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PEDESTRIAN’S BEHAVIOR WITH MILD ALZHEIMER DISEASE OR MILD COGNITIVE IMPAIRMENT AND HOW COULD IT BE PREDICTED BY NEUROPSYCHOLOGICAL MEASURES.

MASTER THESIS

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Pedestrian's behavior with mild Alzheimer Disease or Mild Cognitive Impairment and how could it be predicted by neuropsychological measures.

Abstract

Objective: The aim of the current study was to investigate if the neuropsychological tests examining attentional, executive and visuospatial abilities could be a predictive factor of the pedestrian behavior of patients with mild Alzheimer Disease or Mild Cognitive Impairment as well as to explore how these patients behave as pedestrians (velocity, orientation, crossing in junctions) in contrast to cognitive intact elderly.

Method: Fifteen participants with mild AD, 15 patients with MCI and 15 healthy elderly pedestrian were asked to take a short walking trip outside of the University General Hospital ''Attikon'' in Greece, allowing recording their behavior in real – life traffic conditions. They also underwent a neuropsychological evaluation.

Results: According to the applied One – Way ANOVA analysis the three groups differ significantly in the variables of orientation and velocity, but they did not differ in crossing behavior. AD patients presented to be more disorientated and slower in contrast with MCI patients and healthy elderly. Finally, attentional, executive and visuospatial functions were more strongly associated with crossing decisions in junctions and walking speed than with the orientation ability.

Conclusion: Our findings suggest that neuropsychological tests measuring attention, executive and visuospatial abilities seem to play a more important role in prediction of pedestrian behavior of AD and MCI patients, especially in crossing and walking speed.

1. Introduction

Pedestrian accidents constitute a major road safety problem worldwide. Previous studies have pointed out that a great number (40% in Europe and 52% in Greece) of older pedestrians (> 65 years old) are fatally injured in road accidents in Europe as well as in Greece (ELSTAT, 2016). Street walking is both a sensorimotor and cognitive task as it needs balance and to remember your destination and the names of roads you have to take (Oxley, Charlton, Fildes, 2005). Often is viewed as an automated, rhythmic motor task (Hausdorff , Yogev, Springer, Simon, Giladi, 2005). For this reason, cognitive and executive function associated with dementia (Hauer, et al., 2003) may have functional implications for older pedestrian performance as they affect attention, memory, accuracy of movement, risk perception, ability to perform novel tasks and awareness of their compromised cognitive condition, skills necessary for safe negotiation of traffic and road-crossing decisions (Holland & Rabbitt, 1992; Lajoie, Teasdale, Bard & Fleury, 1996). The elderly appear to be more vulnerable in cognitive deficits as it is estimated that about 10% of individuals aged over 65, suffer from some form of dementia about 90% of which is due to Alzheimer's disease, either alone or in combination with vascular or other degenerative disease (Mckhann et al., 2011; Dubois et al., 2014). Despite a large body of research in normal pedestrians, elderly or younger ones, there is a lack of knowledge regarding the effect of cognitive impairment on pedestrian performance in patients with Alzheimer Disease (AD) or Mild Cognitive Impairment (MCI) which represents a transitional stage between normal ageing and dementia, with none or minimal deficits in everyday activities especially more complex tasks (Petersen,2004 ; Albert et al. 2011). Both are characterized by memory disorders. However, in AD deficits in visuospatial ability, complex attentional processes, executive functions and some forms of abstract reasoning and problem solving some of which will be crucial for the safety of pedestrians. It has been shown that memory deficits increase the risk for the elderly pedestrian to be involved in crash accidents or in unsafe street - crossing decisions as they prevent them from successfully performing even the most basic daily tasks such as driving and walking (Oxley, Charlton, Fildes, 2005). Deficits in executive functions may play a significant role in the ability of elderly pedestrian to adjust walking pace while crossing roads in a complex traffic environment where attentional demands are great.

According to a study that examined the brains of elderly people who died in road accidents in conjunction with traffic reports, Neurofibrillary Tangles (NFT), which constitute a neuropathologic hallmark of AD, were associated with specific road accident conditions; older pedestrians with elevated NFT were more likely to be partly responsible for the accident, had an accident in uncomplicated conditions as well as being hit in the nearby lane or by a car.

In a more recent research, Dommes et al. 2015 investigated the influence of the stage of dementia on the safety of the elderly pedestrians using a pedestrian simulator. Pedestrians with mild dementia were more likely to take road crossing decisions that would lead to potential accidents as well as starting the transit taking into account only the safety of the nearby lane and ignoring the traffic in the instant lane. In addition, Performance of the Useful Field Of View test - a measure of speed of processing in visual- attention tasks) of these individuals in terms of processing speed and visual attention capabilities could significantly predict virtual collisions in the pedestrian simulator.

Despite the fact that signalized junctions provide pedestrians a protective and safety crossing phase, most pedestrians tend to choose the available traffic gaps for crossing (Hamed, 2001) or they cross diagonally in order to save time and distance (Chu, Guttenplan, & Baltes, 2003). Moreover older pedestrians seem to demonstrate slower walking speed exposing themselves to traffic for longer periods of time when they are crossing the street (Lobjois, Cavallo, 2007). Further, elderly pedestrians with dementia make biased decisions about the near lane and they seem to misjudge the distance of approaching cars (Dommes et al., 2015, Lobjois, Cavallo, 2009) that could be related to perceptual and cognitive deficits. Finally, pedestrians with early AD became lost more frequently in familiar environment within two years after the onset of AD as Tu, & Pai, 2006 found or having a difficulty in wayfinding (Satalich, 1995). The impairment of spatial cognition and the degradation of hippocampus caused by AD may seriously affect the wayfinding process. Based on the above, Ou,Lin,Fang & Liu (2013) used computer software to create a virtual environment to simulate a figure walking in the real world in effort to evaluate the interface design of the wayfinding assistance systems. They found that wayfinding abilities were worse in the AD group compared with the MCI group as well as the normal elderly . However, the use of maps could be beneficial for both AD and MCI patients.

The overrepresentation of elderly in pedestrian crash statistics increases the interest to investigate the effects of pathologic ageing on road – crossing behavior. There are significant deficits in the knowledge and understanding of the impact and the extent of functional impairment on pedestrian behavior, especially in those with dementia (Oxley, Charlton, Fildes, 2005). The studies that have been conducted so far have examined the behavior of older people in pedestrian simulators, which has given us an interest in testing their behavior in a real life environment.

The main aim of the present study was to investigate the differences between normal elderly and patients with mild AD or MCI in parameters of pedestrian behavior such as orientation, crossing in junctions and their speed in real-life conditions. Based on the existing literature, patients with AD were expected to have greater difficulty in street – crossing and in wayfinding as well as lower speed than healthy old pedestrians. In addition, in order to investigate whether neuropsychological tests could serve as predictive factors of the pedestrian's behavior that could potentially prevent them from possible fatal accidents. Currently, few studies have been conducted exploring the association of neuropsychological tests and pedestrian performance using pedestrian simulators and they used Useful Field of View (UFOV) test (Dommes et al., 2015), Stroop test (Hausdorff et al., 2004; Melzer & Oddsson , 2004) and the Trail Making Test (Ble et al., 2005).

However, the fact that this research will be carried out in real traffic conditions offers greater ecological validity and the ability to observe the actual behavior of people on the road, that simulator cannot provide. For this reason, as no relevant study has not been carried out in real conditions this research has a significant advantage that will also be a key element of our measurements.

2. Methods

2.1. Participants

The sample of the current prospective study included 15 patients with mild AD, 15 patients with amnestic MCI and 15 cognitively intact older adults matched for age and education. The control group consisted of individuals who did not report any history of neurological or psychiatric disorders or cognitive complaints, and had a Mini-Mental State Examination score over 27.

All participants were recruited from the Cognitive Disorders/Dementia Unit at the Second Department of Neurology at University and General Hospital "Attikon" (UGHA). The diagnosis of the patients was made according to the established clinical criteria for AD (McKhann et al., 2011) and MCI (Petersen 2004) respectively. The patients with AD had mild dementia, measured by the CDR (equal to 1) whereas patients with MCI had a CDR score equal to 0.5 (Morris, 1993).

In order to participate in the study, patients had to meet specific inclusion and exclusion criteria: (a) both patients and healthy old adults had to be able to walk autonomously, without the assistance of a caregiver or a device, (b) all participants had to be over 55 years old.

Exclusion criteria were a) other neurologic or psychiatric disorders, (b) a CDR score greater than 1.0, (c) difficulty in movement, (d) deficits of visual acuity or hearing ability. Informed consent was obtained from all participants and their caregivers.

The study was approved by the institutional ethics committee of the hospital.

2.2 Procedure

2.2.1. Medical/ Neurological Assessment

Medical assessment involved the collection of a detailed medical history, as well as a standardized neurological and ophthalmological examination included MRIs evaluation and biochemical analysis in order to exclude other types of dementia. In addition, all participants completed a wide range of scales that covered the following domains: (a) functionality and daily activities (Clinical Dementia Rating scale; Morris, 1993; Instrumental Activities of Daily Living; Lawton & Brody, 1969), and (b) motor ability. This extended medical/neurological examination was conducted by the same behavioral neurologist who classified the participants in the following clinical categories: (a) Cognitively (Mentally) Healthy, (b) diagnosis of amnestic MCI (Petersen & Morris, 2005), and (c) diagnosis of Alzheimer's disease (McKhann et al., 2011).

2.2.2. Neuropsychological Evaluation

The neuropsychological assessment included the following tests: Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975, Fountoulakis, Tsolaki, Chantzi, Kazis, 2000), 5 Object Test (Papageorgiou, Economou, Routsis, 2013), Clock Drawing Test (CDT; Royal, Cordes & Polk, 1978), Trail Making Test (TMT; Reitan, 1979; Zalonis et al., 2008), Frontal Assessment Battery (FAB; Dubois et al. 2000), Hopkins Verbal Learning Test – Revised (HVLT-R; Brandt & Benedict, 2001), Digit Span (Backwards & Forwards; Wechsler Adult Intelligence Scale- Revised (WAISR)), Judgment of Line Orientation (JLO; Benton et al., 1994).

2.2.3. Walking Task (Route)

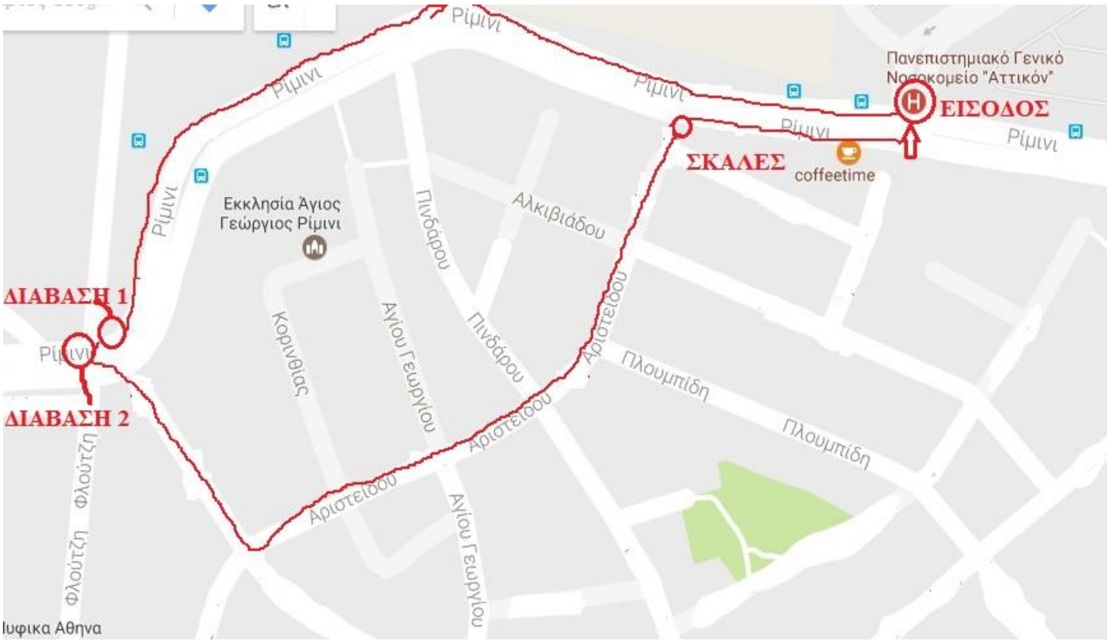
Pedestrian behavior was studied in a real – life environment, especially in a configured route by the National Technological University of Athens (NTUA) - Department of Transportation Planning and Engineering. The first wave of data collection took place in the period of September – December 2017 concerning 20 participants. The second wave of data collection took place in the period of January – April 2018 concerning 25 more participants. Despite the lower temperature in autumn and early December period, all the survey trips executed on good weather, sunny and dry conditions.

Participants were informed for the purpose of the experiment, which was explained to them as ‘‘an experiment aiming to record and understand pedestrian walking and crossing behavior and their interaction with traffic, in order to improve pedestrian safety in urban areas”. Consequently, they were given instructions regarding the walking task, i.e. the origin trip, destination and trajectory to be walked which was also indicated on a map of the survey area as well as the duration of the task. This task has as start and termination point the entrance of UGHA. All participants had to hold a destination map where cross junctions and the roads were pointed out. Furthermore, they were informed that they would be followed along this trip by an observer, who would be recording their behavior, such as walking speed, crossing locations, orientation mistakes, as well as the traffic conditions during the trip. It was elucidated to participants that they could make this route as they would usually do, at their preferred walking pace, and also that they were free to answer their mobile phone during the task. In addition, it was clarified that they were able to ask the observer when they were not sure about the instructions or if they were tired.

Once the participant started the trip, the observer followed him or her in the distance of approximately 20 meters, in order to have a sufficient view of the participants' behavior and remain unobtrusive during the task. This happened in order to minimize the effect of the researcher presence on pedestrians' behavior. The characteristics of the trips in terms of street names and traffic control available in each case needed to be recorded once and were the same for all participants. In contrast, the characteristics concerning the walking and crossing behavior of the participants were recorded in real time conditions.

The parameters can be further detected into: 1) walking speed, 2) orientation (how many times they cannot remember where they had to go and asking the observer) 3) number and duration of crossing attempts, as well as 3a) crossing location (junction or mid-block) and crossing type (diagonal) and 3b) signal display (red/green). The observer recorded these data for each walking task while following the participant, by a video recording in order to have a complete view of their mistakes in pedestrian behavior.

Figure 1. Map of the route that all the participants had to be consulted during the walking task.



3. Statistical Analysis

The statistical analysis was carried out by using SPSS v20.0 statistical software (SPSS, Inc., Chicago, Il). The level of statistical significance was set at the level of <0.05.

Correlation and regression analyses were then conducted to determine whether impairment of attention, visuospatial and executive functions was associated with an increased risk of dangerous pedestrian behavior.

4. Results

The demographic data of the AD, MCI and control group are summarized in Table 1 of the variables of gender, age, years of education for the 3 groups. One – Way ANOVA was conducted in order to see the differences among their demographic data. The participants did not differ significantly according to years of education and age, whereas they differ significantly according to gender.

Table 1. Demographic characteristics of the participants

	AD Patients (N=15)		**MCI Patients** (N=15)		**Controls** (N=15)		**ANOVA**	
	Mean	SD	Mean	SD	Mean	SD	*F*	*P*
Gender(m/f)	13/2		1.47		1.53			.053[a]
Age	77.27	5.09	73.27	5.31	74.93	4.46	2.45	.098
Education	11.53	3.85	10.73	4.65	11.60	4.08	.197	.822

[a] For the variable of gender we used chi- square analysis.

One – way ANOVA is used to determine if there were differences in pedestrian behavior between the groups. The orientation had a statistically significant difference [*F(2,44)= 15.917, p=.000* between the 3 groups, as well as velocity *F(2,44)= 6.711, p=.003*]. Post – hoc analyses with Tukey comparisons revealed that the AD patients had a worse performance in terms of orientation when compared to MCI patients (p=.002) and healthy elderly (p=.000). In contrast, MCI patients seem to not differ significantly from the control group (p=.184). Regarding to the variable of velocity, AD and MCI patients had slower walking speed (p=.011 and p=.007 respectively) compared to the control group, but there were not significant differences for the AD compared to MCI group (p=1.00). Non-significant results were observed for the other two variables namely signal display, crossing and the three groups. Subsequently, Table 2 presents the differences in the variables of pedestrian behavior expressed in percentiles (mean values and SDs) in cognitively healthy participants and patients with AD or MCI.

Table 2. One – way (ANOVA) analysis for the differences between the groups in the variables of pedestrian behavior.

	AD Patients (N=15)		**MCI Patients** (N=15)		**Controls** (N=15)		**ANOVA**		**Post hoc comparisons with Tukey correction**
	Mean	SD	Mean	SD	Mean	SD	*F*	*P*	
Orientation	1.13	.31	-1.13	.31	1.73	.31	15.91	.000	AD<MCI**,AD<CT**
DBC	.73	.53	-.73	.53	-.13	.53	1.07	.353	
DBL	.33	.54	-.33	.54	.66	.54	.749	.479	
Velocity	.043	.27	-0.43	.27	.84	.27	6.71	.003	AD<CT**, MCI<CT**

Note: DBC= Dangerous Behavior Cross, DBL= Dangerous Behavior Lights
*p<.05, **p<.001

The Pearson and Spearman' rho correlation were conducted in order to investigate the association between pedestrian performance and cognitive tests related to attention, visuospatial and executive functions in the group of AD and MCI. It is important to note that for the variables of orientation and velocity were run Pearson's correlations as they are two continuous variables. More specifically, there was a significant positive correlation between velocity and FAB (r=.580, p=.023), but none of these tests showed significant correlation in terms of orientation in regards to the AD group. However, with regard to the orientation and velocity of MCI group there were not any significant correlations with the neuropsychological test and these two variables. As far as the variables of signal display and crossing are concerned, Spearman rho correlations are used in order to evaluate relationships involving ordinal variables due to the four junctions that the participants had to cross. Table 3 presents the correlations that the group of AD patients had between the variables of pedestrian behavior and the neuropsychological tests. In the MCI group, no significant correlations between these two variables and the neuropsychological tests were observed.

Table 3. Spearman's rho and Pearson correlations between neuropsychological tests and measurements of pedestrian behavior for the AD group**.**

Neuropsychological Tests	**Dangerous Behavior Lights**		**Dangerous Behavior Cross**		**Velocity**		**Orientation**	
	r	p-value	R	p-value	R	p-value	r	p-value
MMSE	-.46	.087	-.65	.008**	-.02	.943	-.35	.193
DS(back)	-.69	.004**	-.75	.001**	-.09	.747	-.16	.566
5 Object (DR)	-.71	.003**	-.64	.010**	-.14	.629	.34	.211
JLO	-.34	.213	-.66	.007**	.21	.446	-.49	.061
FAB	-.02	.933	.28	.303	.59	.023*	-.17	.537

Note: MMSE =Mini Mental State Examination; DS (back)= Digit Span (backwards); 5 Object(DR)= 5 Object (Delayed Recall) ; JLO= Judgment of Line Orientation; FAB= Frontal Assessment Battery
*p = .05. **p < .001.

In order to investigate what extent pedestrian behavior is associated with tasks engaging attention, visuospatial and executive resources, multiple regression models were conducted between the neuropsychological test and the measures of pedestrian behavior (orientation, signal display, crossing and velocity). Table 4 presents the results from the multiple regressions that conducted in relation to the pedestrian performance and especially the crossing behavior and the signal displays in the AD patients and not with the other two variables of orientation and velocity as they did not have significant association with the neuropsychological tests.

Table 4. Multiple regressions of neuropsychological test assessing attention, visuospatial and executive functions for the AD group.

Neuropsychological Tests	**Dangerous Behavior Cross**				**Dangerous Behavior Lights**			
	B	SE B	Β	*p*	B	SE B	β	*P*
MMSE	-.10	.16	-.160	.543	-.11	.17	-.188	.520
DS(back)	-1.74	.37	-.790	.000**	-1.4	.45	-.661	.010*
JLO	-.05	.08	-.180	.493	. 09	.09	.296	.318
5Object(DR)	.04	.21	.041	.857	-.18	.22	-.205	.429
R^2		.62				.53		

Note: MMSE =Mini Mental State Examination; DS (back)= Digit Span (backwards); JLO= Judgment of Line Orientation; 5 Object(DR)= 5 Object (Delayed Recall)
*p = .05. **p < .001.

In particular, for the AD group, MMSE, Digit Span (Backwards), 5 Object (Delayed Recall) and JLO were associated with the performance in crossing while 5 Object (Delayed Recall) and Digit Span (Backwards) was related with the performance in signal display. A multiple linear regression analysis was performed to determine the best predictor, or subgroup of predictors, of the variance in crossing. The 3 cognitive ability measures were automatically entered one at a time, using the stepwise method. The input order was determined by the variable that resulted in the greatest R^2 increase, given the variables already entered into the model. Each variable that was significantly associated at the 0.05 level was included, and the nonsignificant ones were discarded. The model was significant, F(1,13)=21.64 p=.000. The results revealed that threshold scores on Digit Span (Backwards) measuring working memory as the only significant cognitive predictor of crossing decisions, accounting for 62% of the variance in crossing. Similarly, a multiple linear regression was run for the variable of signal display in order to determine the best predictor. The model was significant, F (1,13)=14.75, p=002. The results revealed that scores on Digit Span (Backwards) as the only significant cognitive predictor of crossing decisions, accounting for 53% of the variance in signal display.

In case of velocity measurements single regression model was conducted between FAB scores and velocity. The model was significant, F (1,13)=6.60, p=.023.This means that scores on FAB measuring executive functions, was the only cognitive predictor of velocity, accounting for 33%.

Regarding the group of MCI patients only the 5 object Test and especially the delayed recall was associated with both the performance of signal displays and crossing. A single regression model was run between the neuropsychological test and each variable of crossing. The model was significant for signal display F(1,13)=10.076, p=.007 and for crossing F(1,13)=10.231, p=.007. The results revealed that scores on 5 Object Test (delayed recall) measuring visuospatial abilities was the only significant cognitive predictor of crossing decisions, accounting for 44% of the variance of crossing and 46% respectively of the variance of signal display. The variable of orientation did not show significant results with none of these neuropsychological tests neither for the AD group or MCI. Table 5 presents the prediction of street – crossing behavior and the decisions on signal display by 5 Objects Test (Delayed Recall) for the MCI. It is important to note that in this table the variables of orientation and velocity were not conclude as they had no association with these neuropsychological tests.

Table 5. Simple regression models of neuropsychological test assessing visuospatial function for the MCI group.

Neuropsychological Tests	**Dangerous Behavior Cross**				**Dangerous Behavior Lights**			
	R^2	B	F	*P*	R^2	B	F	*P*
5Object(DR)	.44	-.38	10.23	.007**	.44	-1.64	10.18	.007**

Note: 5 Object(DR)= 5 Object (Delayed Recall)
*p = .05. **p < .001.

5. Discussion

According to our knowledge, this is the first study that used a real – life environment for the evaluation of pedestrian behavior. The purpose of the present study was to examine the differences in pedestrian behavior among AD, MCI patients and cognitively intact individuals. For the purpose of the study, an objective measurement of pedestrian behavior was obtained through walking on real – life conditions. The results of this study indicate that, in comparison with their healthy counterparts, patients with AD present significant difficulties in wayfinding in real – life conditions, although they had a destination map. Also, compared with healthy old participants, elderly pedestrians with mild AD or MCI had significantly longer walking times. Despite the fact that pedestrians with AD were slower than healthy pedestrians, no significant differences were found in terms of velocity between AD and MCI patients. More importantly, no group differences were observed in street – crossing decisions and signal display, something that did not point out dementia – specific crash situations like the ones revealed by Gorrie et al (2008) and Dommes et al’s (2015) analyses. The results of Gorrie and colleagues (2008) revealed that pedestrians with moderate Neurofibrillary Tangles (NFT) may be associated with specific crash situations compared to older pedestrians with no, or low NFT. Moreover, Dommes et al (2015) demonstrated that the mild-dementia group was more likely than the control group to make decisions that led to collisions with approaching cars, especially when the traffic was coming from two directions and they were in the far lane.

Our findings agree with those of previous studies that indicate deficits in wayfinding due to Alzheimer's disease (Tu and Pai,; 2006, Chiu et al., 2004; Ou,Lin,Fang & Liu ,2013) as well as a slower walking speed in those with AD or MCI than in cognitive intact individuals (Sheridan et al. ,2003; Camicioli et al., 1997). For example, a recent study by Ou, Lin, Fang & Liu, (2013) exploring a pedestrian navigation system for dementia patients, found that AD patients performed worst in all conditions of wayfinding followed by the MCI group and the controls. Also their study showed that cognitive tests engaging visuospatial and executive functions had a significant correlation with wayfinding performance. A study by Tu and Pai (2006) demonstrated that AD patients had a definite destination in mind when they first became lost after the onset of the disease, which related with the role of hippocampus in navigation system. In addition, from the findings of Chiu et al. (2004), it appears that attentional impairments, consisting of distractibility, impulsivity, and executive function problems, significantly predict the "Getting lost behavior" in familiar and unfamiliar environments.

Similarly, a number of studies demonstrated significant relationship between walking speed and deficits in patients with AD or MCI. For instance, a study by Camicioli et al. (1997) indicated that AD group slowed more than young-old and old-old groups, who did not significantly differ from each other, during dual task performance. Moreover, Sheridan et al. (2003), replicate the previous findings, as they showed that participants walked slowly and with introduction of dual task walking markedly influenced gait. According to the authors, as cognitive function decreases, the ability to maintain a stable gait while performing a simple secondary task decreased in parallel. In another more recent study by Callisaya et al. (2017), participants were classified into cognitive stages (cognitively healthy, mild cognitive impairment, mild and moderate dementia). The results showed that, worse stages of cognitive impairment were associated with poorer ability to increase speed and walk quickly in order to cross the road safely in comparison with cognitively healthy participants.

Regarding the crossing decisions and the mistakes of signal display in junctions our results showed that neither the group of AD or this of MCI significantly differs from the healthy elderly pedestrians in these measurements. However, there are some previous studies that suggest the opposite patterns of findings. More specifically, a recent study of Dommes et al. (2015) indicate that old participants with mild dementia were more likely than healthy ones to make street-crossing decisions that led to collisions with approaching cars in a simulated 2-way traffic environment. However, this previous study has followed a different methodological approach as compared to the present research. First of all, in this aforementioned study the researchers assessed street – crossing decisions through a virtual environment. On the contrary, in our study pedestrian behavior was evaluated with the use of real – life conditions (Papadimitriou, Lassare, & Yannis, 2016) that have the capacity to create a more vivid and active environment as the participants had the chance to walk in different road and traffic conditions as they do daily. Furthermore, in the study of Dommes and colleagues (2015), the participants examined only for their street – crossing behavior and not in their mistakes in signal display at junctions, while in our study the participants examined in both behaviors. From the findings of the Dommes et al. (2015) and of Carthy et al. (1995) it appears that older adults made more potentially unsafe crossings (e.g. poor choice of place to cross and crossings that necessitated evasive action) than younger adults. Hence, the declines in cognitive or executive function skills affect the ability of older persons to interact with traffic safely but it is debatable how these impairments manifest functional changes.

The present study also focuses on exploring the link of attention, visuospatial and executive functions with parameters of pedestrian behavior such as crossing, signal display, velocity and orientation. We found that attentional, visuospatial and executive scores were correlated with crossing variable and the Digit Span (Backwards) and the 5 Objects Test showed significant association with the variable of signal display. The regression analyses conducted here demonstrated that the increased mistakes of crossing in the AD group were associated with impairment of certain perceptual and cognitive abilities. Working memory (Digit Span Backwards) showed to play a crucial role in explaining the variance of wrong crossing and wrong decision in signal display in junctions. Studies that have been conducted so far exploring the association of neuropsychological tests and pedestrian performance used UFOV test ,which associated with increased number of collisions in pedestrian simulator (Dommes et al., 2015) as well as walking time variability was significantly associated with scores on the Stroop test (Hausdorff et al., 2004; Melzer & Oddsson , 2004). A study of Ble et al. (2005), used the Trail Making Test (TMT) and found that there was a significant association between performance on TMT and high attention demanding walking task.

In order to achieve increased ecological validity, we utilized naturalistic advancements by selecting the survey route as a condition that effectively gives some information in interaction with traffic conditions of everyday life. This decision was based on previous research by Papadimitriou, Lassarre, Yannis, (2016) who examined the pedestrian behavior in younger adults also in real – life conditions with survey trips in the center of Athens in Greece.

In contrast to studies that utilized simulators, in order to reduce the amount of random errors that may influence the reliability properties of the obtained measures in a negative way, our research's data recording attempted to be unobtrusive. Although it is still possible that participants could behave differently because they knew they were being observed. The findings of the present study add to the existing knowledge about the presence of attentional, visuospatial and executive impairments and the risky pedestrian behavior of patients with AD or MCI that are not easily identified through typical neuropsychological and neurological evaluation.

There are some limitations of our study in terms of the difficulties in recruitment of participants to undertake a relatively demanding walking task the characteristics of the participants that should meet a variety of inclusion and exclusion criteria, which make the size of the sample relatively low. Nonetheless, this restriction does not appear to influence in a critical way the main findings of the study because of the large effect sizes that were observed in the critical components of the applied statistical analysis.

Further research is required in order to gain more knowledge in pedestrian behavior of patients with mild AD or MCI as there are only few studies that showed a relation of cognitive and executive deficits and measurements of pedestrian performance in contrast with the wide literature concerning the driving abilities of those patients (Papageorgiou et al., 2016; Denvil et al., 2012; Rebok et al., 1994). Finally, future studies could explore the effectiveness of real – life environments procedures on interventions that have as goal to enhance the cognitive functioning of older individuals in the case of both normal and pathological aging.

In conclusion, to our knowledge, this is the first study to investigate pedestrian behavior in naturalistic environment through a detailed and systematic approach by comparing the performance of AD, MCI and cognitive intact participants on a survey trip that measures their behavior in street – crossing, wayfinding and walking speed. Further, this is the first research to utilize four neuropsychological tests in order to predict how these people behave as pedestrians as many of them have stopped driving due to their disease. According to our results, the future utilization of self-evaluation techniques of AD and MCI patients could maximize the effectiveness of the existing medical and psychological interventions; benefit their quality of life as pedestrian and minimizing the risk of fatally injuries or crashes. Nevertheless, to our knowledge, no previous studies have compared patients with AD or MCI according to their behavior as pedestrians in real – life conditions. Our study adds to the existing knowledge in the field of research exploring deficits in attentional, executive and visuospatial abilities with regard to pedestrian behavior in patients with mild AD or MCI.

6. References

Benedict, R. H. B., Schretlen, D., Groninger, L., & Brandt, J. (1998). Hopkins Verbal Leaning Test-Revised: Normative data and analysis of inter-form and test-retest reliability. The Clinical Neuropsychologist, 12, 43–55. doi:10.1076/clin.12.1.43.1726.

Ble, A., Volpato, S., Zuliani, G., et al. Executive function correlates with walking speed in older persons: The InCHIANTI study. Journal of the American Geriatrics Society.2005; 53(3), 410-415.

Chiu, Y. C., D. Algase, A. Whall, J. Liang, H. C. Liu, K.N. Lin and P. N. Wang, “Getting lost: Directed attention and executive functions in early Alzheimer’s disease patients,” Dementia and Geriatric Cognitive Disorders,17, 174–180 (2004).

Chu, X., Guttenplan, M., & Baltes, M. (2003). Why people cross where they do – The role of the street environment. Transportation Research Record No. 1878, pp. 3–10.

Das, S., Manski, C.F., Manuszak, M.D., (2005). Walk or wait? An empirical analysis of street crossing decisions. Journal of Applied Econometrics, 20, 529-548.

Dommes, A., Wu, Y., Aquino, J.P., Ferrandi, H., Soleille, M., Fleury, S., Samnson, M., Rigaud, S.M., (2015). Is Mild Dementia Related to Unsafe Street-Crossing Decisions? Alzheimer Dis Assoc Disord 29,4, 294-300.

Dubois, B., Slachevsky, A., Litvan, I., Pillon, B., (2000). The FAB: a Frontal Assessment Battery at bedside. Neurology, 12;55 (11): 1621-8.

Folstein, M., Folstein, S., & McHugh, P.(1975). Mini-Mental State: A practical method for grading the state of patients for the clinician. Journal of Psychiatric Research,12,189-198.

Fountoulakis, K.N, Tsolaki, M., Chantzi, H., Kazis, A., (2000). Mini Mental State Examination(MMSE): A validation study in Greece. American Journal of Alzheimer’s Disease and other dementias, 15(6), 342-345.

Gorrie, C., Brown, J., Waite, P., (2008). Crash characteristics of older pedestrian fatalities: Dementia pathology may be related to ‘at risk’ traffic situations. Accident Analysis and Prevention 40, 912–919.

Hamed, M. M. (2001). Analysis of pedestrians’ behaviour at pedestrian crossings. Safety Science, 38, 63–82.

Hauer, K., Pfisterer, M., Weber, C., Wezler, N., Kliegel, M., & Oster, P.(2003). Cognitive impairment decreases postural control during dual tasks in geriatric patients with a history of severe falls. Journal of the American Geriatrics Society, 51(11), 1638-1644.

Hausdorff, J., Yogev, G., Springer, S., Simon, E., & Giladi, N. (2005).Walking is more like catching than tapping: gait in the elderly as a complex cognitive task. Exp. Brain Res, 164, 541–548. (doi:10.1007/s00221-005-2280-3)

Holland, C., & Rabbitt, P.(1992). People’s awareness of their age-related sensory and cognitive deficits and the implications for road safety. Applied Cognitive Psychology,6, 217-231.

Lichtenberg, P., Murman, D., & Mellow, A., (2003). Handbook of dementia: psychological, neurological and psychiatric perspectives. New Jersey, USA. Wiley & Sons Inc.

Lajoie, Y., Teasdale, N., Bard, C., & Fleury, M. (1996). Attentional demands for walking: Age-related changes. In A Ferrandez & N Teasdale (Eds.). Changes in sensory motor behaviour in aging, (pp. 235-255). New York, USA, Elsevier Science.

Lawton, M.P., Brody, E.M., (1969). Assessment of older people self – maintaining and instrumental activities of daily living. Gerontologist ,9(3), 179 – 86.

Lobjois R, Cavallo V., (2007). Age-related differences in street-crossing decisions: the effects of vehicle speed and time constraints on gap selection in an estimation task. Accid Anal Prev. 39:934–943.

Lobjois R, Cavallo V.,(2009).The effects of aging on street-crossing behavior: from estimation to actual crossing. Accid Anal Prev. 41:259–267.

McKhann, G. M., Knopman, D. S., Chertkow, H., Hyman, B. T., Jack, C. R., Kawas, C. H., et al. (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, 263–269. doi:10.1016/j.jalz.2011.03.005.

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

Oxley, J., Ihsen, E., Fildes, B., Charlton, J., & Day, R.(2005). Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. Accident Analysis and Prevention,37, 962-971.

Oxley, J., Charlton, J., Fildes, B., (2005). The effect of cognitive impairment on older pedestrian behavior and crash risks. Monash University Accident Research Center, 244

Ou ,Y.K., Lin, S.N., Fang, C.W., Liu, Y.C.,(2013). Effect of electronic maps on wayfinding abilities of patients with mild Alzheimer disease. Journal of Industrial and Production Engineering,30, 397-404.

Papadimitriou, E., Lassarre, S., Yannis, G., (2015). Introducing human factors in pedestrian crossing behavior models. Transportation Research Part F ,36, 69–82

Papageorgiou SG, Beratis IN, Kontaxopoulou D, et al.(2016). Does the diagnosis of Alzheimer's disease imply immediate revocation of a driving license? Int J Clin Neurosci Ment Health, 3:S02–S02.

Papageorgiou, S.G., Economou, A., Routsis, C.,(2013). The 5 Objects Test: a novel, minimal-language, memory screening test. J Neurol , doi 10.1007/s00415-013-7219-1.

Petersen, R.C. (2004). Mild cognitive impairment as a diagnostic entity. Journal of internal medicine, 256(3), 183-194.

Petersen, R. C., & Morris, J. C. (2005). Mild cognitive impairment as a clinical entity and treatment target. Archives of Neurology, 62, 1160–1163. doi:10.001/archneur.62.7.1160.

Reitan, R. (1979). Trail-making test. Arizona: Reitan Neuropsychology Laboratory.

Satalich, G. A., (1995). Navigation and Wayfinding in Virtual Reality: Finding Proper Tools and Cues to Enhance Navigation Awareness, Master's thesis, University of Washington.

Tu, M. C. and M. C. Pai, (2006). “Getting lost for the first time in patients with Alzheimer’s disease,” International Psychogeriatrics, 18, 67–70.

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. J Geriatr. Psychiatry Neurol., 22,87-94

Zalonis, I., Kararizou, E., Triantafyllou, N. I., Kapaki, E., Papageogiou, S., Sgouropoulos, P., et al. (2008). A normative study of the Trail Making Test A and B in Greek adults. The Clinical Neuropsychologist, 22, 842–850. doi:10.1080/1385404070162930.