The traffic behavior of pedestrians with mild Alzheimer's Disease or Mild Cognitive Impairment in urban areas, and its neuropsychological predictors

Olga Fafouti
Neuropsychologist
2nd Department of Neurology, Medical School, National Kapodistrian University of Athens, 75 Mikras Asias str., GR-11527, Greece
E-mail address: olgafa01@gmail.com

Eleonora Papadimitriou*, PhD
Associate Professor
Safety and Security Science Section, Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, 2628BX, Delft, the Netherlands.
E-mail addresses: e.papadimitriou@tudelft.nl

Ion.N.Beratis, PhD
Psychologist, Neuropsychologist
2nd Department of Neurology, Medical School, National Kapodistrian University of Athens, 75 Mikras Asias str., GR-11527, Greece
E-mail address: psychologist@iberatis.gr

Dionysia Kontaxopoulou, PhD
Psychologist, Neuropsychologist
1st Department of Neurology, Medical School, National Kapodistrian University of Athens, 75 Mikras Asias str., GR-11527, Greece
E-mail address: d.kontaxopoulou@hotmail.com

Stella Fragkiadaki, PhD
Psychologist, Neuropsychologist
1st Department of Neurology, Medical School, National Kapodistrian University of Athens, 75 Mikras Asias str., GR-11527, Greece
E-mail address: st.fragkiadaki@gmail.com

Petros Stamatelos
Neurologist
2nd Department of Neurology, Medical School, National Kapodistrian University of Athens, 75 Mikras Asias str., GR-11527, Greece
E-mail address: petstamat@med.uoa.gr

George.Yannis, PhD
Professor
Department of Transportation Planning and Engineering, School of Civil Engineering, National Technical University of Athens, 5 Heroon Polytechniou str., GR-15773
E-mail: geyannis@central.ntua.gr

Sokratis.G.Papageorgiou, PhD
Professor
2nd Department of Neurology, Medical School, National Kapodistrian University of Athens, 75 Mikras Asias str., GR-11527, Greece
E-mail address: sokpapa@med.uoa.ge

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ABSTRACT

The aim of the current study was to investigate how patients with mild Alzheimer's Disease (AD), or Mild Cognitive Impairment (MCI) behave as pedestrians (velocity, orientation, crossing at junctions) compared to cognitively intact elderly, as well as to explore whether neuropsychological tests examining attentional, executive and visuospatial abilities could be a predictive factor of pedestrian behavior for these patients. Fifteen participants with mild AD, 15 patients with MCI and 15 healthy elderly pedestrians 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. According to the applied One – Way ANOVA, the three groups differed significantly in the variables of orientation and velocity, but they did not differ in crossing behavior. AD patients were found to be more disorientated and slower as pedestrians in contrast with MCI patients and healthy elderly. MCI patients appeared to be slower than healthy elderly but there was not any significant difference in orientation between these two groups. Finally, attentional, executive and visuospatial tests were more strongly associated with crossing decisions at junctions and with walking speed. Our findings suggest that patients with mild AD do have deficits in their traffic behaviour. These deficits can be predicted by neuropsychological tests measuring attention, executive and visuospatial abilities.

Key words: pedestrians; Alzheimer's Disease; Mild Cognitive Impairmant; elderly; walking; crossing.

1. BACKGROUND AND OBJECTIVES

Pedestrian accidents constitute a major road safety problem worldwide. Data of the Hellenic Statistical Authority have pointed out that a high number (44% in Greece) of older pedestrians (> 65 years old) are fatally injured in road accidents. Street walking is both a sensorimotor and cognitive task as it needs balance and memory of one's destination and the names of roads one has to take (1). It is often viewed as an automated, rhythmic motor task (2). For this reason, cognitive and executive functions associated with dementia (3) may have functional implications for older pedestrians' walking 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 (4).

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 (5). Despite a large body of research in healthy pedestrians, elderly or younger ones, there is a lack of knowledge regarding the effect of cognitive impairment on pedestrian performance in patients with Alzheimer's Disease (AD) or Mild Cognitive Impairment (MCI).The latter one represents a transitional stage between normal aging and dementia, with none or minimal deficits in everyday activities (6). Both conditions are characterized by memory disorders. However, AD involves 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 elderly pedestrian to be involved in crashes (7) or in unsafe street – crossing decisions, as they prevent them from successfully performing even the most basic daily tasks such as driving and walking (8). Deficits in executive functions may play a significant role in the ability of elderly pedestrians to adjust walking pace while crossing roads in a complex traffic environment, where attentional demands are great.

According to a study of (9), 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, (10) 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 to start the crossing action while taking into account only the safety of the nearby lane and ignoring the traffic in the farside lane. In addition, the performance of these individuals in terms of processing speed and visual attention capabilities, as measured by the Useful Field Of View test, 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 or they cross diagonally in order to save time and distance (11). Moreover older pedestrians seem to demonstrate slower walking speed, exposing themselves to traffic for longer periods of time when they are crossing the street (12). Further, elderly pedestrians with dementia make biased decisions about the near lane and they seem to misjudge the distance of approaching cars (9, 13); these could be related to perceptual and cognitive deficits. Finally, pedestrians with early AD became lost more frequently in their familiar environment within two years after the onset of AD (14) or they had a difficulty in wayfinding. The impairment of spatial cognition and the degradation of hippocampus caused by AD may seriously affect the wayfinding process. Based on the above, (15) 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 with 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 gaps in the knowledge and understanding of the impact and the extent of functional impairment on pedestrian behavior, especially in those with dementia (8). 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 traffic environment.

To the best of the authors' knowledge, no relevant study has been carried out in real traffic conditions; the present research aims to offers greater ecological validity and the ability to observe the actual behavior of cognitively impaired elderly people on the road.

The main aim of the present study was to investigate the differences between healthy elderly and patients with mild AD or MCI in parameters of pedestrian behavior such as orientation, choice of crossing location, and their crossing speed in real-life conditions. Based on the existing literature on simulators, patients with AD or MCI were expected to have greater difficulty in road – crossing and in wayfinding, as well as lower speed than healthy old pedestrians. In addition, it is important to investigate whether neuropsychological tests could serve as predictive factors of pedestrians' behavior that could potentially prevent 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 (9), Stroop test (2; 16) and the Trail Making Test (17).

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.

Also, they were recruited from the Cognitive Disorders/Dementia Unit at the Second Department of Neurology at University General Hospital "Attikon" (UGHA) in Athens, Greece between June 2017 and April 2018. The diagnosis of the patients was made according to the established clinical criteria for AD (19) and MCI (6) 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.

In order to participate in the study, patients had to meet specific inclusion and exclusion criteria: (a) both patients and healthy elderly 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.

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, including 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 (18); Instrumental Activities of Daily Living (19)), and (b) motor ability. This extended medical/neurological examination was conducted by the same behavioral neurologist (Sokratis G. Papageorgiou) who classified the participants in the following clinical categories: (a) Cognitively (Mentally) Healthy, (b) diagnosis of amnestic MCI, and (c) diagnosis of Alzheimer's disease.

2.2.2. Neuropsychological Evaluation

The neuropsychological assessment included the following tests:

- Mini Mental State Examination / MMSE (20, 21) ;

- Clock Drawing Test / CDT (22);
- 5 Object Test (23);
- Trail Making Test / TMT (24, 25);
- Frontal Assessment Battery / FAB (27);
- Hopkins Verbal Learning Test – Revised / HVLT-R (26);
- Digit Span (Backwards & Forwards); Wechsler Adult Intelligence Scale- Revised / WAISR,
- Judgment of Line Orientation / JLO (28).

2.2.3. Walking Task

Pedestrian behavior was studied in a real – life environment, especially in a configured route selected in cooperation with road safety experts from the National Technical University of Athens (NTUA) - Department of Transportation Planning and Engineering. The data collection protocol was based on that of a similar study on young and middle-aged pedestrians in Athens (Papadimitriou et al., 2016). 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 took place during 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 and destination of the trip and the 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 had as origin and destination the entrance of UGHA. All participants had to hold a destination map, on which the junctions to be crossed and the roads to be walked along were pointed out. The route included two signal-controlled junctions and several uncontrolled ones. In order to complete the trip, each participant would have to pass from these two signal controlled junctions. Furthermore, the participants 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 uncertain about the instructions or if they were tired.

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

The parameters measured were as follows:

- Velocity: the walking speed, estimated as the total distance of the route to the total time taken to complete the trip,
- Orientation: the number of times a participant cannot remember where he/she has to go and is asking the observer,
- Number and duration of crossing attempts, and more specifically
    - Dangerous crossing location: the number of times a participant crossed outside a designated location e.g. at mid-block, outside a crosswalk etc.
    - Traffic signal violation: the number of times a participant violated a red pedestrian signal display while crossing).

The observer recorded these data for each walking task while following the participant, by a video recording in order to have a more accurate view of their behavior.

FIGURE 1. Map of the route the participants follow during the walking task

Junction 1	Junction 2	Hospital entrance

2.2.4. Ethical considerations

This study was approved by the Ethics Committee of the University General Hospital "ATTIKON" and was completed in accordance with the Helsinki Declaration. It was explained to all the individuals that participation was on a voluntary basis and that they had the right to withdraw any time they wished to, and they then signed a written consent form to that effect. Participants were assured that the procedure would be confidential and that the use of their data and their background information would be for research purposes only.

3. RESULTS

The demographic data of the AD, MCI and control group are summarized in Table 1 as regards the variables of gender, age and 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	-	8/7	-	7/8	-	-	.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 variable had a statistically significant difference [F(2,44)= 15.917, p=.000 between the 3 groups, as well as speed 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). Moreover, 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 dangerous crossing location / traffic signal violation 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**
Dangerous crossing location	.73	.53	-.73	.53	-.13	.53	1.07	.353	
Traffic Signal Violation	.33	.54	-.33	.54	.66	.54	.749	.479	
Velocity	.043	.27	-0.43	.27	.84	.27	6.71	.003	AD<CT** MCI<CT**

*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 traffic signal violation and dangerous crossing location are concerned, Spearman rho correlations are used in order to evaluate relationships involving the variables concerning the four crossings that the participants had to make. Table 3 presents the correlations that the groups of AD & MCI patients had between the variables of pedestrian behavior and the neuropsychological tests.

TABLE 3. Spearman's rho and Pearson correlations between neuropsychological tests and measurements of pedestrian behavior for the AD & MCI groups.

Group	Tests	Traffic Signal Violation		Dangerous Crossing Location		Velocity		Orientation	
		R	p-value	R	p-value	R	p-value	R	p-value
AD	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
MCI	MMSE	.56	.844	-.28	.336	.34	.207	-.26	.356
	DS(back)	.34	.213	.00	.980	.46	.084	-.44	.095
	5 Object (DR)	-.47	.046*	-.51	.048*	-.19	.492	.29	.284
	JLO	.33	.230	-.22	.440	.10	.716	-.12	.648
	FAB	.40	.132	.52	.046*	.13	.641	-.13	.636

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 to 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 were conducted in relation to the pedestrian performance and especially the crossing behavior and the signal displays in the AD patients. The other two variables of orientation and velocity 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 Crossing Location				Traffic Signal Violation			
	B	SE B	B	*P*	B	SE B	B	*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 location while 5 Object (Delayed Recall) and Digit Span (Backwards) was related with the performance in signal display compliance. A multiple linear regression analysis was performed to determine the best predictor, or subgroup of predictors, of the variance in crossing behavior. 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 R2 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 overall model was significant, F(1,13)=21.64 p=.000. The results revealed that threshold scores on Digit Span (Backwards) measuring working memory is the only significant cognitive predictor of crossing decisions, accounting for 62% of the variance in crossing. This means that the mistakes that AD group make in Digit Span (Backwards) could predict that this group will cross at mid-block or outside junctions/crosswalks. Similarly, a multiple linear regression was run for the variable of traffic signal violation 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) is the only significant cognitive predictor of crossing at traffic signal decisions, accounting for 53% of the variance in signal compliance. Lower scores in this test could easily predict that AD group will cross more often in red light.

In case of velocity measurements, a 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 at signal displays and the crossing behavior. 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 nor for the MCI group. 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 included 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.

4. DISCUSSION

According to our knowledge, this is the first study that used a real – life environment for the evaluation of cognitively impaired pedestrians' 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 in 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, even using 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 walking speed between AD and MCI patients. More importantly, no group differences between AD and MCI patients were observed in road – crossing decisions and signal display compliance, something that did not point out dementia – specific crash situations like the ones revealed by (9) and (10) analyses. The results of (9) 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, (9) 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 (14, 15, 29) as well as a slower walking speed in those with AD or MCI than in cognitively intact individuals (30, 31). For example, a study by (15) 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 (14) 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 (29), 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 (30) 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, (31), 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 (32), that carried out in pedestrian simulator, 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. (7) found that patients with AD and older adults had a significantly higher risk of unsafe crossing behavior at a simulated road crossing situation, if they had lower scores on the Mini Mental State Examination, Complex Figure test recall, Trail Making Test B & A, Useful Field Of View test – total and Visual Form Discrimination.

Regarding the crossing decisions and the mistakes of signal display at junctions, our results showed that neither the group of AD nor 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, (9) 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 (11) 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 (9), 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 were examined in both behaviors. From the findings of (9) and of (33) 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 tests with parameters of pedestrian behavior such as crossing, signal display, walking speed and orientation. We found that attentional, visuospatial and executive scores were correlated with the safe crossing location variable and the Digit Span (Backwards) and the 5 Objects Test showed significant association with the variable of signal display compliance. 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 the UFOV test, which was associated with increased number of collisions in pedestrian simulator (9) as well as walking time variability was significantly associated with scores on the Stroop test (2; 16). A study of (16), 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 (11) 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.

6. CONCLUSION

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. 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.

Further research is required in order to gain more knowledge on 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 (e.g. 34, 35). 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.

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