoCA scores were significantly associated with speed limit violations in the rural area, while this was not the case for the MMSE. Thus, in patients with aMCI, MoCA appears to have a slight advantage as compared to MMSE regarding the number of significant associations that were observed with fitness to drive related-measures. Nonetheless, the MMSE, despite its more general nature and the limited number of items that are related to executive functioning, showed considerable associations with critical indexes of driving fitness, namely accident probability and reaction time.

In the mild AD group, headway distance in the rural area and accident probability in the urban area presented significant associations with both cognitive screening tests. However, the MoCA was also associated with average speed in the rural area, a finding that was not identified in the case of the MMSE. Hence, MoCA appears to have a slight advantage as compared to MMSE also in the case of patients with mild-AD.

Overall, the findings of the current work regarding both clinical groups showed a greater number of significant associations with driving indexes in the case of the MoCA as compared to the MMSE. However, the advantage of the MoCA relatively to MMSE appears to be weaker than what we expected because the MMSE also manifested significant associations of similar magnitude with crucial driving indexes, such as reaction time and accident probability. Hence, this pattern of findings partially supports our hypothesis that predicted a clear advantage of the MoCA as compared to the MMSE due to its greater executive load *(41)*. Therefore, an alternative approach that may take advantage at a greater extent of the executive-related nature of driving *(40)* is the application of specialized tests that focus on executive functioning instead of using measures that assess cognition in a more general way, even if they engage at some extent executive resources. An indicative neuropsychological test assessing specifically executive functioning that appears to be effectively associated with a variety driving indexes according to accumulating findings of previous research is the Trail Making Test *(1, 15, 18, 22, 45)*. Under this perspective, future studies could quantify the contribution of specialized measures on predicting various driving indexes by applying multivariate models that have the capacity to evaluate their effectiveness, after controlling for the shared amount of variance that is also explained by general cognitive measures, such as the MMSE and the MoCA.

Importantly, our findings indicate absence of significant associations between the driving variables and both MMSE and MoCA performance in the healthy elderly group. This pattern of findings may be explained by two complementary factors, namely the presence of ceiling effects regarding the level of performance as well as the limited amount of inter-individual variation that was observed in the group of cognitively healthy individuals in the case of both cognitive instruments. Hence, MoCA and MMSE appear to be effective for detecting associations with fitness to drive related-measures in patients with MCI or mild-AD but not in the case of the cognitively healthy individuals. This finding is in line with previous studies that also detected non-significant associations between MMSE performance and driving indexes in groups of healthy elderly individuals *(26, 27, 28, 29)*.

In conclusion, the current findings add to the existing knowledge regarding the utility of the MMSE and the MoCA for detecting associations with driving indexes in patients with aMCI and mild AD. Overall, the MoCA appears to have a slight advantage as compared to the MMSE. Nonetheless, the MMSE, similarly to the MoCA, revealed associations of considerable strength with crucial indexes related to driving fitness, such as reaction time and accident probability. Therefore, these two measures of general cognitive functioning, with a relative advantage of the MoCA, provide information that may facilitate the effort for detecting those patients with aMCI and mild AD with problematic driving skills. However, for increasing the accuracy of recommendations related to driving fitness it is recommended that measures such as the MoCA and the MMSE should not be used in a sole fashion but instead as elements of a broader evaluation that may be accompanied by specialized neuropsychological tests or even actual driving when this is deemed necessary.

REFERENCES

1. Mathias, J. L., & Lucas, L. K. (2009). Cognitive predictors of unsafe driving in older drivers: a meta-analysis. *International Psychogeriatrics, 21*(4), 637–653.
2. Frittelli, C., Borghetti, D., Iudice, G., Bonanni, E., Maestri, M., Tognoni, G., et al. (2009). Effects of Alzheimer’s disease and mild cognitive impairment on driving ability: a controlled clinical study by simulated driving test. *International Journal of Geriatric Psychiatry, 24,* 232–238.
3. Petersen, R. C., & Morris, J. C. (2005). Mild cognitive impairment as a clinical entity and treatment target. *Archives of neurology*, *62*(7), 1160-1163.
4. Brown, L. B., & Ott, B. R. (2004). Driving and Dementia: A Review of the Literature. *Journal of Geriatric Psychiatry and Neurology, 17*(4), 232-240.
5. Dawson, J. D., Anderson, S. W., Uc,E. Y., Dastrup,E., & Rizzo, M. (2009). Predictors of driving safety in early Alzheimer disease. *Neurology, 72,* 521–527.
6. Tuokko, H., Tallman, K., Beattie, B. L., Cooper, P., & Weir, J. (1995). An Examination of Driving Records in a Dementia Clinic. *Journal of Gerontology, 50*(3), 173-181.
7. Wagner, J. T., Müri, R. M., Nef, T., & Mosimann U. P. (2011). Cognition and driving in older persons. *Swiss Medical Weekly,140*

8. Drachman, D. A., & Swearer, J. M. (1993). Driving and Alzheimer's disease: the risk of crashes. *Neurology, 43,* 2448– 2456.
9. Carr, D., Duchek, J., & Morris, J. C. (2000). Characteristics of motor vehicle crashes of drivers with dementia of the Alzheimer type. *Journal of the American Geriatrics Society*, *48*(1), 18-22.
10. Trobe, J. D., Waller, P. F., Cook-Flannagan, C. A., Teshima, S. M., & Bieliauskas, L. A. (1996). Crashes and Violations among Drivers with Alzheimer Disease. *Arch Neurology, 53,* 411-416.
11. Perkinson, M. A., Berg-Weger, M. L., Carr, D. B., Meuser, T. M., Palmer, J. L., Buckles, V. D., Morris, J. C. (2005). Driving and dementia of the Alzheimer type: beliefs and cessation strategies among stakeholders. *The Gerontologist*, *45*(5), 676-685. doi: 10.1093/geront/45.5.676
12. Ernst, J., Krapp, S., Schuster, T., Förstl, H., Kurz, A., & Diehl-Schmid, J. (2010). [Car driving ability of patients with frontotemporal lobar degeneration and Alzheimer's disease]. *Der Nervenarzt*, *81*(1), 79-85.
13. Hird, M. A., Egeto, P., Fischer, C. E., Naglie, G., & Schweizer, T. A. (2016). A Systematic Review and Meta-Analysis of On-Road Simulator and Cognitive Driving Assessment in Alzheimer's Disease and Mild Cognitive Impairment. *Journal of Alzheimer's Disease*, (Preprint), 1-17.
14. Devlin, A., & McGillivray, J. A. (2014). Self-regulation of older drivers with cognitive impairment: A systematic review. *Australasian journal on ageing*, *33*(2), 74-80.
15. Devlin, A., McGillivray, J., Charlton, J., Lowndes, G., & Etienne, V. (2012). Investigating driving behaviour of older drivers with mild cognitive impairment using a portable driving simulator. *Accident Analysis and Prevention, 49,* 300– 307.
16. Snellgrove, C. A. (2005). *Cognitive screening for the safe driving competence of older people with mild cognitive impairment or early dementia*. ATSB.
17. Wadley, V. G., Okonkwo, O., Crowe, M., Vance, D. E., Elgin, J. M., Ball, K. K., & Owsley, C. (2009). Mild cognitive impairment and everyday function: an investigation of driving performance. *Journal of Geriatric Psychiatry and Neurology, 22*(2), 87-94.
18. Kawano, N., Iwamoto, K., Ebe, K., Suzuki, Y., Hasegawa, J., Ukai, K., ... & Ozaki, N. (2012). Effects of mild cognitive impairment on driving performance in older drivers. *Journal of the American Geriatrics Society*, *60*(7), 1379-1381.
19. Uc, E. Y., & Rizzo, M. (2008). Driving and Neurodegenerative Diseases. *Current Neurology and Neuroscience Reports, 8,* 377-383.
20. Fox, G. K., Bowden, S. C., Bashford, G. M., & Smith, D. S. (1997). Alzheimer's Disease and Driving: Prediction and Assessment of Driving Performance. *Journal American Geriatrics Society, 45*(8), 949-951.
21. Papageorgiou, S.G., Beratis, I., Kontaxopoulou, D., Fragkiadaki, S., Pavlou, D., Yannis, G., "Does the diagnosis of Alzheimer's Disease imply immediate revocation of a driving license?" International journal of clinical neurosciences and mental health*, Special Issue on Controversies in Neurology*. Accepted for publication (August 2016)
22. Youl, C. S., Shin, L. J., & Young, S. A. (2014). Cognitive test to forecast unsafe driving in older drivers: Meta-analysis. *NeuroRehabilitation, 35,* 771–778.
23. Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 2,* 189–198.
24. Herrmann, N., Rapoport, M. J., Sambrook, R., Hébert, R., McCracken, P., & Robillard, A.

(2006). Predictors of driving cessation in mild-to-moderate dementia.*Canadian Medical Association Journal, 175*(6), 591-595.

25. Hollis, A. M., Duncanson, H., Kapust, L. R., Xi, P. M., & and O'Connor, M. G. (2015). Validity of the Mini-Mental State Examination and the Montreal Cognitive Assessment in the Prediction of Driving Test Outcome. *Journal American Geriatric Society, 63,* 988–992.
26. Joseph, P. G., O'Donnell, M. J., Teo, K. K., Gao, P., Anderson, C., Probstfield, J. L. et al. (2014).The Mini-Mental State Examination, Clinical Factors, and Motor Vehicle Crash Risk. *Journal American Geriatrics Society, 62,* 1419–1426.
27. Lesikar, S. E., Gallo, J. J., Rebok, G. W., & Keyl, P. M. (2002). Prospective study of brief neuropsychological measures to assess crash risk in older primary care patients. *J Am Board Fam Pract, 15*(1)*,* 11-19.
28. Diegelman, N. M., Gilbertson, A. D., Moore, J. L., Banou, E., & Meager, M. R. (2004). Validity of the Clock Drawing Test in predicting reports of driving problems in the elderly. *BMC Geriatrics, 4*(10).
29. Wood, J. M., Horswill, M. S., Lacherez, P. F., & Anstey, K. J. (2013). Evaluation of screening tests for predicting older driver performance and safety assessed by an on-road test. *Accident Analysis & Prevention*, *50*, 1161-1168.
30. Ferreira, I. S., Simões, M. R., & Marôco, J. (2012). The Addenbrooke's Cognitive Examination Revised as a potential screening test for elderly drivers. *Accident Analysis & Prevention*, *49*, 278-286.
31. Nasreddine, Z. S., Phillips, N. P., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., et al. (2005). The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool for Mild Cognitive Impairment. *Journal American Geriatrics Society, 53*(4), 695–699.
32. Markwick, A., Zamboni, G., & de Jager, C. A. (2012) Profiles of cognitive subtest impairment in the Montreal Cognitive Assessment (MoCA) in a research cohort with normal Mini-Mental State Examination (MMSE) scores. *Journal of Clinical and Experimental Neuropsychology, 34*(7), 750-757.
33. Freitas, S., Simoes, M. R., Alves, L., & Santana, I. (2013). Montreal Cognitive Assessment Validation Study for Mild Cognitive Impairment and Alzheimer Disease Alzheimer. *Alzheimer Disease and Associated Disorders, 27*(1), 37-43.
34. Smith, T., Gildeh, N., & Holmes, C. (2007). The Montreal Cognitive Assessment: Validity and utility in a memory clinic setting. *The Canadian Journal of Psychiatry, 52*(5), 329–332.
35. Dong, Y., Venketasubramanian, N., Chan, B. P. L., Sharma, V. K., Slavin, M. J., Collinson, S. L., ... & Chen, C. L. H. (2012). Brief screening tests during acute admission in patients with mild stroke are predictive of vascular cognitive impairment 3–6 months after stroke. *Journal of Neurology, Neurosurgery & Psychiatry*, *83*(6), 580-585.
36. Zadikoff, C., Fox, S. H., Tang-Wai, D. F., Thomsen, T., de Bie, R. M. A., Wadia, P., et. al. (2008). A comparison of the Mini Mental State exam to the Montreal Cognitive assessment in identifying cognitive deficits in Parkinson's disease. *Movement Disorders, 23*(2), 297–299.
37. Crizzle, A. M., Classen, S., Bédard, M., Lanford, D., & Winter, S. (2012). MMSE as a predictor of on-road driving performance in community dwelling older drivers. *Accident Analysis and Prevention, 49,* 287– 292
38. Esser, P., Dent, S., Jones, C., Sheridan, B. J., Bradley, A., Wade, D. T., et. al. (2015). Utility of the MOCA as a cognitive predictor for fitness to drive. *J Neurol Neurosurg Psychiatry, 0,* 1–2.

39. McKhann, G. M., Knopman, D. S., Chertkow, H., Hyman, B. T., Jack, C. R., Kawas, C. H., ... & Mohs, R. C. (2011). The diagnosis of dementia due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's & dementia*, *7*(3), 263-269.

40. Asimakopulos, J., Boychuck, Z., Sondergaard, D., Poulin, V., Ménard, I., & Korner-Bitensky, N. (2012). Assessing executive function in relation to fitness to drive: A review of tools and their ability to predict safe driving. *Australian occupational therapy journal*, *59*(6), 402-427.

41. Dong, Y., Lee, W. Y., Basri, N. A., Collinson, S. L., Merchant, R. A., Venketasubramanian, N., et al. (2012). The Montreal Cognitive Assessment is superior to the Mini–Mental State Examination in detecting patients at higher risk of dementia. *International Psychogeriatrics, 24*(11), 1749–1755.

42. Morris, J. C. (1993). The Clinical Dementia Rating (CDR): current version and scoring rules. *Neurology*, *43*(11) 2412-2414

43. Yannis, G., Papantoniou, P., & Nikas, M. (2015, October). Comparative analysis of young drivers behavior in normal and simulation conditions at a rural road. In *Proceedings of the 5th International Conference on Road Safety and Simulation, Universities of Central Florida and Tennessee, Orlando, Florida*.

44. Uc, E.Y., Rizzo, M., Anderson, S. W., Shi, Q., & Dawson, J. D. (2005) Driver landmark and traffic sign identification in early Alzheimer's disease. *J Neurol Neurosurg Psychiatry, 76,* 764-768.

45. Ott, B. R., Heindel, W. C., Whelihan, W. M., Caron, M. D., Piatt, A. L., & DiCarlo, M. A. (2003). Maze Test Performance and Reported Driving Ability in Early Dementia. *Journal of Geriatric Psychiatry and Neurology, 16*(3), 151-155.