Senior Driver Performance on Airport Road Access Wayfinding Design

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***Abstract* — The purpose of this study was to evaluate the wayfinding and signage provisions, sensitivity of senior driving behavior and road safety. A driving simulator to simplify the airport navigation was developed. Three scenario types were designed to provide a variety of driving situations and complexity of the road designs to the airport. The complexity of way finding with the assorted road furniture such as signage adverts and street lights also were included. Experience car drivers who held valid UK driving license were asked to drive simulated routes. Fifteen drivers in range of age 50-54, 55-59 and over 60 years were selected to perform the study. Participants drove for approximately 20 minutes to complete the simulated driving. The types of errors (parameter) of simulated driving were identified: risk of collisions, exceed the speed limit, traffic light tickets, centreline crossings and road edge excursions. The drivers' performance and parameter were compared to the age group. Results were analyzed by ANOVA and discussed with reference to the use of driving simulator. The ANOVA confirmed that senior drivers' age group have no significant effect on the airport road design, wayfinding and all research parameters; risk of collisions, exceed the speed limit, traffic light tickets, centerline crossings and road edge excursions.**

***Keywords* —** *Wayfinding; Driving behavior; Airport Road Design; Driving Simulator*

1. Introduction

Driver capabilities and limitations in performing the driving tasks influence driving behavior and drivers' safety on the road. Past research [1]–[5] have examined the characteristics of drivers' behavior and safety. The research outcomes confirmed that change of behavioral adaption to the road environment (e.g. road design, human errors and drivers' age) have an impact on driving performance. Two main characteristics that lead to senior drivers' wayfinding are attention and wayfinding information, and vision [6]. These two important characteristics of airport road access wayfinding design were based on previous literatures and contributory factors [7], [8]. Attention limitation, ability to process wayfinding information and visual awareness [9] where failing to look properly, poor turn maneuver, 'disobeying' of traffic signs, travelling too fast and exceeding speed limit are examples of these

A good signage aids driver navigates easily [10]. Lynch [11] stated that the wayfinding is the progressive process which used by people to arrive at the destination successfully. Wayfinding helps people to identify their location, next destination, and to choose the best route to the intended destination [12]. Montello and Sas [13] agreed that wayfinding occurs when people need to travel from one place to another on the intended route and direction without having accidents or getting delayed and reach the destination. It is also important to distinguish the destination upon arrival and reversing the process to find the way back. In this paper, drivers' wayfinding is defined as a process in which people make a decision (choose) to navigate using information support systems (clues) such as maps, lighting, sight lines, and signage, and arrive at the destination (results) successfully.

The lack of wayfinding provision in airport areas has discouraged the interests of drivers and much effort has not been directed towards understanding the concepts and its practicality [13], [14]. An ineffective number of signage has been constructed around airport areas which distracts the wayfinding. Harding [15] stated that many airports have not established the concept of 'simple', functional and less is more' on airport navigation system. Therefore, the airport has less attractive and competitive than neighbourhood airports [16], [17]. In many cases, drivers experience most difficulties to understand a complete wayfinding process which stimulates a distraction while driving [18]. The distraction from inadequacy of signage (i.e. too much advertising signage) in airport road access areas could increase confusion of drivers and road accident [19]. From the literature search, it was realized

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that the cost of airport facilities (including wayfinding) regularly appeared in airport studies as a benchmark for measuring industry performance [20]. The lessons learnt from the literature search were quite surprising and the need to fill a knowledge gap (examining the effects on the wayfinding and road safety) appeared to be necessary [21]. As a remedy to counter this problem, efforts to investigate the effect between wayfinding, road safety and drivers' expectation are crucial.

2. Methodology

A driving behavior test can be validated by comparing on the road and simulated driving regarding a very specific driving task such as speed [4], [22], distraction [23], [24], crash avoidance [25] and traffic safety [26], [27]. The standard of validating driver behavior in a simulator involves comparing it to driving performance on the road [4], [22], [28]. The decision to use driving simulator and simulation scenarios was developed after taking into account of the advantages and disadvantages of on the road test (Table 1). In addition, the following measures were identified to improve validity and reliability of the simulated airport road access; the driving simulation test was subjected to a pilot study in order to enhance research quality.

Table 1. Comparison between on road and driving simulation testing

Factors	On Road (Real vehicle)	Driving Simulation
Safety	Expose to risky driving lead to collision	Collision could be avoided
Equipment cost	High equipment cost	Less equipment cost
Experimental control	Behavior of virtual traffic, weather conditions and the road layout were not easy to be manipulated	Behavior of virtual traffic, weather conditions and the road layout can be manipulated as a function of the experiment needs
Ease of data collection	Cumbersome to obtain complete, synchronized and accurate measurement data	Driving performance was measured accurately and efficiently
Opportunity for feedback and instruction	Not easy to achieve	Easy to deliver

Fifteen experienced car drivers volunteered to take part in the intended study. All drivers held a valid driving license. The mean age of the group was 58 years (range 50 – over 60 years). The complete instructions were conveyed before the driving simulation test started. Drivers also were notified that they need to drive to the airport with the aid of wayfinding and signage in the driving scenario. The simulation test was 3.8 miles long for each scenario and took approximately 20 minutes to complete. Participants decided which route to use based on the provided signage and wayfinding systems.

2.1. Driving Simulation Design

Driving scenarios were designed to evaluate the detection of the effectiveness of wayfinding systems (including signage) which were allocated from the starting point until the end of the simulation. A unique aspect of the scenario design was the inclusion of direction, warning and information signage, roundabouts, pedestrians, trees, moving cars, buildings and road furniture (e.g. street lights and bollards).

Three scenarios were developed to provide a variety of driving situations to reach airport. The parameter or types of errors were risk of collisions, exceed the speed limit, traffic light tickets, centerline crossings and road edge excursions.

Three specific goals while developing driving simulations were considered [29]:

- Replicate real driver behavior and performance.
- Make the driving simulation studies easy to conduct with a good plan, execute, reduce, and analyze.
- Subjects should not be threatened or harmed.

Performance of these parameters was recorded from a starting driving point until the driver stop at the arriving point (airport area).

There were three scenarios developed in order to evaluate the impact of wayfinding on drivers' behavior and road safety. Different types of signage were considered in three scenarios to reduce accidents due to crossing paths, left turn movements and to be more effective than conventional signs [30]. Road speed limit is important in order to assess driver behavior. Godley et al. [4] found that driving at appropriate speeds for existing road conditions is related to a driver's confidence. It is also related to driving safety because rear-end collisions are more likely to occur when driving at low speeds.

2.2. Scenario Specifics

The simulated driving was scripted using a Scenario Definition Language (SDL) provided by the STISIM Drive Software Version 2. Scenarios were scripted within a general purpose of the simulator that was a mixture of dual carriageway, buildings, static objects, pedestrian pavement and vegetation [8].

First scenario was designed as 'less complex' as possible to test the effects of road design and wayfinding on the driver's behavior and safety. The signage placement and road furniture were considered to assess drivers' adaption to the actual airport road design provided with accurate signage information system. Scenario two was designed as a 'complex' road access design and signage information systems. Additional number of warning signage was considered to measure the impact of airport road design on drivers' safety and driving behavior. Multiple signage types (i.e. diamond and rectangle sign) were considered to the simulation design.

Scenario three was designed as a 'more complex' road with some different type of direction and warning signs (e.g. diamond and rectangle sign), advertisement signs and complexity of airport road design provided with accurate signage information and wayfinding systems. Advertisement signs are important to the airport as an airport identity or branding [16] and were considered in the simulation scenario. The different signs were considered to reduce accidents due to crossing path and left turn movements and more effective than conventional signs [31]. Additional road furniture such as street lights, bollards, bus stop, traffic lights, zebra crossings, pelican beacon, trees and buildings were included in the simulation design.

Roundabouts were created in all scenarios in order to give way to traffic already in the circle and to increase safety to the drivers. Few types of intersections (i.e. four junctions, left and right junction) were adopted in the scenarios to allow participant to have a freedom of making a decision to get to the intended direction.

Driving speed to assess driver behavior is crucial. Anuar [6] stated that driving at appropriate speeds on existing road conditions is related to driver's confidence. The driving speed is related to driving safety because rear-end collisions are more likely to occur when drive at low speeds. In addition, Shechtman et al. [32] confirmed that a greater forward acceleration indicates variable speed during the turn; the more a driver slows down, the more would need to speed up again. They confirmed that driving at a variable speed through an intersection could potentially increase the possibility of rear-end collisions. As a result, several types of speeding were allocated in the scenario (e.g. 30 mph, 40 mph and national speed limit).

2.3. Procedure and Equipment

The simulation participants were selected based on participation and completely voluntary. Table 2 shows the driving simulation procedures.

Table 2. Driving simulation procedures

Process	Procedure
Access to participants	1. Open invitation through internal email, electronic social media and academic websites to public. 2. Email notification which indicates research background, greetings and consent statement to selected participants.
Verbal description	Simulator room 1. Oral and written instructions on their role in the study performed to participants (i.e. general information, simulated driving procedures, rights of participant as a research subject) 2. A written consent statement received from participants. 3. Participants have a right to withdraw at any time or refuse to participate entirely 4. The information or data collected will be treated in a strictly confidential
Before simulation test	Simulator room 1. A short driving orientation to accommodate participants to the simulator 2. Ensure participants are not experiencing any simulator sickness symptoms
During simulation test	Simulator room 1. Participants are required to perform on three different simulated road scenarios 2. Ensure the participants free from sickness during the simulation exercise 3. Short break (5-10 minutes) after each simulated driving ended
After simulation test	1. Data extraction from the driving simulator

Driving scenarios were scripted using a Scenario Definition Language (SDL) provided by STISIM Drive Software Version 2. The additional software was used to add the necessary objects (e.g., direction and advertisement signs, bollards, pedestrian, etc.) and auditory cues which provided the driver with instructions (e.g. "That is the end of the simulation"). Driving scenarios were scripted within a general-purpose "world" provided with the simulator that contained a mixed of dual carriageway, with buildings, static objects, pedestrian pavement and vegetation.

2.4. Data Analysis

ANOVA was used to test the differences of drivers' behavior in the different driving scenarios. ANOVA test measures the differences of the independent variable (e.g. drivers' age group) and the dependent variables (e.g. risk of collision and centerline crossings) were performed. The level of significance ($p < 0.05$) was set in this study. A 95% confidence level was selected as a conventionally accepted level for most of research [21].

3. Results and Discussion

3.1. Time to Complete Scenario

There is no significant effect of drivers age to complete the scenario (F=0.99, p=0.46). The complexity of road design and wayfinding were not associated to destination on time. Drivers at aged 50 to 54 years (mean=309.02, SD=63.58) tends to arrive to the airport earlier than others. From the observation, drivers aged 50 to 54 years were more concentrates on direction signage as well as focusing on road lanes compare to other group age.

3.2. Frequency Analysis of Driver Mistake in Simulated Driving

Table 3 shows the number of driver mistakes in driving performance for three simulations performed; 'less complex', 'complex' and 'more complex' road design and wayfinding against the drivers' age. As shown in the table, the highest mistakes that drivers identified; 'risk to collisions', 66 times (mean=1.47, SD=0.85) and 'road edge excursions', 199 times (mean=4.42, SD=1.83). Total mistakes in each scenario are 96 times in 'less complex', 102 times in 'complex' and 119 times in 'more complex' scenario. It shows that the complexity of the road design, wayfinding and driving mistakes are related on road design. Drivers aged over 60 years are riskier than the aged 50 to 54 years. The drivers aged 60 and above tend to drive near to the road edges (or road shoulders), 'too careful' at the junctions and roundabouts and surprisingly drive too fast at the low speed limit road.

Drivers crossed the road edge; 50 to 54 years, 9 times (mean=2.25, SD=3.30), 55 to 59 years, 27 times (mean=4.50, SD=1.52), and over 60 years, 29 times (mean=5.80, SD=1.30). Drivers are almost get themselves into accident which are 10 times by aged 55 to 59 years (mean=1.67, SD= 0.82), 9 times by aged over 60 years (mean=1.80, SD=0.45) and 3 times by aged 50 to 55 years (mean=0.75, SD=0.96). This is because drivers are preferred to drive too close to a frontward vehicle. There are no mistakes identified for 'exceed the speed limit', 'traffic light tickets' and 'centerline crossing' by driver aged 50 to 55 years.

Total of 42 times mistakes by drivers aged 56 to 56 and over 60 years and 18 times by drivers aged 50 to 55 years in 'complex' road scenario was identified. In this scenario, drivers aged 56 to 59 assertively drive more exceeding the speed limit (mean=0.83, SD=0.98). Drivers also assertively crossed the road edge frequently as much as less complex scenario; 50 to 54 years, 14 times (mean=3.50, SD=2.65), 55 to 59 years, 27 times (mean=4.50, SD=1.38) and over 60 years, 25 times (mean=5.00, SD=1.00).

Drivers aged over 60 years crossed the centerline 4 times (mean=0.80, SD=0.84) at roundabouts. Drivers aged 55 to 59 and 60 years tends to be tailgating frontward vehicle which can cause accident. There is no 'traffic light ticket' mistake in this scenario.

Table 3. Driver Mistakes on Simulated Driving

Road Design	Mistakes	50-54	55-59	Over 60
Simulation 1 - *Less Complex*	Risk to Collisions	3	10	9
	Exceed the Speed Limit	0	2	2
	Traffic Light Tickets	0	1	1
	Centerline Crossings	0	1	2
	Road Edge Excursions	9	27	29
	Total	12	41	43

Simulation 2 - *Complex*	Risk to Collisions	3	10	11
	Exceed the Speed Limit	1	5	2
	Traffic Light Tickets	0	0	0
	Centerline Crossings	0	0	4
	Road Edge Excursions	14	27	25
	Total	18	42	42
Simulation 3 - *More Complex*	Risk to Collisions	3	8	9
	Exceed the Speed Limit	1	3	11
	Traffic Light Tickets	0	1	2
	Centerline Crossings	0	0	13
	Road Edge Excursions	13	26	29
	Total	17	38	64

Drivers reported to make more mistakes in 'more complex' scenario. Total 119 mistakes were identified in this driving scenario. Total 26 and 29 road edge excursions were reported by drivers aged 55 to 59 (mean=4.33, SD=0.52) and over 60 years (mean=5.80, SD=0.84). Drivers aged over 60 years (mean=2.60, SD=3.71) also assertively tend to drive cross the centerline than other age group of drivers. Tailgating which cause 'risk of collisions' reported 3 times by aged 50 to 54 years (mean=0.75, SD=0.96), 8 times 55 to 59 years (mean=1.33, SD=0.82) and 9 times aged over 60 years (mean=1.80, SD=0.45). Interestingly, driver aged over 60 years assertively drive faster (mean=2.20, SD=0.84) than others. Result also shows that drivers aged 56 to 59 (mean=0.17, SD=0.41) and over 60 years (mean=0.40, SD=0.55) were not aware of red traffic light while performing navigation in complex road design.

3.3. Risk of Collisions

ANOVA indicated that there was a no statistically significance difference in risk of collisions based on drivers' age (F=1.48, p=0.24). It shows that drivers have no difficulties to perform navigation to the airport in scenario one (F=2.48, p=0.13) and scenario 3 (F=2.14, p=0.16). Thus, the drivers' age has no effect on airport road design and wayfinding while performing navigation. Potential of collisions for drivers aged 55 to over 60 years (scenario one, 19 times; scenario two, 21 times and scenario three, 17 times) compare to driver aged 50 to 54 years (3 times each scenario) is higher. From the observation, drivers aged 55 to over 60 years are tending to drive near to the road edges; especially at the roundabouts, difficulties to make a fast decision at the decision point (e.g. junctions and approaching signs) and failed to read speed limit signs at the low speed limit road.

3.4. Exceed the Speed Limit

Based on all three scenarios, there is no significance difference in speed exceedances based on drivers' age (F=2.07, p=0.10). Thus, there is no effect between the airport road design and wayfinding on drivers' age. Drivers tend to speed in more complex road design (F=5.95, p=0.02) than others. Based on frequency analysis, driver aged 55 – 59 (mean=0.33, SD=0.52) and over 60 years (mean=0.40, SD=0.55) are highly drive fast.

3.5. Traffic Light Tickets

The complexity of road design and wayfinding has no statistically effect on drivers' age (F=0.56, p=0.70). Drivers at all level of age are aware of red traffic light.

3.6. Centerline crossings

ANOVA test shows that road design and wayfinding have no effect on drivers' age (F=1.31, p=0.30). Thus, there is no significant effect between airport road design and wayfinding on drivers' age. Drivers tend to cross the centerline more often (13 times) in the complex road design and wayfinding, and interestingly, drivers aged over 60 assertively are tending to cross the centerline.

3.7. Road Edge Excursions

Airport road design and wayfinding has no effect on drivers' age (F=1.74, p=0.17). Drivers aged 55 to 59 (80 times) and over 60 years (83 times) assertively crossed a road edge frequently compares to drivers aged 50 to 54 (36 times) in all three simulations. Additionally, drivers crossed the road edge at more complex simulation (F=6.92, p=0.01) compare to less complex and complex road (F=3.32, p=0.71; F=0.89, p=0.44).

4. Conclusion

The study suggested that driving simulation is useful to test drivers' wayfinding process in virtual environment. The study applied to validate selected research variables (i.e. wayfinding obstacles and contributing factors to wayfinding difficulties). Drivers and architectural clues (i.e. signs, map and building) are included in driving wayfinding simulation [33]. The simulation experiment test requires a real-world environment and information with taking into account of drivers' knowledge and driving experiences. Driving simulation is able to test driver perception, driving behavior and road safety. Researcher has a full control over simulated driving as an alternative to on road assessment; simulation saves time and costs. In addition, high-risk drives can be tested in a driving simulation under safe conditions in which errors can be made without cost to life or property [32].

The study confirmed that the airport road design and wayfinding have no significant effect on the drivers' age. The result shows that the drivers' age has no impact on the research parameters; risk of collisions, exceed the speed limit, traffic light tickets, centerline crossings and road edge excursions. The complexity of road design and wayfinding were associated with poor driving performance on simulated driving task. Drivers' age was also contributed to the risky driving behavior and road safety. Interestingly, the driving behaviors are not contributed to pedestrian hit, road accident, illegal turn and speeding ticket.

Senior drivers' attention and ability to process signage and wayfinding information is limited. These limitations create difficulties for them as driving require the division of attention [34] between control, guidance and navigational tasks in order to navigate AASHTO [35] to the airport. Senior drivers prefer to attend to one of these at a time as the driver's attention can be easily switched from one wayfinding information source to another. For example, senior drivers can only extract a small proportion of the available information from the road scene to navigate to the airport. With regards to limited information processing capacity while driving, these drivers subconsciously determine acceptable information loads that they can manage. They are unaware that important information has been neglected when the incoming information load is exceeded, which leads to the driving errors during this process. AASHTO [35] agreed that a driver may neglect a piece of information that turns out to be critical, while another less important piece of information was retained.

5. Limitation

The research applied a well-established method and utilized a verified arrangement for encoding the driving simulation. It involved collecting primary and secondary data as well as carrying out the required analysis as the availability of research material was limited. The airport road access wayfinding design simulation is new to the aviation industry. Difficulties were encountered in obtaining participants to run the airport road access wayfinding simulation. The barriers in coding of simulation reduce the quality of the data, therefore, assistance from academic and professional experts was highly appreciated [6].

Driving simulators have a few disadvantages such as simulator sickness (a type of motion sickness) is experienced by senior drivers whilst "driving" in the simulator room; it may include dizziness, headache, nausea and vomiting [8], [36]. Senior drivers would be compromised when experiencing these symptoms and it may not be appropriate for them to be involved in a simulated driving experience. Gruening et al. [37] claimed that the information gained through driving simulations may be misleading if the simulator does not provide an appropriate analogue to the simulated scenario, and that high reliability driving simulations are sometimes far more expensive than vehicle testing.

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