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Good Old Gamers, Good Drivers: Results from a correlational experiment among older drivers

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Abstract

In many situations, driving is essential for senior citizens to maintain their independent lifestyle. A systematic literature review was conducted that summarized the age-related physical, visual and cognitive functional declines and their associated risk to driving. Based on these findings, we explored whether the skills required in playing Xbox Kinect video games were correlated with measures of driving performance among older drivers. Fifty-two participants, 65 years of age or older (Mean = 72; SD = 3.84; range 65 – 85 years; 29 males) who have access to a car and drive frequently were invited to play *Just dance*, *Table Tennis* (ping pong), *Bowling*, and *Dr Kawashima's Brain Training Exercises* on an Xbox Kinect 360. Participants also completed a 25-minute on-road driving task along a predetermined route to assess and identify critical driving errors using a similar instrument as that used by a driving license examiner. Bivariate correlation examined the relationship between game scores and these objective driving skills. There was a significant correlation between the Xbox Kinect video games and on-road driving scores ($r = 0.861$, $p < 0.001$), indicating that 'good gamers are good drivers'. This correlation was significant for the males ($r = 0.864$, $p < 0.001$) as well as for the females ($r = 0.878$, $p < 0.001$). We suggest that performance on Xbox games may be a suitable, cost-effective and less-risky indicator of on-road driving skills for older drivers, particularly in jurisdictions in which mandatory testing of older citizens has been introduced or is being considered as a requirement in the driver licensing process.

Keywords: Older drivers; Xbox; gaming; road safety; driving behaviour

1 Introduction

The world's population is ageing rapidly. In 2012, 6.9% of the world population were more than 65 years old, and this is estimated to increase to around 20% by 2050 (OECD, 2012). As the population is ageing, the number of older drivers is also increasing. Unfortunately, older drivers are overrepresented in crash statistics (Insurance Institute for Highway Safety, 2010). In the United States, 17% of all traffic fatalities and 16% of all vehicle occupant fatalities in 2012 were caused by older drivers of age 65 and older. In Australia, older drivers have the higher risk (per distance travelled) of being killed in a crash than any other age group (Transport Accident Commission, 2013).

Ageing is associated with functional declines in abilities such as cognitive skills, physical skills and visual attention which negatively impact on driving of older adults (e.g., decline in information processing speed, cognitive inflexibility, decline in executive functions and motor skills) (Anstey et al., 2012; Bixby et al., 2007). However, the literature (Etnier et al., 1997; Hawkins et al., 1992; Kramer et al., 2002; Shay and Roth, 1992) reveals that exercises or training appears to be positively correlated with improving perception, cognitive, physical and visual abilities. As a result, people who participate in exercise training perform better on tests such as attention capacity, visual-spatial processing, and information processing. In this paper we extend this to investigate the correlations between the skills and abilities required for playing Xbox games and the skills and abilities required for driving.

Cognitive performance in particular has been of considerable interest and appears to be the factor most related to driving limitations of the elderly (Vance et al., 2006). Safe driving necessitates the coordination of cognitive abilities (e.g., speed of processing, perception, attention, memory). The cognitive abilities of older adults are able to be boosted through cognitive training (Ball et al., 2002), (Ball et al., 2007), (Kramer and Willis, 2002). Unsurprisingly given that driving involves skills and abilities to handle complex tasks, a considerable proportion of older driver crashes take place while they are driving in complex situations such as negotiating intersections (Mayhew et al., 2006), (McGwin Jr and Brown, 1999).

Physical abilities are also necessary for safe driving by older adults. Marottoli et al (Marottoli et al., 2007) demonstrate a potential relationship between physical exercise training and physical abilities. They also reveal that there is possibility of maintaining older adults' driving performance by providing physical exercise over a period of time. Furthermore, Ostrow et al (Ostrow et al., 1992) reported that a randomized control trial of a group of elderly drivers on an eight-week physical exercise training regime resulted in improvements in older drivers' shoulder flexibility and trunk rotation, and these improvements were positively related to specific driving skills such as lane changing and shoulder checking. Visual difficulties associated with ageing (e.g. declining speed of visual search, glare sensitivity and acuity, and peripheral field loss) have been found to contribute on unsafe driving or involvement in crashes (Wood et al., 2008). A 12-week exercise intervention with older drivers revealed that visual attention, behavioural speed and visuospatial abilities required for driving were significantly enhanced for the participants (Hancock et al., 2002).

Exercise training has been extensively used to enhance the functional abilities of the elderly (i.e. cognitive, physical and visual abilities) resulting in better driving skills. While exercise training programs can be implemented through playing motion-controlled consoles such as Xbox Kinect, the relationship between the elderly's functional abilities and their score in playing video games has not been examined. Hence, the main objective of this paper is to evaluate the correlation between playing Xbox Kinect video games as an enjoyable and inexpensive way to combine functional abilities with driving performance among older drivers. The literature regarding the driving skills of the elderly and their associated age-related functional declines has been systematically reviewed. Using the experts' opinion, classifications of elderly's risky driving skills and their associated age-related functional declines have been generated. This has led to test the following research questions with respect to Xbox Kinect video games addressing exercise combining functional abilities and how this is correlated to the driving skills of the elderly:

RQ: *Are Good gamers, good drivers?*

Therefore, this study does not aim to prove the effectiveness of the Xbox Kinect video games exercises as an effective intervention to improve driving skills, but it is a correlational study evaluating the game skills and the maintenance of driving skills amongst the elderly.

Conventionally, "elderly" has been defined as a chronological age of 65 years old or greater. Orimo et al (Orimo et al., 2006) have discussed the differences between those from 65 through 85 years old, referred to as "early elderly" and those over 85 years old as "late elderly" or "oldest old". For the purpose of this work, discussing a technological solution that requires minimum functional abilities, we treat the term elderly as being in their early elderly stage; as suggested those who have begun the ageing process and are starting to experience decline in their functional abilities (Orimo et al., 2006).

The rest of this paper is organized in the following way: Section 2 explains a systematic literature review on the relationship of age-related functional declines among the elderly and the associated impact upon their driving performance. This section also introduces Xbox Kinect as a way that can combine different functional exercises. Section 3 presents an experiment that examines the correlation between the elderly's score in playing Xbox Kinect games and their on-road driving performance. Section 4 discusses the findings of the experiments, presents the limitations of the paper and opens new avenues of research for future studies.

2 Xbox Kinect Video Games: Mapping the Combination of Physical, Visual and Cognitive Engagement to Driving Performance of Older Adults

In this section, we map skills required to play Xbox Kinect video games to age-related functional declines associated with driving. This would help us to hypothesize the correlation between Xbox Kinect playing skills and driving performance. The first step for doing so is to systematically review the papers in this area and elucidate the classifications of risky driving skills and their associated age-related functional declines. We customized the guidelines for systematic search suggested by Etnier et al (Etnier et al., 1997) which have been used extensively (e.g., (Vichitvanichphong et al., 2013a), (Vichitvanichphong et al., 2013b)). The systematic method proposes three main steps to carry out a literature search; (1) Exploratory background search to identify the relevant keywords and databases, (2) Searching for the initial list of studies and (3) Relevance appraisal. In what follows, we explain the process that we use in order to conduct our systematic search of the literature for the issues associated with the driving performance of older adults.

Step 1: Exploratory background search: identifying keywords and databases: The first step towards searching the articles was to identify the relevant keywords and online databases. We have conducted a background survey in Google scholar. In order to identify the relevant keywords and related online databases, we have implemented the experimental method proposed by (Dieste et al., 2009). The method was applied in the first 20 relevant papers found by searching in Google Scholar. We have identified the most popular online databases indexing these 20 papers, in addition to the most popular keywords relevant to "driving skill", "functional ability", and "senior". Based on the exploratory search, six databases have been chosen as listed in Table 1.

Step 2: Searching the initial list of papers: The six databases were searched for the terms "aged care", "aged", "aging", "senior", "old", "elderly", "elder", "older", "older driver", "elderly driver" and any of "driving", "driving assessment" and any of "ability", "capability" or "performance" in titles, keywords, abstracts or full texts of papers published since 2000, inclusive. The search returned 71,486 articles. The distribution of papers in each database is presented in Table 1.

Step 3: Relevance appraisal: In this step, the objective was to filter relevant papers from the initial list and exclude the ones which were not related to our study. This process was carried out by excluding papers based on titles, keywords, abstracts, and full texts. Among 71,486 papers indexed in the databases and searched by the keywords 6,942 papers were retained after title filtering, 518 articles remained after abstract filtering and 68 papers were identified as the final list of relevant papers after reading the full text. We also found some of the papers were indexed by multiple databases; see Table 1. It is notable that Zotero (http://www.zotero.org/) was used for reference management.

		Filtered by titles		Filtered by abstract		Filtered by text	
Name of Database	**Initial list of papers**	Number of found articles	Number of duplicated articles	Number of found articles	Number of duplicated articles	Number of found articles	Number of duplicated articles
Springer	838	188	53	60	8	8	5
Wiley InterScience	777	193	36	161	23	30	10
ScienceDirect	6,030	204	44	146	15	59	31
Scirus	41,151	3,326	153	68	6	0	0
PubMed	3,190	922	71	66	8	23	13
Google Scholar	19,500	2,713	247	89	12	46	39
Total	71,486	7,546	604	590	72	166	98
Relevant papers by deducting the duplicated articles			6,942		518		**68**

Table 1 Distribution of papers in each online database

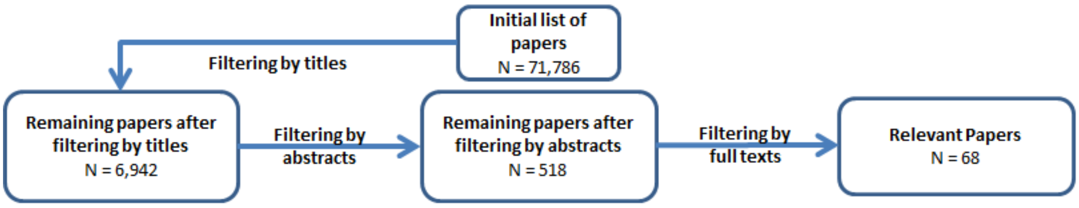

Figure 1 Relevance appraisal Process

The final 68 papers were further categorized as follows: (1) driving skills that have been identified as risky among older drivers and (2) age-related functional declines that have been reported by the literature as contributors to driving risk amongst elderly people. In the following sections, we discuss these two findings. The detailed explanations of the results in this systematic review can be found in Appendix 1 and 2. In addition, the relevant 68 papers are listed online[1]

2.1 What happens to our driving when we get older?

The driving skills that have been identified as associated with increased risk for older drivers can be further categorized as (1) decision making, (2) direction and lane control, (3) lack of regulation compliance and awareness, (4) speed performance, (5) visual checking and physical control, (6) recognizing and responding to signs, (7) recognizing and responding to traffic lights, and (8) skills involved in turning and parking.

The first category is decision making skills such as how elderly people determine, behave, and respond when they approach an intersections or headways (e.g., behaviours in relation to the use of mirrors, signalling, and obedience to signals, judgment, and turning procedures). Not surprisingly, we found that when older drivers have made an error, it is difficult for them to recover the situation by subsequently making the right decisions.

The second category is direction and lane control. This category has been reported as a critical issue for the elderly's driving. Direction and lane control relate to the ability to control the vehicle with respect to heading along the desired route as well as keeping to the lanes. We found large numbers of errors and unsafe behaviours being made by elderly drivers in relation to this. e.g., extreme positioning error (driving too close to lane markings), turning or changing lanes without looking, unsafe performance in steering, failure to observe nearby traffic when merging and changing lanes. Elderly people tend to repeatedly produce errors in direction and lane control which leads to the greater risk and unsafe driving.

The third category is a lack of regulation compliance and awareness. The findings suggest that older people who have better self-awareness and traffic awareness when driving have a reduced

[1] https://onedrive.live.com/?cid=7D934CF0AC729F11&id=7D934CF0AC729F11!470

injury risk, crash involvement, and collisions. Ignoring or not complying with the traffic regulations leads to an increase in number of crash occurrence in this age group.

Another problem that has been reported in the literature is speed performance e.g., how elderly approach an intersection and whether they do it at an appropriate speed, confidence when driving at high speeds, and speed control; not too fast or not too slow. The research findings indicate that older road users are more likely to be involved in traffic accidents caused by being unable to approach an intersection at an appropriate speed. For instance, when elderly enter on to larger roads or even intersections, they are more likely to speed up before getting to the road or the intersections.

Visual checking and physical control have been highlighted by the literature as another risky issue associated with older drivers. The visual checking and physical control entails mirror and blind spot verification, steering wheel control, and brake reaction. These have been reported as one of the common failures related with ageing.

Another category that has been reported in the literature over the past thirteen years is recognizing and responding to signs. That is a failure to recognize and respond to signs. This is ranked as the third critical major mistake made by the elderly. Recognizing and responding to signs include how elderly observe, approach, and react to traffic signs. As they age, perceiving and analysing the situation on the roads becomes difficult and complex for older drivers including in small roads or uncomplicated circumstance. For instance, the elderly fail to stop in the right place, ignore give way signs, and this includes being indecisive of when to proceed when the opportunity arises.

It was also found that recognizing and responding to traffic lights has been reported as one of the significant issues associated with driving skills of elderly people. The findings indicate that older drivers commit more traffic light violations owing to failures to stop before the line at a red light and are involved in greater numbers of traffic accidents and collisions. In addition to this, older drivers sometimes fail to approach or even notice traffic lights whether they are yellow, red, or green.

Turns and parking are also one of the classic examples of risky driving amongst older people. Turning or changing lanes without looking, for example, has been reported as a critical error made by the elderly. Turning position errors (e.g., wide turns or cut turns), aggressive manoeuvres (e.g., risky turns), turning into the wrong lane, particularly in motorways, have been identified as common mistakes made in this age group. We also found that older drivers often fail to perform parallel parking well which in turn can lead to crashes.

Readers wishing more detailed explanations on these categories of risky driving skills among elderly and the citations of the relevant articles are recommended to refer to Appendix 1.

2.2 Age-related functional declines among older drivers

The age-related functional impairments of elderly drivers which have been investigated in the 68 relevant papers into three main groups; namely (1) physical abilities, (2) cognitive abilities, and (3) visual abilities.

We found that the following physical abilities were deemed necessary for skilful driving and these are associated with safe driving for the elderly. The physical abilities include the measures of proprioception, motor conditions, physical reaction time, hearing ability, and so forth. The findings indicate that since accident involvement tends to increase with age, physical declines could make older drivers more vulnerable to serious injuries or even fatalities. For instance, older drivers, who experience a range-of-motion disability such as neck rotation, limbs, shoulder flexion, elbow, hands, and foot abnormalities, will find difficulty in remaining safe on the roads. This range of motion plays an integral role to support the movement of joints. Not surprisingly, driving is a complex task and it is driven basically by body movement. We found that the correlation between physical impairments and lower level driving performance is relatively high.

The effect of cognitive impairment on driving ability has been also found in the literature. Several studies have examined cognitive abilities as a predictor of the elderly's driving performance and safe driving. Safe driving necessitates the coordination of cognitive abilities such as attention, perception, memory, speed of information processing, and self-regulation. However, the literature has reported that a large number of older drivers have suffered from cognitive declines due to ageing as well as chronic diseases. These lead to an increase in the number of collisions.

Changing in visual abilities also impacts on elderly's driving performance. Visual abilities include the measures of visual acuity, useful field of view (UFOV), glare sensitivity and acuity, eye movement, and speed of visual search. Age-related changes in vision have been reported in the literature as a significant factor contributing to various errors or crash involvement while driving. The findings also indicate that older drivers with impaired contrast sensitivity have an increased risk of crashes especially when driving at night or on rainy days. One of the measurements for visual attention and processing speed is useful field of view. UFOV is the area from which a person can extract visual information in a brief glance without head or eye movement which technically deteriorates with age. We found that reduction of UFOV, age and driving skills of the elderly show significant correlation to older adults' driving difficulty.

Readers wishing more detailed explanations on these categories of age-related functional declines among elderly and the citations of the relevant articles are recommended to refer to Appendix 2.

2.3 Mapping: Experts' opinion

A peer review of the findings for the age-related functional declines and the risky driving abilities was undertaken. Four experts from North America, Australia, Europe and Asia were invited to code both interventions and impacting factors of adoption into categories. The experts were chosen based on their academic knowledge and practical experience in the topic. In order to recruit judges, 3 invitation emails to North American experts, 4 emails to Australian experts 4 to European experts and 2 to Asian experts were sent. These emails were sent to people who have known contributions in the field. Out of these invitations, 6 experts showed their interest and one did not reply to the follow up email. Therefore a total of five judges examined the reliability of the results, this meant that there was at least one from each geographical region. The experts were given an instruction sheet including the description of all the items as well as an answer sheet in which they were asked to map the age-related functional declines related to the risky behaviours of the elderly.

A reliability test was then undertaken based on proportional reduction in loss (PRL) reliability indicator introduced by (Ortiz et al., 2013). PRL is used to assess the consensus between judges who are invited to map a number of elements together. Inter-judge agreement was measured by dividing the total pair-wise agreements by the total pair-wise decisions. With five judges, the mapping of each age-related functional decline into a risky driving skill, resulted in a total of 10 pair-wise decisions being made. The consensus of this mapping was the most frequently selected choice by the five judges. The reliability for each contribution was calculated based on the value of Inter-judge agreement. Therefore, the hypothetical mapping resulted in a reliability rating of 81%. Based on measures presented in (Ortiz et al., 2013), the proposed correlation is considered a reliable hypothesis.

3 Correlational Experiment

3.1 Participants

Fifty-two individuals (range 65 – 85 years; Mean = 72; SD = 3.84; 29 males) participated in this study. All the participants had a sufficient level of familiarity with the Xbox Kinect video games and the project.

The recruitment process was as follows;

Senior citizens were emailed and asked to volunteer for the research. The selection criteria were:

- Must be 65 years or greater
- Hold a legal driver licence
- Have been driving regularly for over the last 12 months
- Have access to a car

Older people who wished then to participate in the study were required to give written informed consent stating that they have no medical conditions which would preclude their participation and they accepted the minimum chance of accidents and will carry its liabilities as their responsibilities.

The University provided a $20 fuel voucher for any participant who completed the driving course to compensate them for the use of their car.

Of the participants who volunteered, a two-step process followed. In the first step the older driver was asked to participate in an easy low risk driving course. If the researcher then identified that the participant was a high risk driver, he/she was not included in the second (evaluation) course.

3.2 Design

The study collected data from two different assessments; (1) playing Xbox Kinect video games and (2) on-road driving assessment. The first assessment was to get the subjects to play the four games (just dance, table tennis (ping pong), bowling, and Dr Kawashima's brain training exercises). The second experiment assessed driving performance of the older people. The experiment was a correlational study between two variables resulted in the above-mentioned assessments; (1) gaming score and (2) driving score.

3.3 The Choice of Games

The choice of games was based on a small-scale self-observatory study by Sue et al., (2014a, 2013) in which eleven Xbox Video games were played at least twice per week over a three month period. The player documented his/her experience by explaining how he/she was engaged with these games. The notes from the player were discussed in a focus group of five experts. Experts were provided with an instruction sheet as well as an answer sheet in which they were asked to map the Xbox Kinect Video games, functional abilities and driving skills. Among the eleven games, only Bowling, Just Dance, Table Tennis[2] and Dr Kawashima's Brain Exercises[3] were chosen. This was based on the experts' opinions on the suitability of these games with respect to combining visual, cognitive and physical exercises.

3.4 Procedure

The participants were invited to complete two assessments:

Playing Xbox Kinect video games: All participants were invited to play

1) Just Dance (a rhythm game in which players pick any track of music and attempt to dance with the on-screen dancer; the more the player dances similar to the dance the better score she/he will get),
2) Table Tennis (ping pong),
3) Bowling,

[2] http://marketplace.xbox.com/en-Au/Product/Kinect-Sports/66acd000-77fe-1000-9115-d8024d5308c9
[3] http://www.totalxbox.com/25651/reviews/dr-kawashimas-body-and-brain-exercises-review/

4) Dr Kawashima's brain training exercises (a set of memory performance exercises for the player).

The participants played each game individually, in separate sessions. Each session began with an introduction to the game explained by the assessor. After that, the player was asked to practice each game until he/she was comfortable with the game. Each player was given five minutes' rest after the practice session. The participant was then asked to play each game three times with actual scores being recorded by the assessor (one round). The player was given 3 minutes of rest between rounds. The average score was calculated as the player's score for the game. This was repeated in separate sessions for each of the four games.

On road driving assessment: In order to ensure the safety in the driving experiment, it was recommended by the ethics committee that dangerous drivers be identified in a basic, non-challenging pre-test. Any drivers identified as dangerous were excluded from the full test. Therefore, this experiment consisted of two steps:

Step 1: The main objective of this step was to minimize driver and assessor risk. In this step, all participants were requested to drive for approximately 10 minutes in a basic non-challenging road environment while the assessor was sitting next to them; see the driving course provided in Appendix 3. At this stage, if the researcher felt that the participant had potentially unsafe driving habits (failing in any of the driving tasks in step 1), the participant would not been invited to proceed to Step 2. The participants were given instruction and information regarding the commencement of actual driving, as well as during the driving as required. Nonetheless, the experiment did not include any unusual activity that was more than what the participants do in their everyday driving. If the decision was made not to proceed to the second stage, the participant was informed in a polite and considered way (no indication was given to any perceived problems with the participant's driving abilities). It is notable that no participants were excluded from Step 2 due to being classified as a dangerous driver.

Step 2: Main driving assessment. The on-road driving course took approximately 20-25 minutes to complete (the route is provided in Appendices 3 & 4. The assessor was seated next to the participant who assessed his/her driving skills based on the driving assessment instrument as described in Appendix 3. The participants were given instructions and information on the road prior to the actual driving as well as during the driving anytime they needed it. The objective of this step was to assess the driving skills of the participants. The instructions referred to the direction of driving according to the pre-defined path. Once on the road, if the assessor felt unsafe, she would accordingly advise the participant of regarding her concern, as agreed to in the previously signed written consent form, in a polite manner. Participants could withdraw from the study at any time. The traffic conditions of the on-road route reflected everyday normal driving (e.g., signalized intersections, pedestrian traffic).

3.5 Instruments

In order to assess the gaming score and driving score, as discussed above, the experiment employed two separate instruments:

Instrument for Gaming Assessment: The instrument recorded the scores given by Xbox Kinect 360 Console for each of the four games for each participant. Participants played each game three times, therefore the actual score that was calculated for each game for each participant was the average of his/her scores in each of the three game sessions.

Instrument for Driving Assessment: The driving assessment has been designed based on assessing risky driving skills reported in the literature and identified in the systematic literature review (Appendix 3). The assessing method and the scoring system were borrowed from the guidelines of assessing driving from the transport department of the region where the experiment was conducted (Australian state). The scoring system calculated the scores based on negative marking of driving errors that participants made. There were three types of errors as defined below:

- Critical Driving Error (CDE) that indicates any error that ends up needing a Physical or Oral interference by the driving assessor, Collision, Dangerous action, Disobeys an official direction by a police officer or an authorized traffic controller. (Please note, although it was planned that if such an error occurs the driving test should be immediately stopped, there were no CDE made by any of participants.)
- Non-Critical Driving Error (NCDE) which is driving errors that are not critical.
- Specific repeated driving error (SRDE) that is NCDE associated with a specific assessment item for more than six times.

In this scoring system, as followed by the guidelines of the transport department, the instrument is designed in such a way that for each assessment item (see Appendix 3) the driving assessor only records an NCDE three times and an SRDE once. For example, if a participant makes 4 or 5 NCDE errors, he or she would be still subjected to deduction of only three error points. That is, if a participant repeatedly makes the same error, (more than three times), a maximum of 3 points will be deducted. However, if any errors cause a concern for safety reasons and ends up with assessor interference, then this will be considered to be a CDE and will result in termination of the driving assessment. In calculating the total score, once an SRDE has been recorded, 6 error scores are deducted. Therefore, the maximum error for each item is 6 and as such the maximum error that a participant could make during the test for each item can be calculated based on multiplying 6 to the number of assessment items/ risky driving skills among the elderly (see Appendix 1). The guidelines requires that the actual score for each participant can be calculated based on how far he/she is from the maximum errors that she/he can make during the test.

$$Actual\ Driving\ Score_i = Maximum\ Error - Error\ Score_i$$

3.6 Analysis

After running the above-mentioned assessments, two sets of data were analysed 1) gaming scores and 2) driving score. In the analysis, the following steps were taken:

Step1 – Calculating the relative scores: The objective of the experiment was to evaluate if good gamers are good drivers. Therefore, being ‘good’ was defined as a relative term in which the participants were compared with others in the assessment. This was applied to gaming score as well as to the driving score.

For each game where i is a participant, j is one of the games i.e. Bowling, Just Dance, Table Tennis, Dr Kawashima’s Brain Training, actual score is what score she/he obtained in each game and the relative score is what is going to be used in the analysis. This also resolved the issues of games having different scoring system, as the relative gaming score is a comparative/ratio value.

$$Relative\ Gaming\ Score_i^j = \frac{Actual\ Gaming\ Score_j^i}{Average\ Actual\ Gaming\ Scores_j^i}$$

Based on this equation, the average of these scores for all the four games was calculated and used in the analysis. In this study, the term game score refers to the relative gaming score.

$$Relative\ Gaming\ Score_i = Average\ (Relative\ Gaming\ Score_i^j)$$

Similarly, a relative score for driving was calculated to reflect the measurement of good driving in comparison with other drivers in the assessment. In this study, the term driving score refers to the relative driving score.

$$Relative\ Driving\ Score_i = \frac{Actual\ Driving\ Score_i}{Average\ Actual\ Driving\ Scores}$$

Step 2 - Bivariate Correlation Analysis using Statistical Package for the Social Sciences (SPSS): In order to test the correlation between the two data sets of the relative gaming and driving scores, a Bivariate Correlation Analysis was conducted in SPSS to calculate correlation coefficient (r). The significance level of this correlation was measured by p-value.

3.7 Results

The results indicated that the correlation between the participant's score for playing Xbox Kinect video games and their driving performance score was significantly high (r = 0.861, p < 0.001) thus supporting the hypothesis that "Good old gamers are good drivers". It was found that the participants' score for playing Xbox Kinect video games was positively correlated with their driving performance score for the males, r (29) = 0.864, p < 0.001, as well as for the females, $r(23) = 0.878$, $p < 0.001$. The difference between these correlations was statistically non-significant, $z = -0.194$, $p < 0.846$.

This suggests that a good old gamer would be a good driver and this would be also the case for males as well as female with no significant statistical difference between the two.

4 Discussion, Limitations and Future Work

Recently a new phenomenon of motion-controlled consoles such as Xbox Kinect has entered into the market of video games. These devices have the potential to provide insight into not only the cognition of players but also the physical and visual states requiring interactivity by the use of gestures from the entire body. As such, this technology provides a relatively inexpensive platform upon which the different functional abilities associated with the driving performance of the elderly can be explored, a heretofore unrealised opportunity. Previous work had suggested that when we get older, we experience functional declines that result in risky driving behaviour. The systematic literature review revealed that the ageing-related driving literature encompasses physical, cognitive and visual declines as these functional abilities are associated with risky driving. This study sought to investigate if an elderly driver's skills in playing the Xbox Kinect video games which combines physical, visual and cognitive exercises, can correlate with their on-road driving skills. Interestingly the study demonstrated that an elderly person who plays particular games on the Xbox Kinect also drives well on the road in typical driving conditions.

The consistent finding, irrespective of participant gender, that good gaming performance was strongly correlated with good on-road driving performance suggests that this relationship is relatively robust. This can have important road safety implications. To illustrate, it is noteworthy that a considerable part of the road fatalities involves older drivers aged 65 years and older (Transport Accident Commission, 2013; Transport and Main Roads, 2014). Consequentially some jurisdictions have introduced mandatory driver testing[4], mandatory medical assessments[5], or are considering introducing mandatory testing of older drivers[6] as part of the licensing process. The research findings suggest that inexpensive and low-risk Xbox Kinect games may be an indicator of on-road driving performance for drivers who are familiar with such technology. As such, these devices may suitable for use as a screening tool which could identify drivers requiring on-road assessment to ascertain whether it is safe for them to retain their driving privileges. Furthermore, the gaming scores may also indicate on-road driving performance of drivers with medical conditions such as Parkinson's disease (e.g., Vaux et al., 2010) As such, Xbox games may be used as an inexpensive screening tool to identify drivers who may need additional assessment irrespective of age-related or disease-related impairments, and in particular on-road driving assessment.

The present results are consistent with earlier research in older adults which examined the relationships between functional abilities and driving performance of elderly people. However, the study findings are in stark contrast to the findings of Lutz and Klimmt (Jäncke and Klimmt,

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[4] e.g., http://www.rms.nsw.gov.au/licensing/downloads/olderdriverguide.pdf

[5] e.g., see http://www.qld.gov.au/seniors/transport/safe-driving/

[6] e.g., see http://www.abc.net.au/radionational/programs/backgroundbriefing/compulsory-testing-for-senior-drivers-under-scrutiny/5117828

2011) who reported that expertise in playing video games cannot be transferred to driving measured by computerized tests. There are two possible explanations for this discrepancy. First, while most of the studies in this domain have evaluated the skills of drivers in simulators or computerized tests, the current work measures the on-road driving of participants. The differences between the results of real on-road driving and simulators have been also the topic of discussion in other contexts (Helland et al., 2013). To illustrate, Mullen et al (Mullen et al., 2011) state that simulator approximates the relative driving but does not exactly replicate on-road driving behaviour. This can be one indicator of the conflicting results between (Jäncke and Klimmt, 2011) and the recent experiment. In this regard, the systematic literature review has come up with the list of functional declines among elderly that need to be taken into account in deploying any technological interventions including simulators. Second, the work of Lutz and Klimmt (Jäncke and Klimmt, 2011) targets the whole population and does not specifically examine the on-road driving performance of the elderly. In this regard, the work presented here has developed and evaluated a driving assessment instrument for older drivers. In order to do so, a systematic literature review initially was conducted to identify the risky driving skills among older adults. The reliability of the final instrument was evaluated by a panel of experts while the validity of the instrument was tested in the on-road driving study.

4.1 Limitations and Future Work

The present work examined the relationship between the elderly's skills in playing the Xbox Kinect video games, combining different functional abilities, and their driving performance. The statistical procedure – correlation - used in this work does not evaluate possible casual relationships between these constructs. Therefore, due to the different objective of this work, it cannot be concluded that training based on playing the Xbox Kinect video games would improve driving performance of the elderly and a recommendation for the widespread use of the Xbox in order to improve driving performance cannot be made. However, it does open up an opportunity for future randomized longitudinal studies to investigate the causalities among these two constructs.

Following the recommendation of the ethics committee and to reduce the dangerous risks for the assessor, when assessing the driving performance of the elderly, the drivers first were asked to drive a basic and non-challenging route. If their driving was identified by the assessor as dangerous, then they would not be invited to the main driving test. This could have led to a bias in not assessing poor drivers. However, the assessor did not exclude any participants from the second on-road driving stage.

In addition, it can be also argued that driving assessment is an observational exercise that can be vulnerable to the subjectivity of the assessor. However, the procedures and the guidelines, issued by the department of road safety and transportation of the region where the experiment was conducted, were used to maximise the reliability of the driving assessment. In this regards, further research is planned in which the findings of the current study are compared to the results of driving in a simulated driving environment. Other objective measures such as g-force events (including sudden acceleration, deceleration, and sharp turns) can also be incorporated in these projects, further validating the subjective driving assessments.

5 Concluding remarks

Given the ageing population around the world, the road safety of older drivers is likely to remain of considerable importance. In addition, numerous jurisdictions have mandated driver testing as a licensing requirement for older drivers. Testing requirements (mandatory and other) raise issues regarding social and financial capital investments in measuring driver performance. The findings suggest that readily available and inexpensive technology options, such as Xbox Kinect devices, may be able to assist in identifying drivers in need of further assessment (including on-road driving assessment in specific driving circumstances).

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Appendix 1: Risky Driving Skills Among Elderly

	Detailed Error
Decision making	• Approach to headway • Approach to pedestrians • Avoid taking unnecessary risks in traffic • Be aware of cyclists • Cautious when other erratically • Communication with other road users • Decision and judgement • Error detection (awareness and sensitivity of participants in finding out they had made mistakes) • Error recovery (Driving behaviours when participants tried to rectify mistakes committed) • Foresee dangerous situations in the traffic • Intersection negotiation • Judge when it is safe to enter a larger road from a smaller side street • Judging distanced of oncoming cars • Judging speed of oncoming cars • Beware of railroad crossing • Share road with vulnerable • Stop for the pedestrians at zebra crossings
Direction and lane control	• Centre car in lane • Centreline crossings • Follow direction • Forward view • Proper lane selection • Keep distance change lane • Lane changes/ diverging • Lane keeping and lane position • Lateral lane position on the road • Maintain lane when turn • Use mirror for lane change • Use of indicator • Vehicle control
Lack of regulation	• Comply with traffic regulations • Awareness of driving of others • Be patient with other road users even when they make mistakes • Driving self-regulation e.g. judge whether you are too tired to drive • Traffic awareness • Use seat belt
Speed performan	• Approach intersection at appropriate speed • Approach to speed limit • Low confidence on high speed • Speed control (too fast or too slow)

Visual checking and physical control	• Appropriate steering recovery • Mirror and blind spot verification: Check blind spot before change, check mirror change lane, left-right side mirror check, scan to sides, scan to rear/ head check • Brake reaction (smoothly and accurately) • Car control • Choice visual reaction time • Head rotation towards the left • Head rotation towards the right • Mechanical operations (Fluency and timeliness of steering and pedal control) Steering control: steering torque, steering ability
Recognizing and responding to signs	• Observing signs: approach to stop signs, Traffic sign compliance (give way, sign with caution, stopping in the right place, giving way as required, being decisive to proceed when opportunity arises and correct use of indicators) • Changing traffic signals • Comply with traffic signals and railway crossing signals • Make complete stops • Reaction time to popup stop signs • Respond to signage
Recognizing and	• Approach to signal lights (green, yellow, or red) • Colour choice reaction time • Obey traffic lights
Skills of turns and parking	• Directional turns and K turns • Left turns • Right turns • Position car for turns • Parallel parking • Turn into wrong lane • Postural sway

Appendix 2: Risky Driving Skills Among Elderly

Physical Abilities	**Description**
Proprioception	the ability to sense the position, location, orientation and movement of the body and its part
Postural sway	balance ability or the movement of the body in a still position
Sensorimotor performance	abilities and skills required to acquire and process sensory information in order to produce a desired response
Executive control mechanisms	the ability to regulate the actions of the body
Psychomotor functioning Measures of strength and balance	the measures of strength and balance of dexterity which is related to the ability to control vehicles or maintain lane position
Endurance	the ability or the power to withstand a difficult process or situation
Wrist flexion and abduction	the ability to bend or sway of wrist to the wanted direction
Range of motion (e.g. neck, limbs, shoulder, elbow, hands)	range of flexion and extension of parts of body (e.g. neck, limbs, shoulder, elbow, hands) which joints can be moved
Eyesight	the ability to see that directly impacts on driving
Hearing impairment	the deterioration of sense of hearing which is significantly associated with driving cessation
Motor conditions (e.g. leg strength and mobility, head and neck flexibility)	the flexion and rotation ability of motor/ somatosensory functions of elderly e.g. leg strength and mobility, head and neck rotation, shoulder and elbow flexion, finger curl, ankle plantar flexion and ankle dorsiflexion
Manual dexterity	adroitness of using and controlling hands
Physical reaction time	the interval time between the presentation of a stimulus and the initiation of the muscular response to that stimulus
Cognitive Abilities	**Description**
Executive abilities	Ability to think or manage more likely related to decision making
Visuo-spatial perception	It refers to ability to process and interpret visual information about where objects are in space
Working memory	Explains human beings' ability to hold relevant information in mind and ignoring irrelevant information
Speed of information processing	Speed of process of information evaluation, which declines by age
Attention and concentration	Attention and concentration is a part of cognitive assessments. The results will identify how elderly are able to pay attention to what they are doing
Semantic fluency	Distinctions of between the denotations of different words and symbols
Mental flexibility	the ability to cope with various circumstances in different ways, particularly how to respond effectively to new, complex and problematic situations
Cognitive-perceptual dysfunction	e.g. abnormality in depth perception, sustained attention, and divided attention
Difficulties with orientation	The relationship between physical position and direction

Reacting too slowly	Reaction of doing something which the performance is slower than expected
Self-regulation of driving	The perception and decision of oneself to not to drive when he/ she doesn't feel good or when he/ she realises that health condition is not in a good shape
Visuo-constructional ability	the ability to organize and manually manipulate spatial information to make a design
Visual memory	the ability to store and retrieve previously experienced visual sensations and perceptions when the stimuli that originally evoked them are no longer present
Visuospatial perception	the ability to process and interpret visual information about where objects are in space
Visual Abilities	**Description**
Visual acuity	Sharpness of vision which is measured by how well elderly can see at different distances e.g. far visual acuity, near visual acuity
Visual contrast sensitivity (VCS)	the ability to distinguish the differences between objects and background
Visual field perception	the ability to see objects in one direction
Useful field of view (UFOV)	the area from which one can extract visual information in a brief glance without head or eye movement which basically is measured by visual attention and processing speed
Peripheral vision	the ability to see and identify objects at different degrees/ angles to left or right of the midline while looking straight ahead
Binocular vision	the use of both eyes to produce a single image
Colour vision	the ability to distinguish an object in order to see its colour
Glare sensitivity and acuity	is defined as lowered contrasts in visual filed due to outside sources of light
Glaucoma	an eye disease which damages the optic nerve and impairs vision
Visuospatial ability	related to understand and conceptualizing visual representations and spatial relationships in learning and performing a task
Perception of motion	real movement of objects through visual field
Eye movement	the ability to move eyes to be able to catch an object passed
Speed of visual search	the ability to seek and find something by consuming less time for searching

Appendix 3: Driving Assessment

NCDE: Non-Critical Driving Error
CDE: Critical Driving Error: any error that ends up to:

- Physical or Oral intervention by the driving examiner
- Collision
- Dangerous action
- Disobeys an official direction by a police officer or an authorised traffic controller.

SRDE: Specific repeated driving error: NCDE associated with a specific assessment item for more than six times.

Driving Skills	Assessment Item	Errors				
		NCDE1	NCDE2	NCDE3	SRDE	CDE
Direction/ lane control	Centre car in lane					
	Centreline crossings					
	Forward view					
	Proper lane selection					
	Keep distance change lane					
	Lane changes/ diverging					
	Lane keeping					
	Maintain lane when turn					
	Use mirror for lane change					
	Use indicator					
Visual checking and physical control	Mirror and blind spot verification					
	Brake reaction (smoothly and accurately)					
	Head rotation towards the left					
	Head rotation towards the right					
	Steering control					
Speed control	Approach intersection at appropriate speed					
	Approach to speed limit					
	Control of speed (too fast or too slow)					
Decision making	Intersection negotiation (entail assessment of behaviours related to mirror use, signalling, approach, obedience to sign/ signal, judgement and turning procedures)					
	Judge when it is safe to enter a larger road from a smaller side street					
	Stop/ Start/ Back (Behaviours)					
Recognizing and responding to signs	Observing signs					
	Respond to signage					
Recognizing and responding to traffic lights	Approach to signal lights (green, yellow, or red)					
Turns/ parking	Left turns					
	Right turns					
	Position car for turns					
	Turn into wrong lane					
	Parallel parking					
Awareness	Use seat belt					

Appendix 4: Course of Driving – Step 1

1. Begin: Parking 5a – Olympic Park, Sydney, Australia
2. Leave Parking 5a to the right
3. Drive to Holker way.
4. Go to Parking 5b
5. Leave the Parking 5b to the right.
6. Turn to the left and come back to Holker way.
7. Come back to Parking 5a.

Appendix 4: Course of Driving – Step 2

1. Begin: Parking 5.a – Olympic Park.
2. Turn right toward Turn right toward Hill Rd
3. Take the first left onto Hill Road
4. Continue on John Ian Wing Parade
5. Take Perkins Avenue and Spitz Avenue to Charton Avenue
6. Head west on Beaconsfield St towards Wetherill St North
7. Take the 1st right onto Wetherill St North
8. Turn left onto Carnarvon St
9. Head west on Carnarvon St toward Silverwater Rd/A6
10. Turn right onto Silverwater Rd/A6
11. Turn right onto Holker St
12. Head east on Holker St toward Slough Ave
13. Turn left onto Hill Rd
14. Head northeast on Hill Rd toward Bennelong Parkway
15. Turn right onto Bennelong Parkway
16. Head southwest on Bennelong Parkway toward Marjorie Jackson Parkway
17. Turn right onto Marjorie Jackson Parkway
21. Turn left onto Hills Road.
22. Come back to P5a.