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# Dropout during a driving simulator study: A survival analysis

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ABSTRACT

*Introduction:* Simulator sickness is the occurrence of motion-sickness like symptoms that can occur during use of simulators and virtual reality technologies. This study investigated individual factors that contributed to simulator sickness and dropout while using a desktop driving simulator. *Method:* Eighty-eight older adult drivers (mean age 72.82 ± 5.42 years) attempted a practice drive and two test drives. Participants also completed a battery of cognitive and visual assessments, provided information on their health and driving habits, and reported their experience of simulator sickness symptoms throughout the study. *Results:* Fifty-two participants dropped out before completing the driving tasks. A time-dependent Cox Proportional Hazards model showed that female gender (HR = 2.02), prior motion sickness history (HR = 2.22), and Mini-SSQ score (HR = 1.55) were associated with dropout. There were no differences between dropouts and completers on any of the cognitive abilities tests. *Conclusions:* Older adults are a high-risk group for simulator sickness. Within this group, female gender and prior motion sickness history are related to simulator dropout. Higher reported experience of symptoms of simulator sickness increased rates of dropout. *Practical applications:* The results highlight the importance of screening and monitoring of participants in driving simulation studies. Older adults, females, and those with a prior history of motion sickness may be especially at risk.

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Driving simulators are becoming more widely available and these instruments have many useful applications for research, training, assessment, rehabilitation, and entertainment (Allen, Rosenthal, & Cook, 2011; Classen & Brooks, 2014; Crisler et al., 2011; Dickerson, Meuel, Ridenour, & Cooper, 2014; Pollatsek, Vlakveld, Kappe, Pradhan, & Fisher, 2011). The availability of lower-cost options means that driving simulators are now increasingly accessible to researchers and therapists. Simulators have been used successfully to investigate how to improve the training of novice drivers, (Allen, Park, Cook, & Fiorentino, 2012; de Winter et al., 2009; Pollatsek et al., 2011), and for re-training older drivers and patients with acquired brain injury (Casutt, Theill, Martin, Keller, & Jäncke, 2014; Pollatsek, Romoser, & Fisher, 2012; Unsworth & Baker, 2014). They have also proved useful for investigating distractions common among on-road drivers including use of cell phones while driving (Caird, Willness, Steel, & Scialfa, 2008), text messaging (Casutt et al., 2014), and use of in-vehicle entertainment systems (Engström, Johansson, & Östlund, 2005; Horberry, Anderson, Regan, Triggs, & Brown, 2006); and, more generally, for monitoring driver responses to challenging driving situations (Bélanger, Gagnon, & Yamin, 2010; de Waard, Dijksterhuis, & Brookhuis, 2009; Martin et al., 2010). They have also found wide application for studying the relationship between cognitive abilities and driving performance (Bélanger et al., 2010; Hoffman, Atchley, McDowd, & Dubinsky, 2005; Shanmugaratnam, Kass, & Arruda, 2010) and the effects of cognitive interventions on driving performance (Roenker, Cissell, Ball, Wadley, & Edwards, 2003). A survey of driver rehabilitation specialists found that 11% of specialists reported successfully using a simulator as part of assessment and training procedures (Dickerson, 2013), and a meta-analysis of occupational therapy interventions found that simulator interventions were the most commonly reported and were effective for use with older adults and brain injury patients (Unsworth & Baker, 2014). Driving simulators have been effectively used in different populations, including novice drivers (Allen et al., 2012; de Winter et al., 2009), older drivers (Hoffman & McDowd, 2010; Horberry et al., 2006; Lee, Cameron, & Lee, 2003; Martin et al., 2010; Stinchcombe & Gagnon, 2013), and clinical groups including patients with cognitive impairment (Devlin, McGillivray, Charlton, Lowndes, & Etienne, 2012; Frittelli et al., 2009), HIV (Vance, Fazeli, Ball, Slater, & Ross, 2014), diabetes (Cox, Gonder-Frederick, Kovatchev, Julian, & Clarke, 2000), sleep disorders (Smolensky, Di Milia, Ohayon, & Philip, 2011), and brain injury (Lew et al., 2005; Schultheis et al., 2006).

Driving simulators have several advantages compared to an on-road driving assessment. Most importantly, they are safer than on-road driving, allow dangerous and unusual situations to be assessed, and provide a consistent and repeatable test environment. They also avoid the cost, space, and personnel requirements of on-road testing (Allen et al., 2011; Classen, Bewernitz, & Shechtman, 2011; Classen & Brooks, 2014). Potential clinical patients, physicians, and users agree that driving simulators are an acceptable tool for assessment, research, and training (Crisler et al., 2011; Gibbons, Mullen, Weaver, Reguly, & Bédard, 2014; Schultheis, Rebimbas, Mourant, & Millis, 2007). A growing body of research indicates that driving simulators provide a valid representation

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of on-road driving behavior, depending on the equipment used and the situation being evaluated (Mullen, Charlton, Devlin, & Bédard, 2011; Shechtman, 2010). For example, driving simulator performance predicted at-fault or partially at-fault crashes in the five years following assessment (Hoffman & McDowd, 2010) and, for learner drivers, performance on a driving simulator predicted performance on an on-road assessment 6 months later (de Winter et al., 2009). Discriminant validity has been demonstrated by significant differences in the performance of non-drivers, novice drivers, and experienced drivers both on a simulator and during on-road driving (Mayhew et al., 2011). Measures of overall performance, when compared between simulator and on-road assessment, display concurrent validity across all age groups from young adults to the elderly (Engström et al., 2005; Lee, Cameron, et al., 2003; Mayhew et al., 2011). Specific aspects of driving are also related for simulated driving and on-road driving; for example, Shechtman, Classen, Awadzi, and Mann (2009) demonstrated relative validity for types of driving errors made, and Kaptein, Theeuwes, and van der Horst (1996) showed absolute validity for route choice behavior and relative validity for speed and lateral control. Furthermore, results have indicated that lower-fidelity simulators can produce results that are comparable to high cost, high fidelity simulators (Gibbons et al., 2014; Lemieux, Stinchcombe, Gagnon, & Bédard, 2014).

One of the potential disadvantages of using driving simulators is the occurrence of Simulator Sickness (SS), a well-documented side effect of using a wide range of simulators and virtual reality technology (Brooks et al., 2010; Classen et al., 2011; Johnson, 2005; Kennedy, Lane, Berbaum, & Lilienthal, 1993; McCauley, 1984; Stoner, Fisher, & Mollenhauer, 2011; Trick & Caird, 2011). Overall estimated prevalence of simulator sickness varies greatly: for example McCauley (1984) reported rates of 10–84%, and Johnson (2005) reported rates of 0–90%. Of 3691 trials on a flight simulator, 50% of all users experienced some SS (Kennedy et al., 1993). Experience of SS is related to high rates of participant dropout in driving simulator studies; Trick and Caird (2011) reported estimated dropout rates of between 35% and 75% from various institutions conducting driving simulation research with older drivers, with an average of around 40% attrition. This high dropout rate not only is a concern for users of driving simulators, but also poses an ethical challenge when seeking to recruit research participants due to simulator sickness being considered as a potential risk (Brooks et al., 2010).

Simulator sickness is usually measured through specialized self-report questionnaires, such as the Simulator Sickness Questionnaire (SSQ; Kennedy et al., 1993). The SSQ has been called the 'gold standard' for measuring simulator sickness (Johnson, 2005). Symptoms related to SS and measured by the SSQ include general discomfort, fatigue, headache, eyestrain, difficulty focusing, increased salivation, sweating, nausea, difficulty concentrating, feelings of fullness or pressure in the head, blurred vision, dizziness, vertigo, stomach awareness, and burping. Participants respond on a four-point scale the extent to which they are experiencing each of the 16 symptoms. The 16 symptoms form three factors: oculomotor symptoms (e.g., eyestrain), disorientation symptoms (e.g., dizziness), and nausea symptoms (e.g., nausea, stomach awareness; Kennedy et al., 1993). A short form of the SSQ, the mini-SSQ, has also been used (Mourant, Rengarajan, Cox, Lin, & Jaeger, 2007). This version was developed to avoid delays involved in repeated administration, and includes only six symptoms: general discomfort, headache, blurred vision, sweating, feeling faint, and stomach discomfort. The mini-SSQ was shown to be sensitive to changes in driving conditions (Mourant et al., 2007). Park, Allen, Fiorentino, Rosenthal, and Cook (2006) reported that higher increases in SSQ score were related to dropout, with participants who dropped out of the study displaying increased SS over time, compared to non-dropouts, whose SSQ scores remained stable over time.

Factors contributing to simulator sickness can be located within three categories: (a) factors related to the individual, (b) factors related to the simulator, and (c) factors related to the simulated task (Cassavaugh, Domeyer, & Backs, 2011; Kolasinski, 1995). Of these, the simulator and task specifications can be controlled to an extent, for example by using a motion base simulator that replicates the pitch and roll movements of a real car (Stoner et al., 2011), using shorter scenarios (Cassavaugh et al., 2011), avoiding turns (Mourant et al., 2007; Stoner et al., 2011), and reducing the field of view (Johnson, 2005; Kolasinski, 1995). Factors related to the individual are harder to control because they are often related to inherent characteristics of the person, such as age, gender, and medical history (Johnson, 2005). It is nonetheless important to recognize these factors so that steps can be taken to identify risk-factors and take appropriate steps to ensure SS is kept to a minimum.

Age has been identified as an important individual factor contributing to SS. Early reviews stated that SS occurs most frequently for ages 2–12, declines rapidly for ages 12–21, and continues to decline as age increases so that it is almost non-existent beyond age 50 (Johnson, 2005; Kolasinski, 1995). However, many of these earlier reports were based on flight simulation and older adults were not specifically considered. Based on more recent driving simulation reviews, it appears that older drivers represent a particularly at-risk group (Cassavaugh et al., 2011; Classen et al., 2011; Trick & Caird, 2011). For example, in a review of recent driving simulation studies, Classen et al. (2011) reported that drivers over the age of 70 are particularly at risk for SS, and Cassavaugh et al. (2011) noted dropout rates from simulation studies of up to 50% among older adult drivers. Several recent studies have reported dropout rates of between 0% and 44% for older adults (e.g., Bélanger et al., 2010; Brooks et al., 2010; Caird, Chisholm, Edwards, & Creaser, 2007; Domeyer, Cassavaugh, & Backs, 2013; Edwards, Creaser, Caird, Lamsdale, & Chisholm, 2004; Lee, Lee, Cameron, & Li-Tsang, 2003; Shanmugaratnam et al., 2010; Sklar, Boissoneault, Fillmore, & Nixon, 2014) and between 0% and 17% for younger adults (e.g., Bélanger et al., 2010; Domeyer et al., 2013; Shechtman et al., 2007; Yang, Jaeger, & Mourant, 2006); see Table 1 for a summary. However, estimating a reliable average dropout rate is hampered because many driving simulation studies have not reported dropout information. Additionally, dropout rates vary depending on the configuration of the simulator and the demands of the simulated task. Nonetheless, in general, results show that older adults drop out more frequently than younger adults. However, due to the small sample sizes often participating in such studies, the differences have frequently not been statistically significant.

Gender is another individual factor that is related to simulator sickness. Generally, reviews have suggested that females are more at-risk than males, especially older females (Classen et al., 2011; Johnson, 2005; Trick & Caird, 2011). Females have been reported to be more susceptible to motion sickness, simulator sickness, and visually induced motion sickness (Allen et al., 2003; Keshavarz & Hecht, 2014; Klosterhalfen et al., 2005; Mourant & Thattacherry, 2000; Park et al., 2006). Females may be particularly sensitive to simulator scenarios involving high sensory conflict and increased vection (visual illusion of self-motion) and visual flow (Jäger, Gruber, Müri, Mosimann, & Nef, 2014). Thus, females have been found to report a more severe history of motion sickness than males (Flanagan, May, & Dobie, 2005) although Mourant et al. (2007) found no gender differences in driving simulator sickness among a sample of older adults (aged 50–65). Graeber and Stanney (2002) have suggested that gender differences in simulator sickness and visually induced motion sickness may be accounted for by differences in susceptibility based on individuals' prior histories of experiencing motion sickness; when males and females were balanced for susceptibility, they found no difference in self-reported sickness between genders and no difference in study duration. Significantly higher levels of sickness were instead reported in the high-susceptibility group.

Health status is related to susceptibility to simulator sickness. Many researchers have suggested that individuals who are not in their usual state of fitness do not participate in simulator studies because they are at increased risk for SS (Johnson, 2005; Kennedy et al., 1993; Kolasinski, 1995; McCauley, 1984; Stoner et al., 2011). Specific health problems related to simulator sickness include head cold, influenza, upper respiratory illness, ear infection, ear blockage, and upset stomach (Kennedy et al., 1993). Fatigue, sleep loss, recent use of alcohol or drugs, and a history of

**Table 1**
Reported dropout rates in driving simulation studies.

| Study | Older adult dropout | Younger adult dropout | Group difference (Fisher's exact test) | Notes |
|---|---|---|---|---|
| Bélanger et al. (2010) | 37.5% (12/32) | 0% (0/20) | Significant | Age 25–42 vs age 65–83 |
| Brooks et al. (2010) | 27.8% (15/54) | 6.7% (4/60) | Significant | Age 18–50 vs age 65–81 |
| Caird et al. (2007) | 34.6% (9/26) | 9.3% (7/75) | Significant | Over 65 vs under 65. |
| Domeyer et al. (2013) | 30% (12/40) | 12.5% (5/40) | Non-significant | Young 18–28; old 60–90. (Middle age 30–58, 20% (8/40)). For remaining participants, there was no difference in SS scores between age groups after accounting for baseline scores. |
| Edwards et al. (2004) | 40% (8/20) | 14% (2/14) | Non-significant | Age 65–83, age 19–22. |
| Kaber et al. (2012) | 16.7% (2/12) | 0% (0/10) | Non-significant | Under 25 vs over 65 |
| Kawano et al. (2012) | 17.6% (5/17) | 0% (1/15) | Non-significant | Younger adults mean age 35.2 ± 5 SD vs over 60 (mean 66.6 ± 4.7 SD). |
| Lee, Lee, et al. (2003) | 0% (0–129) | – | – | 9% experienced SS, but 0 dropped out. Age 60+. |
| Park et al. (2006) | 37.3% (25/67) | 13.7% (7/51) | Significant | Age 21–50 vs age 70–90 |
| Roenker et al. (2003) | 11.5% (3/26)* | – | – | Age 55–86 Participants assigned to simulator training group |
| Schwebel et al. (2007) | 10% (10/101) | – | – | Age 75+ |
| Shanmugaratnam et al. (2010) | 17.5% (5/18) | 4.5% (2/44) | Significant | Age under 40 vs age over 40 |
| Shechtman et al. (2007) | 35% (10/30) | 17% (4/23) | Non-significant | Age 25–25 vs age 65–85 |
| Sklar et al. (2014) | 37.9% (22/58) | 4.5% (3/67) | Significant | Age 55–70 vs age 25–35. |
| Trick et al. (2010) | 44% (15/34) | – | – | Age range not reported. Mean age of non-dropouts 70.8 years ± 5.98. Participants were judged "at-risk" after completing screening and a practice drive and were removed from the study. |
| Yang et al. (2006) | – | 0% (0/24) | – | Novice and experienced drivers aged 16–45 |

motion sickness are also risk factors for SS (Johnson, 2005; Stoner et al., 2011). Experience with the real-world task may also be related to SS. Thus, Kolasinski (1995) reported that pilots who were more experienced and had accrued more real-world flying hours were more likely to suffer from SS. No evidence relating to motor vehicle driving is currently available about this possibility but, for driving simulation with older adults, such a trend would be of particular concern because many older drivers have been driving for most of their lives and may find it difficult to adapt to the simulator. Older adults are also more likely to be experiencing health concerns or to be using medication than younger adults (Eckert et al., 2013; Gu, Dillon, & Burt, 2010).

Knowledge about susceptibility will enable high-risk individuals to be more effectively informed and monitored and, if necessary, screened out. However, one concern is that it is possible that drivers who drop out due to SS may be different in some way from those who do not suffer from SS; for example, those who drop out of simulator studies may be more impaired in their everyday lives or may be more at-risk for adverse driving outcomes. There has been some investigation into systematic differences between SS sufferers and non-sufferers in terms of cognitive performance and driving ability. Where reported, analysis has shown that in general, there are no significant differences between dropout and non-dropouts on a range of cognitive tests and on-road driving measures (Kawano et al., 2012; Mullen, Weaver, Riendeau, Morrison, & Bédard, 2010).

The aim of this study was to investigate factors related to simulator sickness and dropout in a sample of older drivers on a low-cost simulator. We aimed to develop a model to identify those older drivers who are most at risk of dropout. Based on previous work reported here, it was predicted that age, gender, medical status, and mental status would be related to simulator sickness and dropout. Additionally, it was predicted that SSQ score would also be related to dropout. Participants completed a battery of cognitive and visual tests, enabling investigation of whether there would be differences between dropouts and non-dropouts in cognitive abilities and visual status. Based on the foregoing review, we expected that there would be none.

## 1. Method

### 1.1. Participants

We recruited 117 volunteer older drivers from the community to participate in a study investigating cognitive predictors of simulated driving performance. Participants were required to hold a current Australian driver's license, be living independently in the community, and all reported being in good general physical and mental health.

The current analysis included 88 of these participants. These had attempted all aspects of the driving task (until stage of dropout) and had complete data available on all relevant covariates. Reasons for exclusion were voluntary withdrawal from the study prior to attempting the driving task (n = 8), participant or experimenter decision to complete only a subset of the driving task (n = 7), and missing data (n = 14, incomplete SSQ data).

### 1.2. Materials

#### 1.2.1. Demographics and driving information

Demographic information collected included date of birth, gender, and information about the car that they drive most often (year of manufacture, make and model, transmission). Participants also completed items relating to driving avoidance, distractions while driving, and driving confidence.

#### 1.2.2. Medical conditions

Participants answered YES or NO to the following questions: Are you currently experiencing (fatigue, sleep loss, hangover, upset stomach, headache, ear conditions or ear blockage, upper respiratory illness/cold/flu)? Have you recently used alcohol/drugs (today)? Do you have epilepsy or a seizure-related condition? Do you have prior experience of motion sickness? Due to low rates of responding to each item, results were considered as two binary items: prior motion sickness (yes/no), and presence of other medical conditions (0 conditions/1 or more conditions).

#### 1.2.3. MMSE

The Mini-Mental State Examination is a short questionnaire designed to identify possible dementia or mild cognitive impairment (Folstein, Folstein, & McHugh, 1975). Scores of 26 or below out of 30 indicate possible impairment. The MMSE was administered using standardized instructions and scoring (Molloy, Alemayehu, & Roberts, 1991).

#### 1.2.4. Mini-SSQ

The Mini-SSQ (Mourant et al., 2007) contains six questions and is a short form of the Kennedy SSQ (Kennedy et al., 1993). The Mini-SSQ is quick to administer, suitable for repeated administration, and sensitive to changes in driving conditions (Mourant et al., 2007). Six symptoms are assessed: general discomfort, headache, blurred vision, sweating, feeling faint, and stomach discomfort. Possible responses were on a four-point scale, corresponding to none (0), slight (1), moderate (2), and severe (3). Scores for each symptom were summed to give a total score. The mini-SSQ was administered via tablet computer and results were automatically recorded and collated. Participants completed the questionnaire at up to three time points throughout the study: after a practice drive (SSQ1), and after each of two test drives (see below). If dropout occurred, the participant completed the questionnaire as soon as they were able to following dropout. Due to concerns of simulator sickness symptoms being suggestible (Young, Adelstein, & Ellis, 2007), the Mini-SSQ was not administered prior to the practice drive.

### 1.3. Computerized cognitive tasks

#### 1.3.1. Useful field of view (UFOV) divided attention subtest

UFOV is a computer-based test of visual attention and processing speed involving detection and localization of briefly presented targets throughout the visual field (Ball & Owsley, 1993)). There are three subtests: processing speed, divided attention, and selective attention. Only the divided attention subtest (UFOV2) was administered. Of the three subtests, UFOV2 is most correlated with UFOV total score and best predicts driving outcomes (Ball et al., 2006; Bowers et al., 2013; Edwards et al., 2006; Owsley et al., 1998). In the divided attention subtest, participants are required to identify a briefly-presented central stimulus and locate a simultaneously presented peripheral stimulus. The score is exposure time (ms) for which 75% of trials were answered correctly.

#### 1.3.2. Inspection time

Inspection time (IT) is a measure of visual processing speed (Burns & Nettelbeck, 2003). Two high-contrast lines, one markedly shorter than the other, appear as a briefly-presented target before being masked. Participants indicate whether the shorter line was located left or right of a focal point. IT was measured in ms as the duration between target onset and mask onset at which the viewer achieves 79% accuracy.

#### 1.3.3. Sentence span

A sentence span task was used to assess working memory. Task specifications are described by Lewandowsky, Oberauer, Yang, and Ecker (2010). Briefly, participants were presented with a series of sentences and to-be-remembered letters. Each trial consisted of between 4 and 8 sentence/letter pairs. Participants were required to answer TRUE or FALSE to each question (e.g., "All trees are plants"); after answering, a single letter was briefly presented on screen. At the end of each trial, participants were required to enter the remembered letters in order of presentation. The outcome was the overall proportion of correctly remembered letters.

#### 1.3.4. ProPerVis (crowding subtest)

ProPerVis assesses visual processing of briefly presented stimuli across the visual field on a computer screen (Burns & White, 2007). There are two subtests: crowding and inspection time (see Burns, Kremer, & Baldock, 2005). Only the crowding subtest was administered. The stimuli are a four-square parent figure and six figures derived from it, resembling characters M, E, W, 3, 5, and 2. In each of the 40 crowding trials, one of the six figures is flanked on either side by the parent figure and appears randomly in one of five lateral positions on the screen. Participants attempt to identify which of the six figures was presented. The outcome was the total number of errors made across the five positions.

#### 1.3.5. Vision tests

Participants completed tests of visual acuity and contrast sensitivity. The Freiburg Visual Acuity Test (Bach, 1996) was computerized and was completed along with the computerized cognitive tasks. Acuity was recorded as the logarithm of the Minimum Angle of Resolution (log MAR), with lower scores representing better visual acuity. Contrast sensitivity was assessed using a Pelli–Robson contrast sensitivity wall chart (Pelli, Robson, & Wilkins, 1988). The outcome was log contrast sensitivity (possible range: 0 to 2.25, higher scores indicate better contrast sensitivity), which was measured according to the faintest group of three letters for which the participant correctly identified two of the three letters.

#### 1.3.6. Driving simulator and task

The driving simulator was custom-designed and low-cost. The setup included 3 42-in. high definition LCD monitors with a 100 Hz refresh rate. The screens provided approximately 140° horizontal field of view. Participants sat on a standard desk chair and controlled the car using a small force-feedback gaming wheel and pedals. Transmission was automatic. The setup is shown in Fig. 1.

The driving task consisted of 3 stages: a practice drive of approximately 10 min duration (although participants could continue to practice until they felt comfortable with the controls); Drive 1, a test drive of approximately 15 min, which required participants to drive a set route around suburban and city areas and respond to hazardous events; and Drive 2, similar to Drive 1, but with the addition of a Peripheral Detection Task requiring participants to respond to flashing lights appearing in their side mirrors. Responses to the Peripheral Detection Task were made using a button on the steering wheel. Emergency events occurred eight times per drive and included cars pulling out suddenly from the side of the road or intersections, and pedestrians jaywalking across the path of the car. Participants were required to brake to avoid a collision. The speed limit was 50 km/h. The drives required participants to navigate intersections (signed and traffic light controlled), including stopping, and the route required multiple 90° turns. The city area was densely populated with roadside objects including buildings, pedestrians, parked cars, signage, and other typical objects (e.g., bins, benches, trees). Driving performance is not considered here.

### 1.4. Procedure

The study was approved by The University of Adelaide Human Research Ethics Committee and all participants provided written consent. Participants provided demographic information and completed questionnaires relating to driving behavior, the MMSE, computerized cognitive assessments, vision screening, and the simulated driving task. The complete protocol took approximately 2 h to complete. The order of administration was briefing information, consent, and demographic information; questionnaires relating to driving behavior and medical conditions; MMSE; practice drive; Drive 1; cognitive and visual assessments; Drive 2.

Participants completed the SSQ up to three times throughout the study depending on stage of dropout and were monitored for signs of simulator sickness. SSQ was completed after the practice drive (SSQ1), and after each of the two test drives (SSQ2 and SSQ3). Participants were told to alert the experimenter and stop driving if they wished to discontinue for any reason. They were also monitored by the experimenter and driving was stopped if they appeared visibly uncomfortable or distressed.

Frequent breaks were provided throughout the experiment. Mandatory 5–10 min breaks were provided after the Practice Drive, Drive 1, and Drive 2. Participants were told they could request additional breaks whenever required. The computerized cognitive tasks were completed between Drive 1 and Drive 2. If a participant dropped out of the driving component of the study, they could elect to cease participation or

**Fig. 1.** Driving simulator setup.

continue with the non-driving components after a mandatory break, and if they reported that they had recovered from simulator sickness symptoms.

## 2. Results

### 2.1. Analysis

Data analyses were completed in R (R Core Team, 2013) using the packages 'car' (Fox & Weisberg, 2011) and 'survival' (Therneau, 2014). Logistic regression analysis was used to investigate predictors of dropout at any stage. Survival analysis (Kaplan–Meier) and Cox Proportional Hazards models were used to investigate stage of dropout.

### 2.2. Descriptive statistics

Of the 88 participants included, 52 (29.1%) dropped out of driving during the study as follows: 26 during the practice drive, 16 during Drive 1, 8 after Drive 1, and 2 during Drive 2. Median dropout stages are shown in Table 2, which shows longer survival for males compared with females, and marked advantage.

Covariates of interest were age, MMSE, medical conditions, prior motion sickness, and SSQ scores. Descriptive statistics for these variables are shown in Table 3. Participants reported the following medical conditions: fatigue ($n = 4$), sleepiness ($n = 7$), hangover ($n = 1$), upset stomach ($n = 3$), cold or influenza symptoms (5), ear conditions (7), recent use of alcohol or medication (3), and prior experience of motion sickness (23). No participant reported epilepsy or a seizure related condition. Only 14 participants reported 2 or more conditions (11 reported 2 conditions, 2 reported 3 conditions, 1 reported 4 conditions). Prior motion sickness was considered separately from other medical conditions.

SSQ was analyzed as both a time-independent and time-dependent covariate. For the time-independent analysis the reported score on the Simulator Sickness Questionnaire after completion of the practice drive (SSQ1) was available for all participants and was used as a predictor of dropout. SSQ1 was considered as informative for survival risk because it is measured early on and may represent an inherent susceptibility to simulator sickness. Subsequent measurements of SSQ were found to be correlated with each other (SSQ1–SSQ2, $r = .69$, $n = 62$, $p < .01$; SSQ1–SSQ3, $r = .24$, $n = 38$, $p = .15$; SSQ2–SSQ3 $r = .78$, $n = 38$, $p < .01$). For the time-dependent analysis, SSQ scores were available for participants at up to three time points in the study, depending on stage of dropout. These represent the change in reported SSQ over the duration of the study.

Age was not significantly correlated with MMSE ($r = -.07$, $p = .54$) or SSQ score (SSQ1 $r = -.04$, $p = .72$; SSQ2 $r = -.19$, $p = .14$; SSQ3 $r = -.004$, $p = .98$), and was not associated with prior motion sickness or presence of other medical conditions. There were no gender differences in age, history of motion sickness, MMSE, or SSQ scores. Compared to males, females tended to be more likely to report having one or more other medical conditions (females 41%, males 22%; $t(61.3) = 1.84$, $p = .07$). In terms of driving, males reported higher confidence in their own overall driving ability than females (females 85.5%, males 92.2%; $t(56.5) = 3.4$, $p = .002$).

### 2.3. Differences between dropouts and non-dropouts

#### 2.3.1. Cognitive and visual performance

Dropouts and non-dropouts were compared on the cognitive and visual variables: Inspection time (IT), UFOV subtest 2, crowding, sentence span, MMSE, visual acuity, and contrast sensitivity. For IT, UFOV2, crowding, visual acuity, and contrast sensitivity, two dropouts had missing data (voluntary withdrawal). For sentence span, two completers and six dropouts had missing data (voluntary withdrawal/technical fault/insufficient computer skills). Means and standard deviations for each variable are shown in Table 4. According to Levene's test, variances were equal for all variables. Independent samples t-tests found no significant differences between the groups on any of the variables, although there was a weak trend with a small-to-medium effect size

**Table 2**
Median survival stages.

| Population | Median survival stage |
|---|---|
| All | Completed Drive 1 |
| Female | During Drive 1 |
| Male | Completed Drive 2 |
| Prior motion sickness | During practice drive |
| No prior motion sickness | Completed Drive 2 |

**Table 3**
Descriptive statistics for covariates of interest.

| Variable | Mean | SD | Range |
|---|---|---|---|
| Age | 72.8 | 5.42 | 65–87 |
| MMSE | 29.3 | 0.90 | 26–30 |
| Medical conditions | 0.26 | 0.46 | 0, 1 |
| Prior motion sickness | 0.29 | 0.44 | 0, 1 |
| SSQ (all) | 2.45 | 2.66 | 0–12 |
| SSQ1 | 2.74 | 2.78 | 0–12 |
| SSQ2 | 2.66 | 2.59 | 0–10 |
| SSQ3 | 1.42 | 2.27 | 0–10 |

Note. SSQ (all) includes all SSQ results. SSQ1, SSQ2, and SSQ3 are SSQ scores from each of the three time points.

($p = .08$, Cohen's $d = 0.40$) for IT favoring completers. This effect was moderated by gender; for females, mean IT for completers and dropouts was 70 ms, but for males, mean IT for completers was 63 ms, and mean IT for dropouts was 82 ms ($t(30.2) = 1.96$, $p = .059$).

#### 2.3.2. Medical conditions and motion sickness

Dropouts were significantly more likely to report a history of motion sickness, $X^2(1) = 10.00$, $p = .002$. Of the 23 participants who reported prior motion sickness, 20 dropped out. There was no association between medical conditions (excluding MS) and dropout, $X^2(1) = 1.57$, $p = .21$.

#### 2.3.3. Gender

Females were significantly more likely to drop out than males, $X^2(1) = 6.92$, $p = .009$. Of the 56 male participants, 28 dropped out (50%). Of the 34 female participants, 26 dropped out (76%).

#### 2.3.4. Age

There was no age difference between dropouts ($M = 72.58$ years) and completers ($M = 73.17$ years); $t(86) = 0.50$, $p = .62$.

#### 2.3.5. SSQ

As expected, there were significant differences in SSQ scores for dropouts and completers (see Table 4), with dropouts reporting much higher SS symptoms than completers.

### 2.4. Logistic regression: dropout

Fifty-two participants dropped out and 36 participants completed all driving. Binary logistic regression analysis was used to determine if age, gender, prior motion sickness, medical conditions, MMSE, and SSQ were predictive of dropout (see Table 5). The dependent variable was dropout, considered as a binary variable (YES or NO for dropout at any stage of the study). Age, gender, motion sickness, medical conditions, and MMSE were entered into the model first. These are characteristics of the driver that are available prior to any simulated driving being attempted. This model was significant, $X^2(5) = 20.70$, $p < .001$, with pseudo-$R^2$ (Nagelkerke) of .283. Gender and prior motion sickness were significant predictors of dropout. SSQ1 score was added to the model in Step 2 and significantly improved prediction of dropout, $X2(1) = 39.27$, $p < .001$ with a pseudo-$R^2$ (Nagelkerke) of .666. The model correctly classified 86.4% of cases. Motion sickness and SSQ1 score were significant predictors. Gender was no longer significant. For every 1 point increase in SSQ1 score, participants were 2.84 times more likely to drop out. Participants with prior history of motion sickness were 8 times more likely to dropout than those without.

**Table 4**
Comparison between dropouts and completers on cognitive and visual measures and SSQ scores.

| Variable | M (SD) | | t (df) | p | Cohen's d |
|---|---|---|---|---|---|
| | Dropouts | Completers | | | |
| MMSE | 29.3 (1.02) | 29.5 (0.70) | 1.08 (86) | .28 | 0.22 |
| IT | 75.7 (35.8) | 64.2 (18.7) | 1.75 (84) | .08 | 0.40 |
| UFOV2 | 79.4 (72.3) | 79.5 (63.9) | 0.01 (84) | .99 | 0.00 |
| Crowding | 11.8 (4.91) | 11.06 (4.71) | 0.74 (84) | .46 | 0.16 |
| Sentence span | 0.51 (0.17) | 0.54 (0.15) | 0.65 (78) | .52 | 0.19 |
| Visual acuity | 0.11 (0.13) | 0.11 (0.13) | 0.14 (84) | .89 | 0.00 |
| Contrast sensitivity | 1.80 (0.17) | 1.83 (0.15) | 0.81 (84) | .42 | 0.19 |
| SSQ1 | 4.12 (2.78) | 0.75 (1.03) | 7.97 (69.1) | <.001 | 1.61 |
| SSQ2 | 4.73 (2.33) | 1.17 (1.54) | 7.26 (60) | <.001 | 1.80 |
| SSQ3 | 5.50 (0.71) | 1.19 (2.11) | 2.85 (36) | .01 | 2.74 |

Note. MMSE = Mini Mental State Examination, IT = inspection time, UFOV2 = UFOV subtest 2, SSQ1 = − SSQ time 1, SSQ2 = SSQ time 2, SSQ3 = SSQ time 3.

### 2.5. Survival analysis: stage of dropout

There were 88 participants (54 male) with complete data available. Descriptive statistics for variables of interest are shown in Table 3. Survival analysis and Cox Proportional Hazards models were used to investigate dropout. Dropout stage was coded was coded as five stages: Stage 1 (practice drive), Stage 2 (during Drive 1), Stage 3 (after Drive 1), Stage 4 (during Drive 2), and Stage 5 (no dropout; completed Drive 2). The event of interest was dropout or withdrawal from the driving task. The stage that each participant dropped out or withdrew was recorded. Participants who completed all driving were considered censored at Stage 5 (that is, for the purposes of the survival analysis, the outcome of interest (dropout) did not occur during the observation period).

Participants tended to dropout early in the study rather than later; 29.5% of participants dropped out at stage 1, half of all dropouts. Fewer than half of all participants (40.9%) completed all driving. Median survival stages for all participants and subgroups based on gender and medical conditions are shown in Table 2. These median survival stages suggest that female gender and having one or more medical condition increases the risk of dropout.

#### 2.5.1. Kaplan–Meier survival analysis

Fig. 2 shows the Kaplan–Meier survival plot for all participants. There were 88 participants who had complete data available. Of these 88, 36 (41%) participants were censored at stage 5 (that is, they completed the study without drop out). The median survival stage was stage 3.

Fig. 3 shows the Kaplan–Meier survival plot by gender. Males generally survived longer than females, with 49% of males surviving until stage 5, compared to 28.2% of females. The difference in survival plots was significant according to the log-rank test, $X^2(1) = 9.00$, $p = .002$. The median survival stage for females was 2, and the median survival stage for males was 5.

Fig. 4 shows Kaplan–Meier survival plots by history of motion sickness. Participants with no history of motion sickness survived longer

**Table 5**
Logistic regression analysis for dropout.

| | B | SE B | OR | p |
|---|---|---|---|---|
| Step 1 | | | | |
| Age | −0.06 | 0.05 | 0.95 | .25 |
| Gender (baseline: male) | 1.20 | 0.53 | 3.32 | .02 |
| MMSE | −0.42 | 0.30 | 0.65 | .15 |
| Prior motion sickness | 2.03 | 0.72 | 7.61 | .01 |
| Other conditions | 0.48 | 0.56 | 1.62 | .39 |
| Constant | 16.00 | 9.90 | | .11 |
| Step 2 | | | | |
| Age | −0.05 | 0.06 | 0.95 | .40 |
| Gender (baseline: male) | 0.66 | 0.73 | 1.94 | .36 |
| MMSE | −0.26 | 0.35 | 0.77 | .46 |
| Prior motion sickness | 2.09 | 0.88 | 8.08 | .02 |
| Other conditions | 1.21 | 0.84 | 3.36 | .15 |
| SSQ1 | 1.04 | 0.26 | 2.84 | <.001 |
| Constant | 8.44 | 11.78 | | .45 |

Note. Model 1 $X^2(5) = 20.70$, $p < .001$. Model 2 $X^2(6) = 59.97$. OR = odds ratio.

than those with a history of motion sickness. The plots were significantly different according to the log-rank test, $X^2(1) = 11.2$, $p < 001$. Median survival stage for participants with a history of motion sickness was 1, and the median survival stage for participants with no history of motion sickness was 5.

*2.5.2. Cox Proportional Hazards model: time independent analysis*

Cox Proportional Hazards models were used to investigate the effects on individual predictors on dropout. Gender, motion sickness, other conditions, age, MMSE, and SSQ1 score were included. Analyses showed there were no significant interactions between these factors. Two models were calculated; the first included gender, motion sickness, other conditions, age, and MMSE, and the second added SSQ1 to these predictors. Both models are shown in Table 6. The log-likelihood test showed that Model 2 was a significant improvement on Model 1, $X^2(1) = 32.3$, $p < .001$. Gender was a significant predictor in Model 1, but was reduced to marginal significance in Model 2. Motion sickness was a significant predictor in both models, while other conditions, age and MMSE were not significant in either model. In Model 2, SSQ1 was a highly significant predictor, and the significance and HRs of gender and conditions decreased slightly. Prior motion sickness and SSQ1 were the most useful predictors of dropout. People with a history of motion sickness had 106% increased risk of dropout compared to people with no prior history of motion sickness. For each point increase in SSQ1 score, hazard rate increased by 35%.

Overall, the models met the assumption of proportional hazards, although age was shown to have non-proportional hazards.

*2.5.3. Cox Proportional Hazards model: time dependent analysis*

It was also possible to consider SSQ score a time-dependent covariate. SSQ was completed up to three times by participants: after the practice drive, after drive 1, after drive 2, and/or after dropout if applicable. Therefore there were 5 possible stages for SSQ data to be collected: after practice drive (1), after dropout during drive 1 (2), after completion of drive 1 (3), after dropout during drive 2 (4), and after completion of drive 2 (5). SSQ scores were collected up to three times per participant. For example, a participant who dropped out during drive 1 would have two SSQ scores available, at stage 1 and stage 2. As another example, for participants who completed all driving, SSQ scores were collected at stages 1, 3, and 5. For these cases, missing data were filled by duplicating the next occurring rating (i.e., stage 2 was equal to stage 3; this is because ratings at stage 3 were assumed to reflect level of simulator sickness throughout the duration of the drive).

The Cox Proportional Hazards model in Table 7 included SSQ as a time dependent covariate. The log-likelihood test showed that the model was significant, $X^2(6) = 87.0$, $p < .001$. SSQ was a highly significant predictor of dropout. For every 1 point increase in SSQ score, participants had a 55% increased risk of dropout during that stage of the driving task. Gender remained a significant predictor of dropout, with females being twice as likely to drop out compared to males. History of motion sickness was associated with a hazard ratio of 2.22. Other medical conditions, age, and MMSE did not significantly affect risk of dropout in the time-dependent model. The Survival Plot for this model is shown in Fig. 5.

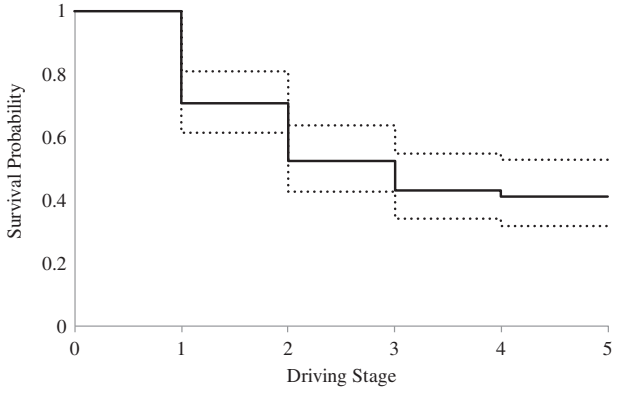


**Fig. 2.** Kaplan–Meier Survival Plot for all participants. The dotted line shows the 95% confidence interval.

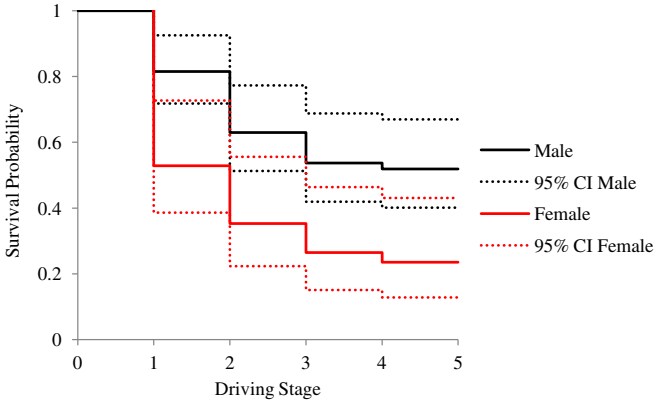


**Fig. 3.** Kaplan–Meier survival plots by gender.

## 3. Discussion

The aim of this study was to investigate factors related to simulator sickness and dropout in a sample of older drivers on a low-cost simulator. We aimed to develop a model to identify those older drivers who are most at risk of dropout. Based on previous work reported here, it was predicted that age, gender, medical status, and mental status would be related to simulator sickness and dropout. Additionally, it was predicted that SSQ score would also be related to dropout. Participants completed a battery of cognitive and visual tests, enabling investigation of whether there would be differences between dropouts and non-dropouts in cognitive abilities and visual status. Based on the foregoing review, we expected that there would be none.

We investigated individual predictors of dropout and simulator sickness among older adults using a custom-designed, low-cost driving simulator. It was predicted that age, gender, and medical history would be related to simulator sickness and dropout, and that simulator sickness would be predictive of stage of dropout. Using logistic regression and survival analysis models, the results showed that SSQ score was the best predictor of dropout. In the logistic regression analysis, adding SSQ1 score to the demographic predictors increased the pseudo-$R^2$ by 40%. This confirms that self-reported simulator sickness symptoms are related to dropout (Park et al., 2006). SSQ scores were considerably higher throughout the study for dropouts. On average, those completing all stages of driving reported a score of 1 on the SSQ

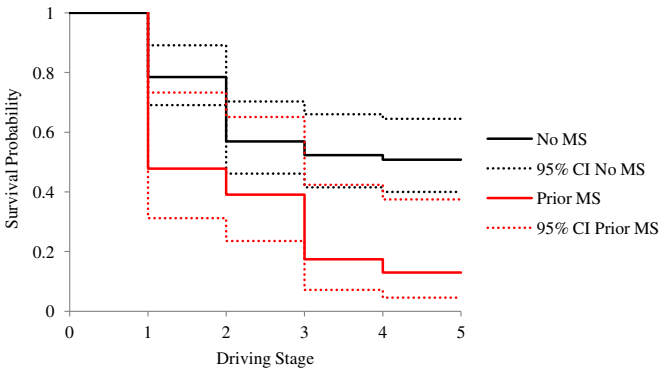


**Fig. 4.** Kaplan–Meier survival plot by prior motion sickness (MS).

**Table 6**
Cox Proportional Hazards model for time to driving dropout.

| | HR | CI | p |
|---|---|---|---|
| Model 1 | | | |
| Gender | 1.94 | 1.07–3.51 | .03 |
| Motion sickness | 2.03 | 1.15–3.59 | .02 |
| Other conditions | 1.07 | 0.58–1.98 | .82 |
| Age | 0.99 | 0.94–1.04 | .66 |
| MMSE | 0.89 | 0.67–1.19 | .43 |
| Model 2 | | | |
| Gender | 1.71 | 0.95–3.06 | .07 |
| Motion sickness | 2.06 | 1.16–3.64 | .01 |
| Conditions | 1.15 | 0.64–2.09 | .64 |
| Age | 1.01 | 0.96–1.07 | .64 |
| MMSE | 0.90 | 0.66–1.22 | .50 |
| SSQ1 | 1.35 | 1.22–1.50 | < .001 |

Note. HR = hazard ratio, CI = 95% confidence interval.

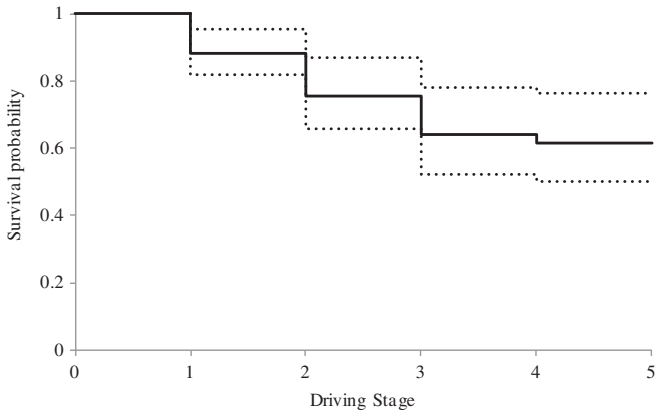


**Fig. 5.** Cox survival plot displaying stage of dropout, controlling for gender, prior motion sickness, medical conditions, SSQ score, age, and MMSE. The dotted lines show the 95% confidence interval.

throughout the study (equivalent to 'slight' experience of one symptom), while dropouts reported scores above 4 at each time point (equivalent to slight, moderate or severe experience of two or more symptoms). Higher SSQ scores were associated with a higher hazard ratio in both the time-independent and time-dependent Cox Proportional Hazards models. In the time dependent analysis in particular, each point increase in SSQ score was associated with 55% increase in risk of dropout. This confirms the importance of monitoring SS symptoms throughout the study.

Of the covariates that would be available before study commencement, gender, and history of motion sickness significantly predicted risk of dropout. Females dropped out more frequently than males, as reflected in the median survival stages, with females having a median survival stage corresponding to part way through Drive 1, while males on average completed all driving. The Cox Proportional Hazards models showed that females were at twice the risk of dropout as males. This corresponds with numerous reviews that have found that females are more susceptible to visually-induced motion sickness and simulator sickness (Allen et al., 2003; Keshavarz & Hecht, 2014; Klosterhalfen et al., 2005; Mourant & Thattacherry, 2000; Park et al., 2006). Jäger et al. (2014) reported that females were more affected by scenes involving high sensory conflict and visual flow than males. This may have been related to the significantly higher dropout of females in the present study; the scene was very visually complex and involved numerous turns associated with high visual flow. It has been reported that females are also more likely than males to suffer from motion sickness in any form (Flanagan et al., 2005), but, in the present study, there was no reported gender difference on prior motion sickness (our study used a single item to assess motion sickness history; more comprehensive scales are more typical). There were also no gender differences in reported medical conditions, age, MMSE, or any of the cognitive or visual variables.

Prior experience of motion sickness significantly increased the risk of dropout. Thus, of 23 participants who reported a history of motion sickness, 20 dropped out during the study. As reflected by the median survival stages, participants with a history of motion sickness tended to drop out after attempting the practice drive, while participants with no history of motion sickness tended to complete the study. The Cox Proportional Hazards models showed that a history of motion sickness was associated with more than twice the increased risk of dropout than no prior history of motion sickness. As suggested by Johnson (2005), past behavior is often the best predictor of future behavior, and that was certainly the case in the present study.

Contrary to our expectation, presence of other medical conditions was not related to dropout. Drivers were required to be in good general health to participate in the study, and overall incidence of health conditions was low. Thus, self-selection and the screening procedure likely contributed to this outcome.

Although age was not related to dropout in this sample, the overall dropout rate in this study was very high (59%). A separate study was run with younger participants, undergraduate students aged 18–30, using the same simulator and a very similar simulated task (Tan, 2014). Of 66 participants, only 2 dropped out (3%). Both were female and had prior experience of motion sickness but were otherwise in their usual state of good health. This dropout rate was significantly different from that in the present study, $X^2(1) = 52.1$, $p < .001$. This comparison adds strong evidence to the observations that older adults are a high-risk group for simulator sickness (Cassavaugh et al., 2011; Classen et al., 2011; Trick & Caird, 2011) and dropout rates between younger and older drivers (Brooks et al., 2010; Caird et al., 2007; Park et al., 2006; Sklar et al., 2014).

The 59% dropout observed in the current study was higher than has generally been previously reported. For example, Trick and Caird (2011) reported a dropout rate of 44%, and Cassavaugh et al. (2011) noted dropout rates of up to 50%, while most other studies have reported dropout rates between 10% and 40% (Bélanger et al., 2010; Brooks et al., 2010; Kaber, Zhang, Jin, Mosaly, & Garner, 2012; Kawano et al., 2012; Roenker et al., 2003). The high dropout rate here was likely a result of the simulator configuration and task demands of the current study. It is well known that simulator type and aspects of the simulated environment and task requirements are related to simulator sickness (Cassavaugh et al., 2011; Kolasinski, 1995). Our simulator contained a number of features that can increase simulator sickness, for example a wide field of view (Kolasinski, 1995; Stoner et al., 2011), turning several corners (Cassavaugh et al., 2011; Edwards et al., 2004; Mourant et al., 2007), a visually complex scene (Park et al., 2006), relatively long scenario duration (Cassavaugh et al., 2011; Johnson, 2005; Kolasinski, 1995), and elements of the scene prone to flicker (Kolasinski, 1995; Stoner et al., 2011). The control system was also prone to lag (delay between input and response) and was poorly calibrated (poor correspondence between degree of input and reaction of the vehicle, especially for steering; Classen et al., 2011; Kolasinski, 1995; Stoner et al., 2011). Moreover, many participants reported dissatisfaction with the gaming

**Table 7**
Cox Proportional Hazards model for stage of study dropout, with SSQ as a time-dependent covariate.

| Variable | HR | CI | p |
|---|---|---|---|
| Gender | 2.02 | 1.12–3.65 | .02 |
| Motion sickness | 2.22 | 1.24–3.97 | .01 |
| Other conditions | 0.71 | 0.38–1.34 | .30 |
| SSQ | 1.55 | 1.40–1.72 | < .001 |
| Age | 1.04 | 0.98–1.10 | .20 |
| MMSE | 1.06 | 0.77–1.47 | .72 |

Note. HR = hazard rate, CI = 95% confidence interval.

controls, expressing concerns that the wheel was too small and did not feel realistic, and unfavorable opinions have been related to increased SS (Schultheis et al., 2007). Modifications to the scenario, scene, and simulator setup can help to reduce SS (Cassavaugh et al., 2011), as can thorough screening procedures (Trick & Caird, 2011) and use of adaptation procedures (Domeyer et al., 2013).

It has been suggested that drivers with a history of motion sickness be excluded from simulator studies (Brooks et al., 2010; Stoner et al., 2011); and such screening procedures have been shown to reduce cases of simulator sickness (Trick, Toxopeus, & Wilson, 2010). It should be noted, however, that doing so would tend to introduce a male bias into the sampling of driving behavior. Nonetheless, our results showed that there were no differences between dropouts and those who completed all stages on any of the cognitive or visual measures. These included tests of visual processing and attention, including the UFOV, a well-established predictor of driving outcomes (Clay et al., 2005). This result suggests that older drivers who were unable to complete the simulated driving task were not more impaired than those who did. Results were remarkably uniform across the two groups. Similar findings have been reported by Kawano et al. (2012) and Bélanger et al. (2010). Mullen et al. (2010) compared dropouts and non-dropouts on an on-road driving test and found that those who dropped out actually committed fewer on-road driving errors than those who did not drop out. Evidence therefore suggests that people who drop out of simulator studies are not more impaired or at-risk than those who do not drop out. Johnson (2005) also reported that simulator sickness has little to no effect on cognitive and perceptual abilities; this was confirmed in the present study, where those who dropped out performed the cognitive testing after discontinuing driving, and performed equivalently to those who did not experience SS. Therefore, these results tend to suggest that it may be possible to screen out individuals who report prior motion sickness without biasing results from cognitive testing.

We used the Mini-SSQ, a much briefer version of the more frequently-used, 'gold standard' SSQ (Johnson, 2005; Kennedy et al., 1993). The Mini-SSQ was developed to save time when repeated administration and monitoring is required (Mourant et al., 2007). Mourant et al. (2007) reported that the Mini-SSQ was sensitive to changes in driving environment, such as increased scene complexity and increased task demands. Our results show that the Mini-SSQ is sensitive to changes in SS over time and is able to accurately identify drivers who may be at increased risk for dropout. The Mini-SSQ was quick and easy to administer and was well accepted by the participants. It therefore appears to be appropriate for quickly and accurately monitoring SS symptoms over the course of a study, in situations where the more complete symptom breakdown of the full SSQ is not required.

Overall, the results show that females and people with a history of motion sickness had a significantly increased risk of dropout from the study. Although age did not predict dropout within the sample, evidence from a study with younger participants using the same equipment has suggested that older adults in general are a high-risk group for simulator sickness. As expected, experience of simulator sickness symptoms was related to risk of dropout. The time-dependent analysis of SS confirmed the importance of monitoring symptoms throughout the study, because changes in SS affected risk of dropout. The study has highlighted the importance of thorough screening procedures and effective monitoring of participants. The results also showed that participants who dropped out were not cognitively impaired compared to those who did not dropout, and, given that cognitive testing was completed post-dropout, the results suggest that simulator sickness does not have a negative impact on cognitive performance.

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