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Personality factors are associated with simulated driving outcomes across the driving lifespan ☆

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ABSTRACT

Research has shown that personality factors are related to driving safety. However, the majority of existing studies rely on self-report measures of driving behaviour and sample drivers from limited age ranges. This study sought to examine the relationship between personality and objective driving outcomes as assessed by a driving simulator in a sample of young, mid-aged, and older adults. A total of 114 active drivers completed personality questionnaires as well as a simulated driving assessment protocol. The results showed that: (1) Extraversion and neuroticism were significantly associated with driving simulator performance; (2) conscientiousness was significantly associated with driving performance among middle-aged adults; (3) sensation seeking was an important personality factor primarily for young drivers and was positively correlated with driving speed in the simulator. These results provide further support for the link between personality factors and driving performance, and suggest certain directions for future research.

1. Introduction

Driving a vehicle is an important feature of modern North American culture and is inextricably linked to independence, autonomy, and quality of life (Dickerson et al., 2007; Kua, Korner-Bitensky, Desrosiers, Man-Son-Hing, & Marshall, 2007). Unfortunately, traffic-related collisions represent a considerable social and economic burden on our society. Canadian data from 2013 show that there were approximately 120,000 collisions that resulted in personal injuries and 1750 collisions that resulted in fatalities (Transport Canada, 2015).

In Canada, drivers aged 16–24 years are consistently overrepresented in traffic collision statistics (Transport Canada, 2011). While this age group constitutes only 13% of the driver population, it represents 24% of driver fatalities and 26% seriously injured drivers (Transport Canada, 2011). However, not all younger drivers are equally at risk. In particular, national hospitalization data shows that among young drivers, males are almost twice as likely as females to be hospitalized due to a

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motor vehicle collision and three times more likely than females to die due to a motor vehicle collision (Public Health Agency of Canada, 2012).

Given the increased susceptibility of older age groups to injury and death, it is not surprising that the second highest rate of fatal and non-fatal crash injuries per kilometer driven is among those aged 70 years or older (McGwin, Owsley, & Ball, 1998). For example, Bédard, Guyatt, Stones, and Hirdes (2002) compared drivers aged 65–79 years and drivers aged 80 or older to drivers aged 40–49, and found significantly higher odds of a fatal injury in both of the older groups: for drivers aged 65–79 years, the odds ratio (OR) was 2.33 (99% CI, 1.58, 3.43); and for drivers aged 80 or older, the OR was 4.98 (99% CI, 2.01, 12.37). Increases in the occurrence of crashes among older drivers are expected over the next several decades as Canadians aged 65 years or older represent the fastest growing segment of the driving population and this group is projected to make up 24% of the total population by the year 2036 (Statistics Canada, 2010; Turcotte, 2012). The crash risk across the lifespan of drivers is often described as exhibiting a U-shape with young and older drivers being at greatest risk (Evans, 2000).

Research indicates that approximately 90% of all crashes are the result of driver characteristics and behavior (Lewin, 1982). Identified risk factors for crash involvement are quite different among young and older drivers (Owsley, McGwin, & McNeal, 2003). Crash risk among young drivers has been associated with driving inexperience, risk-taking behavior (e.g., speeding, passing when not safe to do so), moving violations, and alcohol use (Owsley et al., 2003). Among older adults, traffic-related collisions have been attributed to difficulties negotiating driving situations where complexity and time pressure are elevated (e.g., unprotected left turns, stop sign controlled intersections; Bédard, Stones, Guyatt, & Hirdes, 2001; Freund, Colgrove, Burke, & McLeod, 2005).

Given that human factors explain significantly more variability in crash rates than any other factors (e.g., vehicular, roadway), it is not surprising that more recent research has focused on examining the relationship between human factors and unsafe driving (Dahlen & White, 2006). One factor consistently linked to unsafe driving among young and mid-aged adults is personality (Schwebel et al., 2007). Proponents of personality psychology argue that some individuals are more likely than others to regularly engage in unsafe driving behaviour (Boyce & Geller, 2002). Research has revealed that personality characteristics are a direct contributor to engaging in unsafe driving behaviour among young and mid-aged adults and there is evidence to suggest that personality may act as a distal influence on driving behaviour through risk perception (Machin & Sankey, 2008). Surprisingly, little research has examined the role of personality characteristics in unsafe driving behaviour among older adults. However, the challenge for researchers is to provide a better understanding of how personality characteristics contribute to crashes among drivers, particularly those most at risk (Elander, West, & French, 1993).

Personality traits refer to relatively stable, enduring patterns of thoughts, feelings, and behaviours that describe the ways in which people differ from or are similar to one another (McCrae & Costa, 1995; Tellegen, 1991). The taxonomy of personality traits that has received the most empirical support over the past two decades is the five-factor model (FFM; Costa & McCrae, 1992). Also referred to as the *Big Five*, the broad traits composing the FFM have been provisionally named Extraversion (i.e., outgoing, expressive, energetic, and dominant), Neuroticism (i.e., tendency to experience negative affect and anxiety), Conscientiousness (i.e., dependability, responsibility, self-discipline), Agreeableness (i.e., helpfulness, trust), and Openness to Experience (i.e., adventurous, broad-mindedness) (Caspi, Roberts, & Shiner, 2005). As a comprehensive trait model of personality, the FFM has been widely used to provide a systematic approach to various outcome variables from organizational behaviour to crash involvement (Sümer, Lajunen, & Özkan, 2005).

A number of empirical studies have explored the relationship between personality and driving behaviour. Arthur and Graziano (1996), for example, sampled 227 college students and 250 individuals recruited from an employment agency. They determined that among the college student sample, Extraversion was statistically significantly related to both self-reported number of at fault crashes, $r = 0.13$, 95% CI [0.000, 0.255] and total crashes, $r = 0.15$, 95% CI [0.021,0.274], while Conscientiousness and Openness were related to at-fault crashes, $r = 0.14$, 95% CI [0.010, 0.265], $r = 0.13$, 95% CI [0.000, 0.255] respectively. Among the individuals recruited from the employment agency, Conscientiousness was inversely related to total crashes, $r = -0.19$, 95% CI [−0.306, −0.068]. In a follow-up study, Arthur and Doverspike (2001) found an inverse relationship between Conscientiousness and self-reported crashes in a sample of young drivers. These results point to the importance of conscientiousness towards safe driving and also highlight that the relationship between personality and driving outcomes may be dependent on characteristics of the population from which the sample was drawn.

Sümer, Lajunen, and Ozkan (2005) sought to examine the relationship between the Big Five factors of personality, self-reported driving behaviour, and crash history. To this end, they had 1001 drivers complete a questionnaire related to aberrant driving behaviour, the Big Five Inventory, and a demographic questionnaire with self-reported crashes. Their results indicated statistically significant correlations between many personality factors and driving variables. However, Conscientiousness and Agreeableness correlated significantly and negatively with all of the driving variables that were assessed with r-values ranging from between $r = -0.10$ and $r = -0.38$.

In their meta-analysis of the relationship between crash involvement and the Big Five, Clarke and Robertson (2005) determined that Conscientiousness, Agreeableness and Extraversion are associated with self-reported crash involvement. Clarke and Robertson (2005) also provided a brief discussion of the hypothesized mechanisms underlying the relationship between personality and driving. In particular, they suggest that there is a tendency for extraverts to seek stimulation to a far greater extent and consequently demonstrate significantly poorer performance on vigilance tasks relative to introverts; there is evidence to support a decline in performance under monotonous conditions such as driving among extraverted individuals. Individuals low in conscientiousness tend to focus on their immediate needs and ignore future consequences and they fail to follow rules and regulations. Agreeableness and crash risk may be related to one another due to higher emotional arousal

(e.g., more likely to respond aggressively to situations) and an inability to cooperate effectively with others among individuals low on Agreeableness. The link between Neuroticism to crash risk may be related to the stress response of those high on the trait and results suggest that individuals high on the trait of Neuroticism may respond more negatively to environmental stressors. Finally, individuals low on the trait of Openness-to-Experience may have an enhanced ability to focus on the task at hand and consequently be less at risk of crash.

However, while the FFM of personality has been shown to be more robust and replicable than any other taxonomy of personality factors, critics of the model suggest that there are personality factors beyond the Big Five. In addition to the broader constructs that comprise the FFM, Sensation Seeking has received considerable attention in studies examining the relationship between personality and driving (Dahlen & White, 2006). Sensation seeking is characterized by the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience (Zuckerman, 1994). For example, if an individual drives while intoxicated they may kill or injure themselves (physical risk), they may be arrested (legal risk), they may be fined (financial risk), or they may be condemned by others as a drunk driver (social risk; Zuckerman, 1994).

There is a considerable body of literature examining the relationship between the personality trait of Sensation Seeking and unsafe driving. Individuals high in Sensation Seeking are assumed to engage in unsafe driving to provide the type of stimulation they find satisfying (Dahlen & White, 2006). High Sensation Seeking is related to crashes, moving citations, driving while intoxicated, speeding, not wearing seatbelts, passing when it is not safe to do so, and a variety of other unsafe driving behaviours (Arnett, 1990; Furnham & Saipe, 1993; Jonah, 1997; Jonah, Thiessen, & Au-Yeung, 2001; Trimpop & Kirkcaldy, 1997). In Jonah's (1997) review of 40 studies on Sensation Seeking as a direct risk factor of unsafe driving, all but four studies found a positive association between Sensation Seeking and some aspect of risky driving. He also noted that Sensation Seeking accounted for approximately 10% to 15% of the variance in risky driving. This relationship has been observed among drivers in Canada, the United States, and numerous European countries (Jonah et al., 2001). In a similar study, Jonah et al. (2001) examined the relationship between Sensation Seeking and risky driving in 279 college students. Participants completed two questionnaires designed to assess their driving behaviour and their level of Sensation Seeking. The results demonstrated that participants high in Sensation Seeking reported engaging in significantly more risky driving behaviours than those low in Sensation Seeking. For example, those high in Sensation Seeking were more likely to speed, not to wear seat belts, to drink and drive, and to perceive a low risk of detection for impaired driving.

A more recent study investigated the potential contribution of Sensation Seeking to the prediction of aggressive and risky driving (Dahlen, Martin, Ragan, & Kuhlman, 2005). Two hundred and twenty-four undergraduate students completed measures designed to assess driving behavior, anger, boredom, impulsiveness, and Sensation Seeking. Findings demonstrated that Sensation Seeking was associated with risky driving, $r = 0.33$, $p < .01$, 95% CI [0.208, 0.441]. Similarly, Dahlen and White (2006) examined the role of personality traits in the prediction aggressive driving, risky driving, and various crash-related outcomes in 312 undergraduate psychology students. Consistent with earlier results, Sensation Seeking was associated with risky driving, $r = 0.26$, $p < .01$, 95% CI [0.154, 0.360]. The results revealed support for the role of Sensation Seeking towards risky non-aggressive driving, aggressive driving, loss of concentration while driving, moving citations, minor/major crashes.

Taken together, the existing literature indicates that, while variables such as driver's age and sex are associated with driving outcomes, so too are personality factors. In particular, the literature indicates that Conscientiousness and Sensation Seeking are consistently associated with driving behaviour. The majority of studies reported here, however, used self-reported collisions and questionnaire data as indicators of driving safety. As highlighted by Lajunen (2001), there is a need to examine the relationship between personality variables and objective driving outcomes. Moreover, the studies reported here generally focused on convenience samples with participants of a limited age range. Thus, a sampling frame that encompasses the lifespan of drivers and allows for the analysis of personality and driving outcomes while examining the intersection between demographic variables, such as age and sex, might explain some of the discrepant findings that have been reported in the literature.

Thus, the purpose of this investigation was to examine the relationship between personality and objective driving outcomes as assessed by a driving simulator in a sample of young, mid-aged, and older adults. It was hypothesized that in addition to demographic variables, personality factors would account for an appreciable proportion of the variance in objective measures of driving behaviour. In particular, based on the aforementioned literature, it was anticipated that Extraversion and Neuroticism would be associated with poor driving performance in the simulator. On the other hand, Conscientiousness and Agreeableness were hypothesized to be positively related to indicators of safe driving behaviour. It was also predicated that Sensation Seeking would be related to risk taking (e.g., speeding) in the driving simulator, especially among younger drivers.

2. Method

2.1. Participants

Fifty-eight young adults between the ages of 18 and 24 years (37 female, 21 male), 17 mid-aged adults between the ages of 25 and 64 years (11 female, 6 male), and 39 older adults over the age of 65 years (14 female and 25 male) participated in

the present study. All participants were healthy with no persistent psychological or physical health problems, had a valid class 5 driver's license, reported driving actively (an average of at least once a week for at least one year) and were fluent in English. Younger and mid-aged participants were selected from a pool of undergraduate volunteers enrolled in a Psychology course at Lakehead University in Thunder Bay, Ontario. Undergraduate participants received either course credit or a $10 gift card in exchange for their participation. Older participants (i.e., aged 65 years and older) were recruited from the community through newspaper advertisements, flyers, and by contacting local community centres. Older participants were compensated $50 for their participation.

Prior to recruitment of participants, this study was approved by the Lakehead University Research Ethics Board (REB).

2.2. Personality measures

NEO Five-Factor Inventory (NEO-FFI; Costa & McCrae, 1992). The NEO-FFI is an authorized short form of the Revised NEO Personality Inventory (NEO PI-R) and consists of 60 items that provide a quick, reliable, and accurate measure of the five domains of adult personality: Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness-to-Experience. The NEO-FFI can assist in understanding an individual's basic emotional, interpersonal, experiential, attitudinal, and motivational styles. Items are answered on a five-point Likert-type scale ranging from *strongly disagree* to *strongly agree.*

The Sensation-Seeking Scale – Form V (SSS-V; Zuckerman, 1994). Sensation Seeking is operationally defined in terms of scores on the SSS-V. The SSS-V is a 40 item forced choice measure that requires individuals to choose between two statements: one reflecting a desire for sensation (e.g., "I like wild and uninhibited parties") and one that reflects a more cautious predilection (e.g., "I prefer quiet parties with good conversation"; Jonah, 1997). The measure yields an overall score of Sensation Seeking as well as four individual subscale scores. The four subscales are: (1) Thrill and Adventure Seeking (TAS; a measure of an individual's desire to engage in activities involving some physical danger or risk); (2) Experience Seeking (ES; a measure of the desire to seek new experiences through the mind and senses); (3) Boredom Susceptibility (BS; a measure of an aversion for repetitive experience of any kind); and (4) Disinhibition (Dis; a measure of the need to disinhibit behaviour in the social sphere); Jonah, 1997; Zuckerman, 1994). While these dimensions of Sensation Seeking are modestly correlated, they appear to measure different components of Sensation Seeking and have been found to relate differently to various risky behaviours (Jonah, 1997).

2.3. Driving simulator

Objective driving behaviour was measured with a STISIM Drive® M400 simulator consisting of a driver's seat, passenger seat, steering console with horn, brake and accelerator foot pedals, signal light, and dash board (including speedometer and tachometer). The presentation of the simulated driving environment consisted of three 17″ monitors (135 degree field-of-view) with the rear-view mirror displayed on the central monitor, and side-view mirrors displayed on the outer monitors.

All participants completed a simulated driving assessment patterned after a standard assessment circuit administered by a provincial licensing authority. The simulated assessment took approximately 20 min to complete. Participants received pre-programmed auditory instructions throughout the simulated assessment.

The driving simulator recorded several relevant indices of driving performance related to longitudinal control (e.g., average speed, number of speed exceedances), lateral control (road edge and lane excursions), and total collisions.

In addition, for each drive, a research assistant scored participants using the Manitoba Road Test (MRT) (see Bédard, Parkkari, Weaver, Riendeau, & Dahlquist 2010 for a detailed description). The MRT assesses drivers on five performance criteria: Starting/Stopping, Signal Violation/Right of Way/Inattention, Moving in a Roadway, Passing/Speeding, and Turning. More demerits are assigned for grievous errors than for minor mistakes. For example, running a red light results in 10 demerit points whereas driving 10 km/h over the posted speed limit results in 5 demerit points.

2.4. Procedure

Upon arrival for their appointment, participants read an information letter and signed a consent form. Participants were then asked to complete a demographic questionnaire, the SSS-V, and the NEO-FFI.

Upon completing the questionnaires, participants were seated in the driving simulator and asked to familiarize themselves with the instruments and to adjust the seat as required. Participants were informed that some people experience physical discomfort when driving the simulator and that should they experience this discomfort, they should immediately inform the researcher. Given that 5% to 30% of users in virtual environment research end participation early due to simulator sickness (e.g., symptoms of physical discomfort; Stanney et al., 1998), measures were taken to minimize the likelihood of these symptoms occurring (e.g., maintaining cool room temperature and air flow).

After familiarizing themselves with the mechanics of the driving simulator, participants completed a 15-minute orientation drive. Upon completion of the orientation drive, participants were given the following instructions: "Please go through the course as if you are actually driving. We ask that you drive as closely as possible to how you would normally drive on-road". The 20 min simulated route consisted of mixed city and highway driving as well as environmental cues such as traffic signs and signals, and pedestrians.

In addition to indices of driver performance collected in real time by the driving simulator, simulator driving behaviour was also assessed post-simulated drive (using the play-back function of the simulator) by the experimenter using the MRT. Upon completion of the simulated drive participants were debriefed and thanked for their participation.

2.5. Data preparation

Items of the personality questionnaires were grouped according to which personality factor they belonged to and subsequently summed to generate six composite scores representing Extraversion, Neuroticism, Conscientiousness, Agreeableness, Openness-to-Experience, and Sensation Seeking. Next, personality composite scores were converted to T-scores to facilitate comparisons.[1] The errors recorded by the driving simulator were also summed to generate a composite measure of simulated driving behaviour. Demerit points assigned using the MRT were also summed. All analyses detailed in this manuscript were performed with PASW Statistics version 18.

An analysis of missing values revealed that about 5% of the driving simulator data were missing. There was no missing data for the other instruments. The missing simulator data were due to six participants failing to complete the simulated drive due to do simulator adaptation syndrome (SAS; Galvez-Garcia, 2015). A Missing Value Analysis (MVA) was performed in order to determine whether participants who completed the simulated drive differed significantly from those who completed the drive on any of the main variables of interest. The results of the MVA revealed that participants who failed to complete the simulated drive were significantly older than individuals who completed it, $t = -5.3$, $p = .001$.

2.6. Bivariate relationships

A series of linear regressions were executed to examine the effect of age, driving performance, and personality. Age was treated as a continuous variable.

To measure the degree association between personality factors and driving outcomes, Pearson product moment correlation coefficients were computed. Confidence intervals (95%) were calculated using the !rhoCI macro for SPSS developed by Weaver and Koopman (2014).

2.7. Multivariable models

It was of interest to explore the relative contribution of personality factors while controlling for other potential explanatory variables of driver behaviour including age and sex. To this end, three multiple regression models were used to examine the presence of possible relationships between sex, age, personality and objective simulated driving performance. MRT scores were treated as the outcome variable of interest because previous research has shown the MRT to have strong reliability, high face validity (given its use by provincial licensing authorities), and high criterion validity (Bédard et al., 2010). Participant sex, age, and the personality factor of interest were entered into Model 1. Given the possibility of a curvilinear relationship between participant age and unsafe driver behaviour, a variable representing the quadratic age term (age-squared) was also included. Model 2 included the variables listed in Model 1; however, it also included a variable capturing the linear component of the age by personality variable interaction. Model 3 included all variables from Model 2 as well as a variable representing the quadratic component of the age by personality variable interaction.

We sought to identify the most parsimonious models for the data and, to achieve this, Model 3 was examined first. When there was evidence (i.e., $p \leq .10$) for the quadratic component of the age by personality variable interaction, Model 3 was retained. When there was evidence for the linear component (i.e., $p \leq .10$), but not the quadratic component (i.e., $p \geq .10$) of the age by personality variable interaction, Model 2 was retained. When there was no evidence (i.e., $p \geq .10$) for either the linear or the quadratic component of the age by personality variable interaction, Model 1 was retained. Alpha was set to 0.10 as power to detect interactions in regression models is generally lower than power to detect first order effects (Baguley, 2012).

Centering, the practice of subtracting a constant from predictors before fitting the model, was applied to age and personality for both statistical and practical reasons. In multiple regression, the intercept represents the fitted value of the outcome when all of the predictors take a value of zero. Given that there are some predictors for which a value of zero makes little sense (e.g., having an age of zero), centering the predictors changes the meaning of the intercept (Tabachnick & Fidell, 2001). As such, Extraversion, Neuroticism, Conscientiousness, and Sensation Seeking were centered at 50 (population mean of T-scores). Age was centered at 20, a value close to its minimum in our sample. As the regression coefficient represents the expected change in Y for a one-unit change in X (the predictor), the magnitude of that coefficient is partly determined by the length of the units being used. When units are quite small and not necessarily clinically or theoretically meaningful, rescaling can be useful. As the original scales of the predictor variables do not lend themselves to immediately meaningful coefficients, the predictor variables were rescaled to produce more meaningful coefficients. It should be noted that rescaling the predictors to make meaningful regression coefficients has no impact on the strength of the association or on significance levels. As such, we divided age and personality by a scaling constant (10) before performing the regression analyses. To rep-

[1] Like Z-scores, T-scores are simple linear transformation of the original scores and do not change the shape of the distribution.

resent this in our regression we rescaled the explanatory variables by dividing them by 10 and then replacing (in the equation) the original explanatory variables with the newly created ones (Tabachnick & Fidell, 2001). Thus, the new coefficients for age and personality factors represent the change in the fitted value of *Y* for a 10-point increase in the original variables.

3. Results

3.1. Personality

Table 1 presents descriptive statistics for age and sex, personality factors, and measures of driving behaviour. Fig. 1 presents plots of the six personality factors that were assessed as a function of age.

To examine the effect of age on personality across the driving lifespan, six linear regressions were estimated, each with age and age-squared entered as predictors of one of the six personality factors. The results showed a statistically significant

Table 1
Descriptive statistics for age, personality factors, and measures of driving behaviour.

Variable	Mean	SD	Range
Age	42.30	26.5	18–89
Sex (0 = female, 1 = male)	0.49	0.50	0–1
Extraversion (T-score)	28.09	3.59	19–36
Neuroticism (T-score)	22.94	5.43	10–39
Conscientiousness (T-score)	29.51	3.94	18–38
Agreeableness (T-score)	25.56	4.34	16–36
Openness-to-Experience (T-score)	24.32	3.74	15–34
Sensation Seeking (T-score)	17.02	6.82	1–29
Number of speed exceedances	12.75	7.18	0–27
Average speed (ft/sec)	39.74	4.99	24.98–58.24
Total Errors	16.20	8.08	0–32
MRT Total	60.54	24.41	10–122

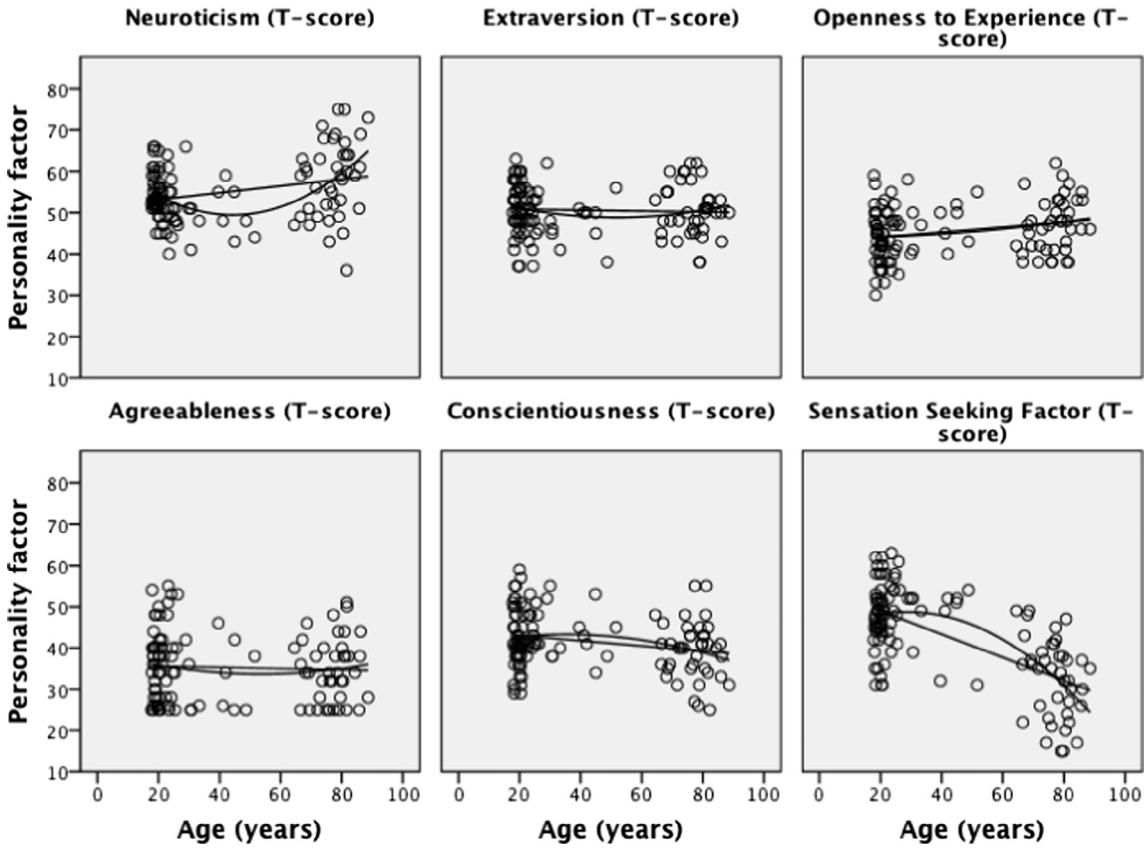

Fig. 1. Matrix of scatterplots showing personality and age with linear and quadratic fit lines.

effect of age in predicting Openness to Experience [F(1, 113) = 7.37, p = .008] where older drivers had higher levels of Openness relative to younger drivers. Age accounted for 6% (4% adjusted) of the variance in Openness to Experience. A significant effect of age was also observed for the model predicting Conscientiousness [F(1, 113) = 6.43, p = .013] with conscientiousness decreasing with increasing age. Age accounted for 5% of the variance (5% adjusted) in Conscientiousness.

Significant quadratic effects of age were observed for the models examining Neuroticism [F(2, 113) = 11.76, p < .001] and Sensation Seeking [F(2, 113) = 47.26, p < .001]. Neuroticism was found to decrease in the middle years and increase in older ages. The quadratic age term accounted for 18% (16% adjusted) of the variability in Neuroticism scores. Sensation Seeking was found to be relatively consistent during young and mid-adulthood but was shown to decrease in older age. The quadratic age term accounted for 46% (45% adjusted) of the variability in Sensation Seeking scores.

The models examining Agreeableness and Extraversion did not reach statistical significance.

3.2. Driving performance

Fig. 2 presents scatterplots of key measures of driving performance as a function of age and including two composite scores, the sum of all simulator-recorded driving errors (i.e., Total errors) and the sum of demerit points on the MRT (i.e., MRT Total).

To explore the effect of age on driving outcomes, several simple linear regressions were estimated. Given the nature of the variables (i.e., counts) and their respective distributions, speed exceedances, average speed, Total errors and MRT Total were analysed using the Ordinary Least Squares (OLS) method. The results indicated a significant linear effect of age for speed exceedances [F(1, 113) = 27.52, p < .001], with the number of speed exceedances decreasing with increasing age. Age accounted for 20% (19% adjusted) of the variance in speed exceedances. A similar pattern of results was observed for average speed [F(1113) = 37.67, p < .001] with age accounting for 25% (25% adjusted) of the variance. The model examining Total errors showed a significant effect of age [F(1, 113) = 24.64, p < .001] and accounted for 18% (17% adjusted) of the variability. A quadratic effect of age was observed in the model examining MRT Total [F(2, 113) = 7.13, p = .001] where demerit points were higher in younger and older drivers; 11% (10% adjusted) of the variance in MRT Total was accounted for.

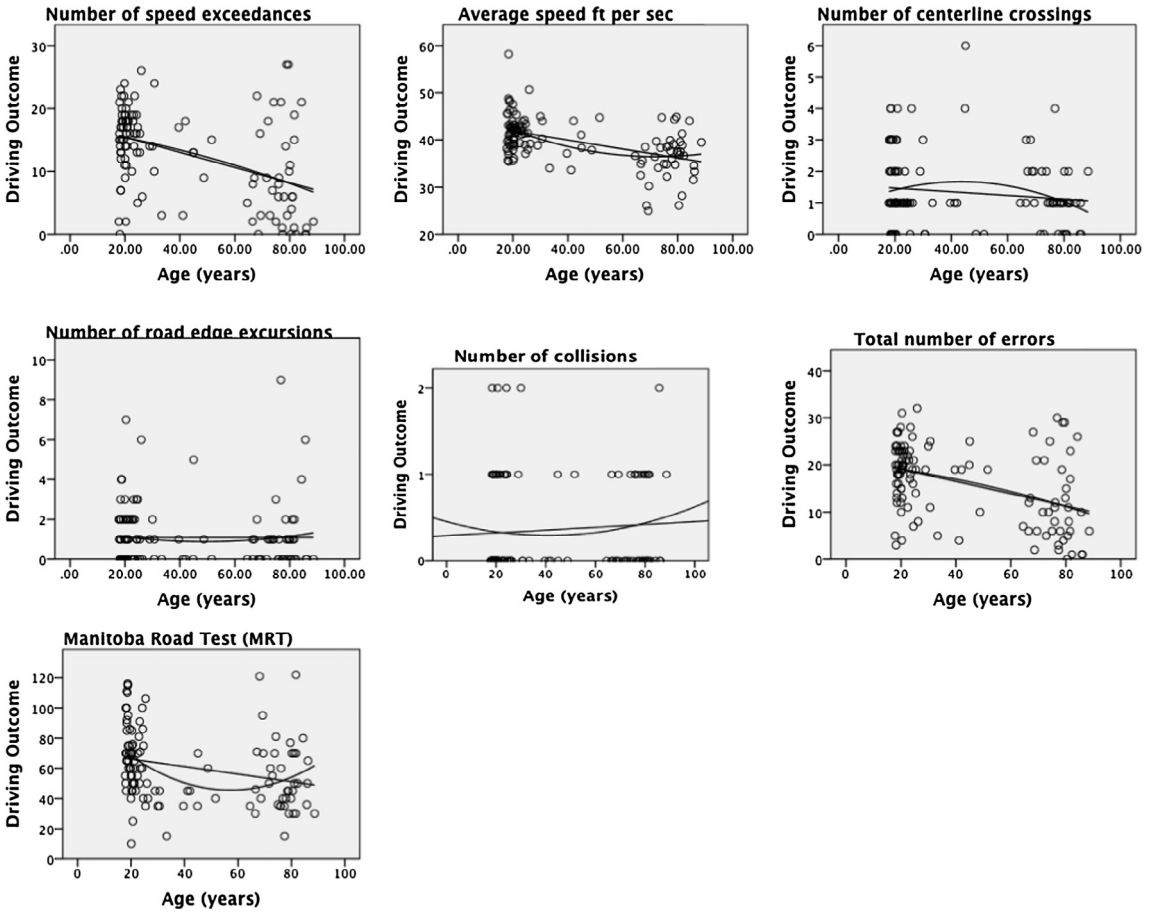

Fig. 2. Scatterplots showing driving outcomes by age with linear and quadratic fit lines.

The effect of age on the number of centreline crossings was examined through Poisson regression and the model was non-significant suggesting no effect of age on centreline crossings. Similarly, the number of road edge excursions was analyzed via negative binomial regression and the effect of age was non-significant. The number of collisions was dichotomized (i.e., collision vs. no collision) and submitted to a logistic regression with age and age-squared as the explanatory variables. The model was non-significant, suggesting no effect of age in explaining collision risk in the simulator.

3.3. Correlations

The preceding regression models revealed significant age differences in average speed, the number of speed exceedances, MRT scores and the number of simulator errors. It was subsequently of interest to explore the degree of association between these measures of driving performance and personality factors. To that end, Pearson Product Moment correlation coefficients were computed between the six personality factors driving outcomes. A full correlation matrix is presented in Table 2.

Statistically significant correlations were observed between Openness to Experience and the number of speed exceedances ($r = -0.188$, $p = .046$), between Conscientiousness and drivers' mean speed ($r = 0.214$, $p = .022$), and between Extraversion and MRT Total ($r = 0.192$, $p = .04$). The most striking correlations we observed, however, were between Sensation Seeking and the number of speed exceedances ($r = 0.302$, $p = .001$), drivers' average speed ($r = 0.372$, $p < .001$), and Total Errors ($r = 0.326$, $p < .001$).

3.4. Multiple regression analysis

To determine the relationship between individual personality factors and objective driving performance (i.e., MRT Total) while controlling for other known determinants of safe driving, notably age and sex, several multiple linear regression models were estimated. The results of the multiple linear regression models are presented in Table 3. All six regression models reached statistical significance and accounted for between 12% and 17% of the variance in MRT scores. For each of the six regression models, we produced a plot showing the fitted value of MRT Total as a function of drivers' age. Figs. 3–8 show fitted values of MRT demerit points from the multivariable linear regression models described earlier. The fitted values for males aged 20, 50 and 75 years are plotted as a function of the relevant personality variable. (Recall that age was treated as a continuous variable. We selected 20, 50 and 75 as three convenient ages for which to display fitted values, but those fitted values are from models using data from all of the subjects. Recall too that the regression models included no interaction terms involving sex. Therefore, the fitted value functions for females are parallel to those presented for males.) For all of the personality variables except Conscientiousness and Agreeableness, there was no evidence of a Personality x Age interaction, so for those variables, the fitted value functions for the three selected ages are parallel (see Figs. 3, 4, 7 and 8). The linear and quadratic components of the Personality x Age interaction were both statistically significant for Conscientiousness, and the linear component was statistically significant for Agreeableness. Therefore, the fitted value functions for the three selected ages are not parallel in the plots for those variables (see Figs. 5 and 6).

The model with Extraversion [$F(4, 109) = 4.66$, $p < .01$] accounted for 15% (12% adjusted) of the variability in the MRT Total. Age ($B = -11.26$) and age-squared ($B = 1.56$) were statistically significant explanatory variables of demerit points on the simulated drive. Increasing age was associated with a decrease in the number of demerit points until the relationship was eventually reversed (increasing age associated with an increase in demerit points). In addition, Extraversion ($B = 7.48$) emerged as a statistically significant explanatory variable, such that participants higher in Extraversion committed a greater number of demerit points on the simulated drive (see Fig. 9).

The model with Neuroticism as an explanatory variable was statistically significant, $F(4, 109) = 5.14$, $p = .001$. The model explained 16% (13% adjusted) of the variability in MRT Total. Age ($B = -9.30$) was a significant explanatory variable of demerit points on the simulated drive, such that increasing age was associated with a decrease in demerit points on the simulated drive. Neuroticism ($B = 7.96$) was also a statistically significant explanatory variable of the MRT Total. Compared with those low on Neuroticism, participants high on Neuroticism committed a greater number of driving demerit points on the simulated drive (see Fig. 10).

The model with Conscientiousness was statistically significant, $F(6, 107) = 3.67$, $p < .01$. Altogether, 17% (12% adjusted) of the variability in the MRT Total was accounted for by the model. Age ($B = -27.95$) and age-squared ($B = 4.21$) were significant explanatory variables of demerit points on the driving simulator. In addition, both the linear ($B = -17.96$) and quadratic ($B = 2.92$) components of the interaction between age and Conscientiousness were statistically significant. In order to interpret the significant interaction between age and Conscientiousness, a plot of predicted values of the MRT Total at various combinations of age and Conscientiousness is presented in Fig. 5. As demonstrated in Fig. 5, the effect of Conscientiousness on the fitted value of MRT depends on age. As age increases, the effect of Conscientiousness on the Manitoba Road Test total becomes greater, until approximately 50 years of age, where the effect of Conscientiousness begins to decrease. In other words, the effect of Conscientiousness on unsafe driving behaviour was greatest among mid-aged participants.

The model with Sensation Seeking was statistically significant, $F(4, 109) = 3.55$, $p < .01$. Altogether, 12% (8% adjusted) of the variability in the MRT Total was accounted for by the explanatory variables. Age ($B = -12.12$) and age-squared ($B = 1.61$) were both significantly associated with demerit points on the simulated drive, with the number of demerit points decreasing with increasing age until the relationship was eventually reversed.

Table 2
Correlation matrix including age, personality factors, and measures of driving behaviour. * indicates statistical significance at the p < .05 level. ** indicates statistical significance at the p < .001 level.

Variable	1 r (p) 95% CI (lower, upper)	2 r (p) 95% CI (lower, upper)	3 r (p) 95% CI (lower, upper)	4 r (p) 95% CI (lower, upper)	5 r (p) 95% CI (lower, upper)	6 r (p) 95% CI (lower, upper)	7 r (p) 95% CI (lower, upper)	8 r (p) 95% CI (lower, upper)	9 r (p) 95% CI (lower, upper)	10 r (p) 95% CI (lower, upper)	11 r (p) 95% CI (lower, upper)	12 r (p) 95% CI (lower, upper)
1. Sex	1.00											
2. Age	0.080 (.072) −0.007, 0.166	1.00										
3. Extraversion (T-score)	0.293* (.001) 0.115, 0.453	−0.045 (.635) −0.227, 0.140	1.00									
4. Neuroticism (T-score)	0.431* (<0.001) 0.268, 0.570	0.286** (.002) 0.108, 0.446	0.164 (.081) −0.020, 0.338	1.00								
5. Conscientiousness (T-score)	−0.029 (.756) −0.212, 0.155	−0.233* (.013) −0.400, −0.051	0.205* (.029) 0.022, 0.375	−0.088 (.350) −0.268, 0.097	1.00							
6. Agreeableness (T-score)	0.184* (.049) 0.001, 0.357	−0.050 (.594) −0.232, 0.135	0.096 (.311) −0.090, 0.275	0.397** (<0.001) 0.230, 0.542	0.027 (.778) −0.158, 0.210	1.00						
7. Openness-to-Experience (T-score)	0.056 (.546) −0.128, 0.238	0.248** (.008) 0.068, 0.413	0.154 (.102) −0.031, 0.328	0.250** (.007) 0.070, 0.415	0.113 (.231) −0.072, 0.291	0.090 (.343) −0.096, 0.269	1.00					
8. Sensation Seeking (T-score)	−0.192* (.040) −0.363, −0.008	−0.654** (.<0.001) −0.748, −0.535	0.083 (.380) −0.103, 0.263	−0.205* (.029) −0.375, −0.022	0.047 (.622) −0.138, 0.229	0.122 (.197) −0.064, 0.299	−0.252** (.007) −0.416, −0.071	1.00				
9. Number of speed exceedances	−0.027 (.779) −0.209, 0.158	−0.444** (<0.001) −0.581, −0.283	0.092 (.328) −0.093, 0.272	−0.022 (.815) −0.205, 0.162	0.098 (.299) −0.087, 0.277	0.158 (.093) −0.027, 0.332	−0.188* (.046) −0.359,−0.004	0.302** (.001) 0.125, 0.460	1.00			
10. Average speed (ft/sec)	−0.008 (.933) −0.192, 0.176	−0.502** (<0.001) −0.628, −0.350	0.077 (.413) −0.108, 0.258	0.129 (.170) −0.056, 0.306	0.214* (.022) 0.031, 0.383	0.178 (.059) −0.006, 0.350	−0.054 (.569) −0.235, 0.131	0.372** (<0.001) 0.202, 0.520	0.717** (<0.001) 0.615, 0.796	1.00		
11. Total Errors	−0.047 (.619) −0.229, 0.138	−0.425** (<0.001) −0.564, −0.261	0.086 (.365) −0.100, 0.265	−0.058 (.543) −0.239, 0.128	0.152 (.106) −0.033, 0.327	0.128 (.173) −0.057, 0.305	−0.183 (.052) −0.355, 0.001	0.326** (<0.001) 0.151, 0.481	0.952** (<0.001) 0.931, 0.967	0.713** (<0.001) 0.609, 0.793	1.00	
12. MRT Total	−0.083 (.381) −0.263, 0.103	−0.272** (.003) −0.434, −0.093	0.192* (.041) 0.008, 0.363	0.150 (.112) −0.035, 0.325	0.024 (.801) −0.161, 0.207	0.152 (.107) −0.033, 0.326	−0.090 (.339) −0.270, 0.095	0.125 (.184) −0.060, 0.302	0.404** (<.001) 0.238, 0.547	0.321** (<.001) 0.146, 0.477	0.409** (<.001) 0.243, 0.551	1.00

Table 3
Results of multiple linear regression analysis predicting scores on the Manitoba Road Test (MRT) from age, sex, and personality factors.

Model	Variables	*B*	*SE B*	*t*	*p*
Extraversion	(Constant)	31.51	18.88	18.88	.098
R^2 = 0.15	Sex	−4.38	4.73	−0.93	.356
Adjusted R^2 = 0.12					
	Age	−11.26	4.39	−2.56	.012
	Age^2	1.53	0.73	2.10	.038
	Extraversion	0.75	0.37	2.00	.048
Neuroticism	(Constant)	27.21	17.65	1.54	.126
R^2 = 0.16	Sex	−5.82	4.82	−1.21	.230
Adjusted R^2 = 0.13					
	Age	−9.30	4.50	−2.07	.041
	Age2	1.09	0.76	1.43	.155
	Neuroticism	0.80	0.33	2.39	.018
Conscientiousness	(Constant)	56.39	17.55	3.21	.002
R^2 = 0.17	Sex	−0.22	4.49	−0.05	.961
Adjusted R^2 = 0.12					
	Age	−27.95	7.38	−3.79	<.001
	Age^2	4.21	1.25	3.38	.001
	Conscientiousness	0.29	0.40	0.72	.471
	Age x Conscientiousness	−17.96	6.73	−2.67	.009
	Age^2 x Conscientiousness	2.92	1.12	2.60	.011
Agreeableness	(Constant)	68.69	12.09	5.68	<.001
R^2 = 0.16	Sex	−2.42	4.57	−0.53	.598
Adjusted R^2 = 0.12					
	Age	−8.38	4.68	−1.79	.076
	Age^2	1.53	0.74	2.10	.038
	Agreeableness	0.01	0.33	0.02	.985
	Age x Agreeableness	1.99	1.02	1.95	.054
Openness-to-Experience	(Constant)	73.88	16.11	4.59	<.001
R^2 = 0.12	Sex	−1.47	4.57	−0.32	.749
Adjusted R^2 = 0.08					
	Age	−12.18	4.44	−2.74	.007
	Age^2	1.66	0.74	2.24	.027
	Openness-to-Experience	−0.12	0.36	−0.33	.741
Sensation Seeking	(Constant)	68.54	3.47	19.76	<.001
R^2 = 0.12	Sex	−1.46	4.57	−0.32	.750
Adjusted R^2 = 0.08					
	Age	−12.12	4.45	−2.72	.008
	Age^2	1.61	0.76	2.11	.037
	Sensation Seeking	−0.68	2.64	−0.26	.796

The model predicting demerit points on the simulated drive from age, sex, and Agreeableness was statistically significant, $F(5, 108) = 4.17$, $p = .002$. The model accounted for 16% (12% adjusted) of the variance in the MRT Total. Age ($B = -8.38$) and age-squared ($B = 1.53$) emerged as statistically significant explanatory variables of interest. In addition, the linear ($B = 1.99$) component of the interaction between age and Agreeableness reached statistical significance. As illustrated in Fig. 6, the effect of Agreeableness depends on age and the effect is most pronounced among older participants.

The model including Openness to Experience reached statistical significance, $F(4, 109) = 3.06$, $p < .01$. Overall, 12% (8% adjusted) of the variability was accounted for by the combination of explanatory variables. Age ($B = -12.18$) and age-squared ($B = 1.66$) were significant explanatory variables.

4. Discussion

In this study we investigated the contribution of personality to simulated driving outcomes as assessed by a driving simulator. The sample consisted of one hundred and fourteen active drivers from 18 to 89 years of age. Our study yielded a number of noteworthy findings.

Specifically, through bivariate analysis of personality factors and driving outcomes, Sensation Seeking was found to correlate significantly with measures of speed (i.e., mean speed and speed exceedances), as well as with MRT Total. These findings are in line with the existing literature showing that individuals high in Sensation Seeking are more likely to have had convictions for driving offences and are at higher risk of crash involvement when compared to low sensation seekers (e.g., Dahlen & colleagues, 2005; Trimpop & Kirkcaldy, 1997). After controlling for age, sensation seeking was no longer significantly associated with driving performance suggesting that driver's age was accounting for the same variance in MRT Total as that of Sensation Seeking. Differences in personality by age showed that older drivers exhibited the lowest levels of

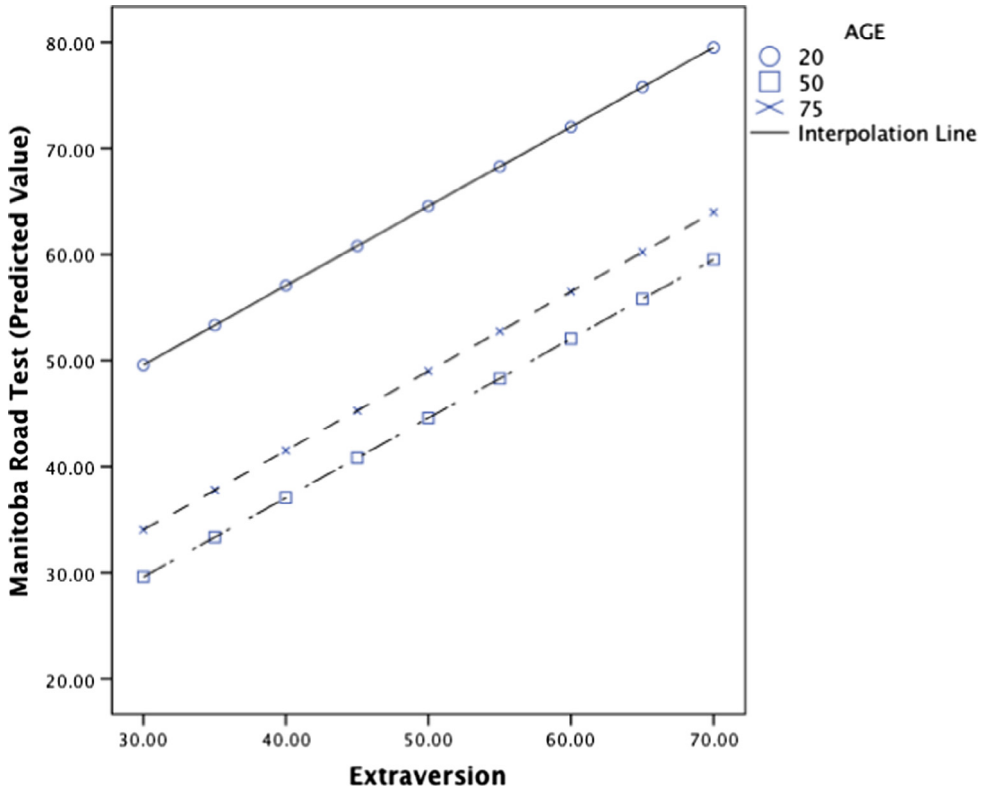

Fig. 3. Predicted values of the Manitoba Road Test total at selected combinations of age and Extraversion.

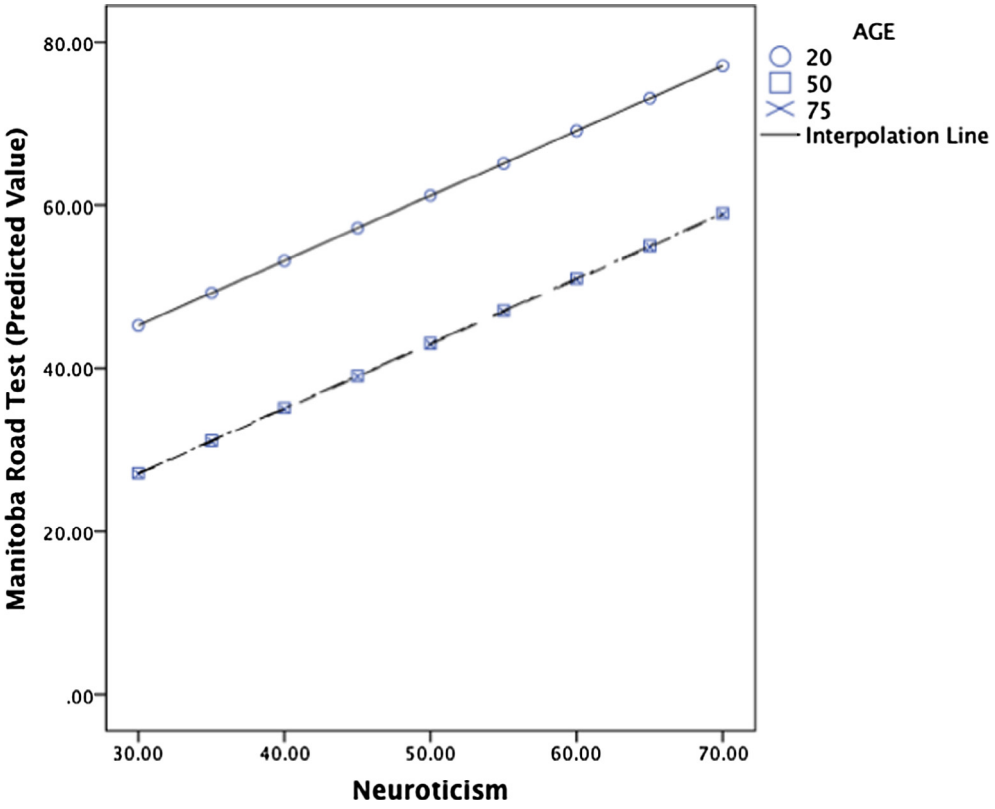

Fig. 4. Predicted values of the Manitoba Road Test total at selected combinations of age and Neuroticism.

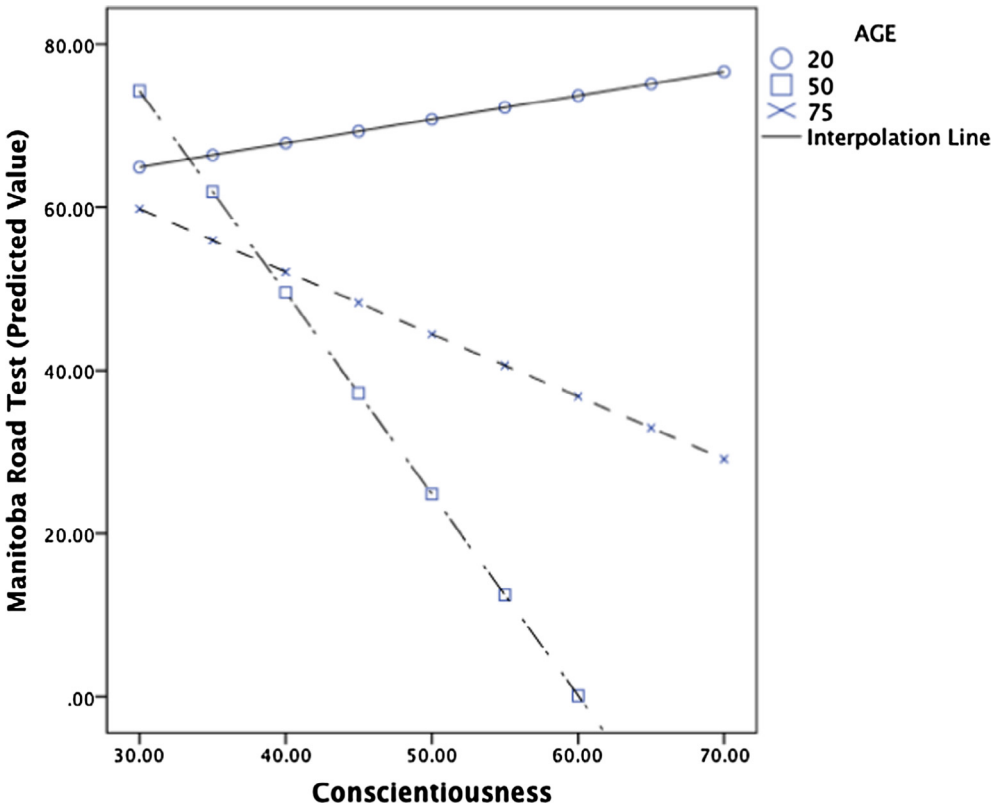

Fig. 5. Predicted values of the Manitoba Road Test total at selected combinations of age and Conscientiousness.

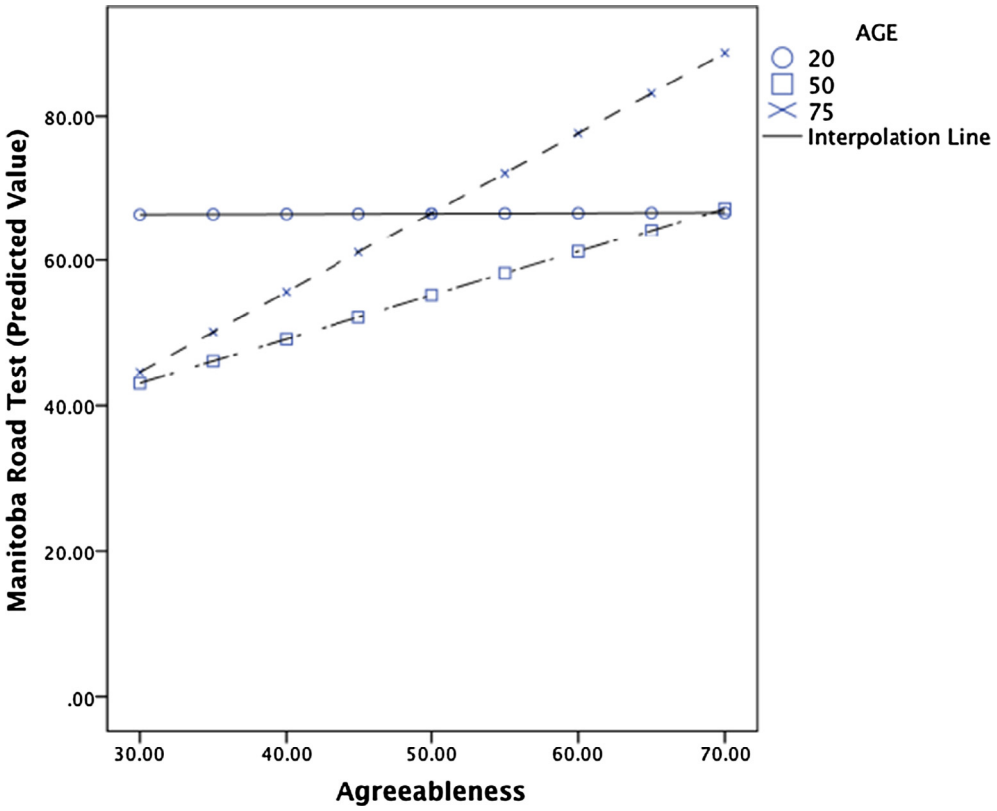

Fig. 6. Predicted values of the Manitoba Road Test total at selected combinations of age and Agreeableness.

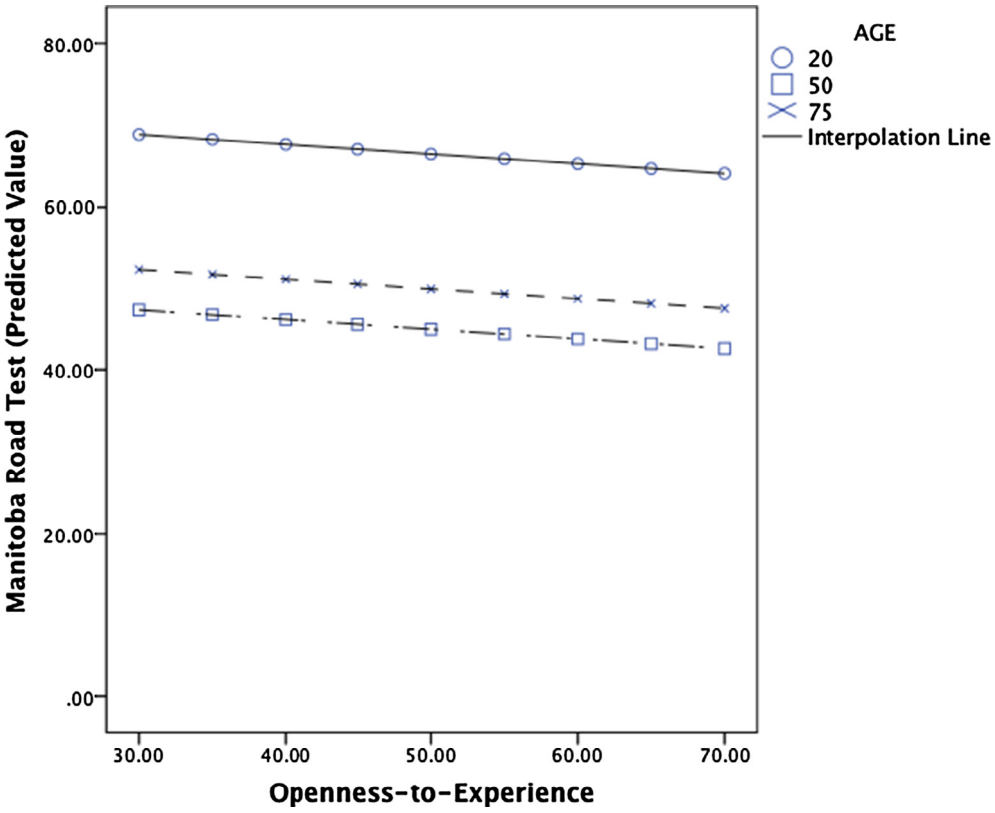

Fig. 7. Predicted values of the Manitoba Road Test total at selected combinations of age and Openness-to-Experience.

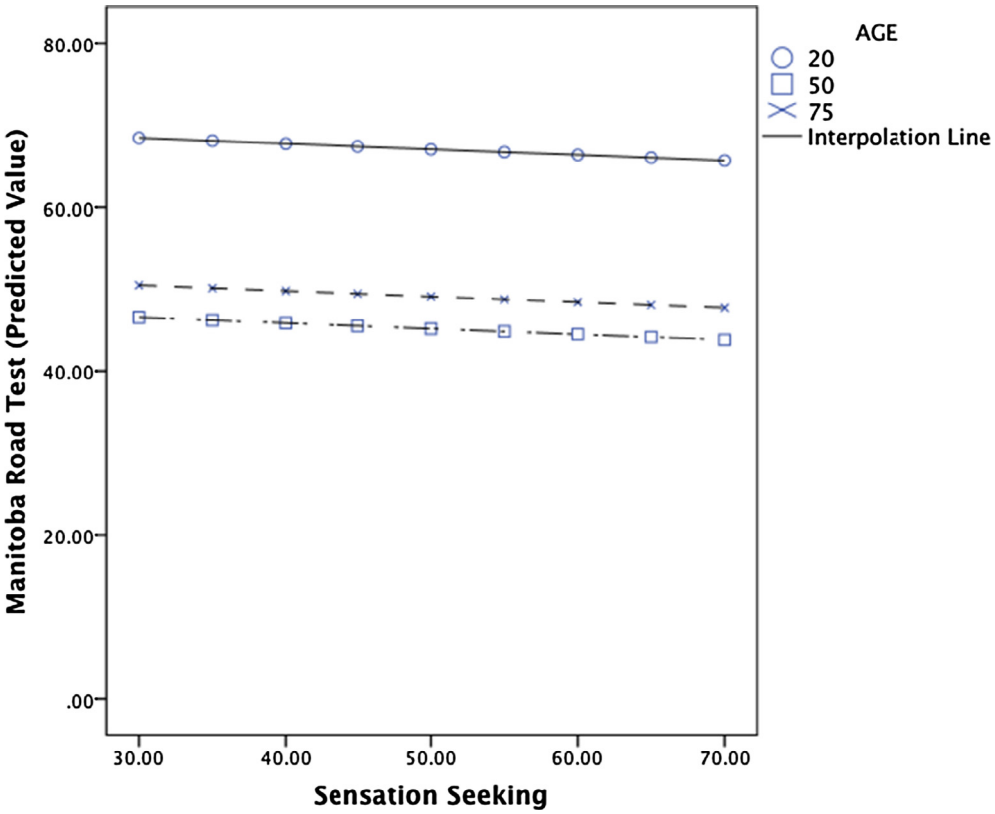

Fig. 8. Predicted values of the Manitoba Road Test total at selected combinations of age and Sensation Seeking.

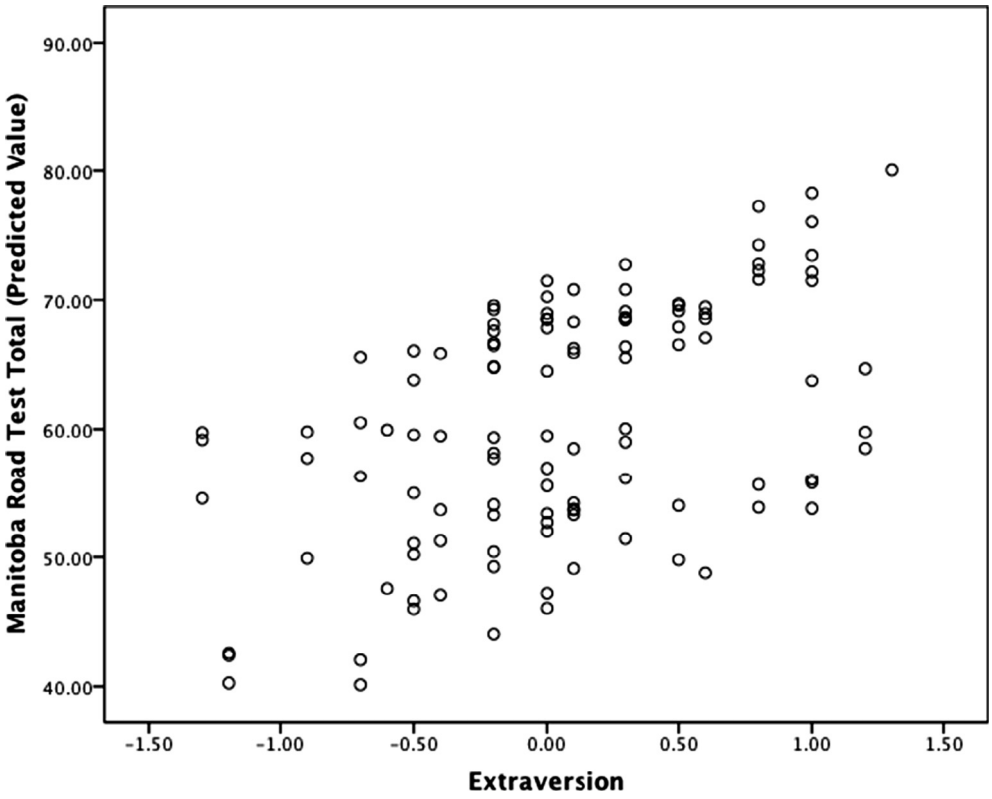

Fig. 9. Plot of Extraversion with the predicted value of the Manitoba Road Test total.

Sensation Seeking and younger adults exhibited the highest levels. Similarly, driver age was significantly correlated with Sensation Seeking ($r = -0.65$, $p < .001$) such that increasing age was associated with lower levels of Sensation Seeking. While research on the consistency of Sensation Seeking across the lifespan is limited, the literature suggests that it increases with age from childhood to adolescence and peaks around ages 18–20 years. Beyond this age, there is a gradual and progressive decline (Larsen & Buss, 2008). Thus, the effect of Sensation Seeking on driving performance can be understood as a risk factor that is salient for younger drivers and tends to dissipate with age.

The results of the analysis examining unsafe driver performance on the simulated drive revealed a significant nonlinear interaction between age and Conscientiousness. The effect of Conscientiousness was most pronounced among mid-aged drivers, such that those high in Conscientiousness were at a lower risk of unsafe driving compared to those low in Conscientiousness. The results observed among mid-aged drivers are consistent with research demonstrating a significant inverse link between Conscientiousness and unsafe driver behaviour (Arthur & Graziano, 1996). These results suggest that mid-aged drivers who describe themselves as more responsible, attentive, careful, persistent, and orderly are less likely to commit unsafe driver actions on the driving simulator. Contrary to previous literature (e.g., Clarke & Robertson, 2005), Conscientiousness did not have an effect on unsafe driver behaviour among drivers at either end of the age continuum. These results suggest that the effect of potentially protective personality attributes may be overshadowed by the presence of other variables that affect the driving performance of the young and old. To date, much of the literature on safety among older drivers has focused primarily on cognitive, perceptual, and motor processes that change in ways that may influence safe driving. It is possible that such factors may have diluted the effect of Conscientiousness on driving performance among older drivers. This interpretation is consistent with Owsley and colleagues' (2003) proposal that research on personality focus on the interaction of personality with functional impairment in understanding older driver behaviour. Conversely, the problems encountered by young drivers are often attributed to inexperience. Experience is important in that drivers learn to handle a number of driving tasks, some of which become automated, thus allowing more time and capacity for assessing the situation on the road (Dewar & Olson, 2007). Thus, among younger drivers, driving inexperience may negate the effect of Conscientiousness on driving performance.

A statistically significant positive relationship between Extraversion and unsafe driving on the simulator was observed, in that those higher on the trait of Extraversion engaged in significantly greater unsafe driving actions. These results are consistent with the assertion that extraverts are at higher risk of crash involvement due to low levels of vigilance and subsequently reduced attention to tasks (e.g., driving). Given the inherent safety in the simulated environment (e.g., free from injury), it is possible that participants high in Extraversion sought stimulation to a greater degree (as proposed by Clarke

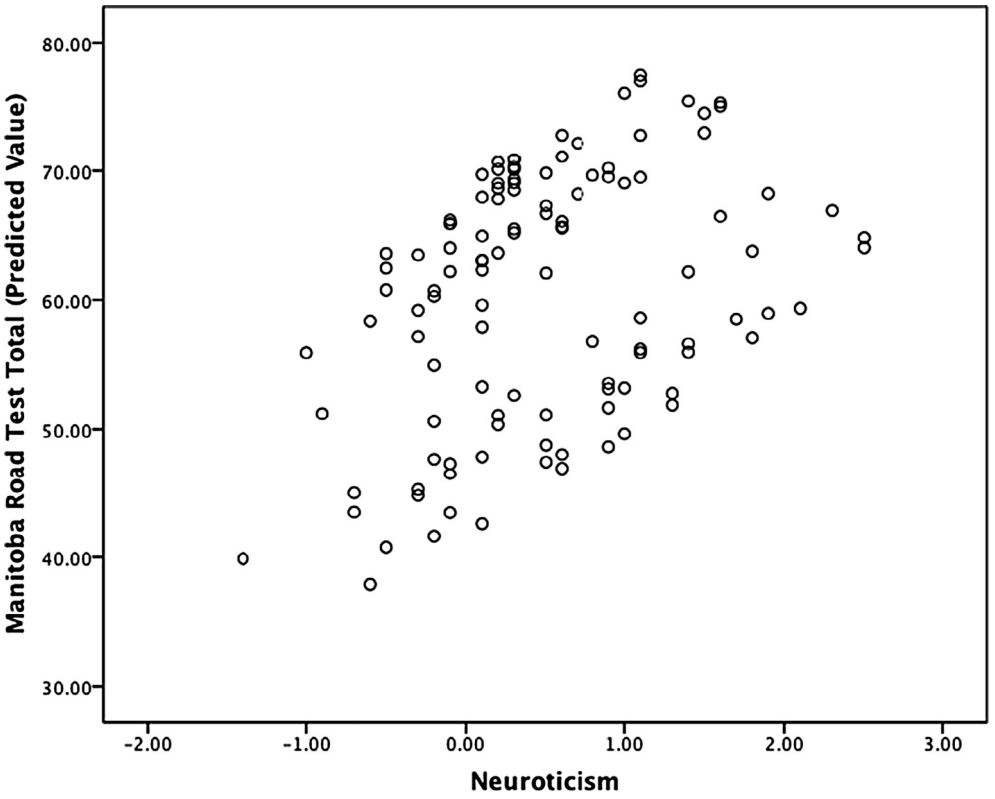

Fig. 10. Plot of Neuroticism with the predicted value of the Manitoba Road Test total.

& Robertson, 2005) and consequently demonstrated significantly greater unsafe driver actions on the simulated drive, relative to those low in Extraversion.

Neuroticism emerged as a significant explanatory variable of demerit points on the simulated drive, such that compared to those low in Neuroticism, participants high in Neuroticism were assigned a greater number of demerit points on the simulated drive. These results are consistent with the literature suggesting a positive relationship between Neuroticism and unsafe driver behaviour (Hansen, 1989; Matthews, Dorn, & Ian Glendon, 1991; Sümer et al., 2005). Individuals high in Neuroticism have been described as anxious, vulnerable to stress, lacking in confidence, moody, and easily frustrated (McCrae & Costa, 2003). These features have the effect of decreasing cognitive and performance capacities (e.g., reaction time) and of increasing errors (Clarke & Robertson, 2005). Clarke and Robertson (2005) proposed that individuals high on the trait of Neuroticism may respond more negatively to environmental stressors. The simulated environment enables researchers to ensure that environmental stressors are held constant among participants, thereby eliminating varying degrees of stressors as possible confounders.

Within the multiple regressions that were performed, age was found to consistently predict driving performance in the driving simulator. In all models except the one that included Neuroticism, age-squared also reached significance. The results are consistent with the U-shaped function that is typically reported in the driving literature, with driving fatality rates being high for young drivers, declining and remaining steady for mid-aged drivers, and then steadily increasing for drivers aged 65 and older (Bédard et al., 2001; McGwin & Brown, 1999; Whitfield & Fife, 1987). These findings highlight the importance of treating age as a continuous variable when feasible as well as the potential for the presence of non-linear relationships.

The present study represents a significant contribution to the existing literature on personality and driving in that it: (a) administered appropriate measures of the Big Five and Sensation Seeking personality factors; (b) measured objective driving performance through a driving simulator, and; (c) collected data from a large sample of drivers from across the lifespan. It is not, however, without limitations. In particular, this study employed a driving simulator as a proxy for real-world driving. While the association between performance on the driving simulator and performance on the open road has been well established in the scientific literature (e.g., Bédard et al., 2010; Johnson et al., 2011; Lee, Cameron, & Lee, 2003), this study is unable to make inferences about personality and on-road crash risk. Similarly, the present study is cross-sectional in nature and thus cannot comment on whether the aging process impacts personality and consequent driving behaviour. In other words, given the nature of our data we are unable to ascertain whether the age differences in personality reflect the aging process or cohort differences. Future longitudinal research could help shed light on these issues. Finally, while this study

treated age as a continuous variable, there were relatively few participants in the middle of the age range and, as such, fitted values in the middle of the age range should be interpreted cautiously.

Undoubtedly, personality factors are associated with objective outcomes as measured by a driving simulator over and above demographic variables. In particular, Extraversion, Neuroticism and Conscientiousness were found to significantly contribute to simulated driving performance across the lifespan. Moreover, Sensation Seeking emerged as an important personality factor for driving safety, especially among young drivers.

References

Arnett, J. (1990). Drunk driving, sensation seeking, and egocentrism among adolescents. *Personality and Individual Differences, 11*(6), 541–546.

Arthur, W., & Doverspike, D. (2001). Predicting motor vehicle crash involvement from a personality measure and a driving knowledge test. *Journal of Prevention & Intervention in the Community, 22*(1), 35–42.

Arthur, W., Jr, & Graziano, W. G. (1996). The five-factor model, conscientiousness, and driving accident involvement. *Journal of Personality, 64*(3), 593–618.

Baguley, T. (2012). *Serious stats: A guide to advanced statistics for the behavioral sciences*. Palgrave Macmillan.

Bédard, M., Guyatt, G. H., Stones, M. J., & Hirdes, J. P. (2002). The independent contribution of driver, crash, and vehicle characteristics to driver fatalities. *Accident; Analysis and Prevention, 34*(6), 717–727.

Bédard, M. B., Parkkari, M., Weaver, B., Riendeau, J., & Dahlquist, M. (2010). Assessment of driving performance using a simulator protocol: Validity and reproducibility. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association, 64*(2), 336–340.

Bédard, M., Stones, M. J., Guyatt, G. H., & Hirdes, J. P. (2001). Traffic-related fatalities among older drivers and passengers: Past and future trends. *The Gerontologist, 41*(6), 751–756.

Boyce, T. E., & Geller, E. S. (2002). An instrumented vehicle assessment of problem behavior and driving style: Do younger males really take more risks? *Accident; Analysis and Prevention, 34*(1), 51–64.

Caspi, A., Roberts, B. W., & Shiner, R. L. (2005). Personality development: Stability and change. *Annual Review of Psychology, 56*, 453–584. https://doi.org/10.1146/annurev.psych.55.090902.141913.

Clarke, S., & Robertson, T. (2005). A meta-analytic review of the big five personality factors and accident involvement in occupational and non-occupational settings. *Journal of Occupational and Organizational Psychology, 78*(3), 355–376.

Costa, P. T., & McCrae, R. R. (1992). *Revised NEO personality inventory (NEO PI-R) and NEO five-factor inventory (NEO-FFI): Professional manual*. Odessa, FL: Psychological Assessment Resources.

Dahlen, E. R., Martin, R. C., Ragan, K., & Kuhlman, M. M. (2005). Driving anger, sensation seeking, impulsiveness, and boredom proneness in the prediction of unsafe driving. *Accident; Analysis and Prevention, 37*(2), 341–348.

Dahlen, E. R., & White, R. P. (2006). The big five factors, sensation seeking, and driving anger in the prediction of unsafe driving. *Personality and Individual Differences, 41*(5), 903–915.

Dewar, R. E., & Olson, P. L. (2007). *Human factors in traffic safety*. Lawyers & Judges Publishing Company.

Dickerson, A. E., Molnar, L. J., Eby, D. W., Adler, G., Bédard, M., Berg-Weger, M., et al (2007). Transportation and aging: A research agenda for advancing safe mobility. *The Gerontologist, 47*(5), 578–590.

Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road-traffic crash risk: An examination method and findings. *Psychological Bulletin, 113*(2), 279–294.

Evans, L. (2000). Risks older drivers face themselves and threats they pose to other road users. *International Journal of Epidemiology, 29*(2), 315–322.

Freund, B., Colgrove, L. A., Burke, B. L., & McLeod, R. (2005). Self-rated driving performance among elderly drivers referred for driving evaluation. *Accident; Analysis and Prevention, 37*(4), 613–618.

Furnham, A., & Saipe, J. (1993). Personality correlates of convicted drivers. *Personality and Individual Differences, 14*(2), 329–336. https://doi.org/10.1016/0191-8869(93)90131-L.

Galvez-Garcia, G. (2015). A comparison of techniques to mitigate simulator adaptation syndrome. *Ergonomics*, 1–8.

Hansen, C. P. (1989). A causal model of the relationship among accidents, biodata, personality, and cognitive factors. *The Journal of Applied Psychology, 74*(1), 81–90.

Johnson, M. J., Chahal, T., Stinchcombe, A., Mullen, N., Weaver, B., & Bedard, M. (2011). Physiological responses to simulated and on-road driving. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology, 81*(3), 203–208.

Jonah, B. A. (1997). Sensation seeking and risky driving: A review and synthesis of the literature. *Accident; Analysis and Prevention, 29*(5), 651–665.

Jonah, B. A., Thiessen, R., & Au-Yeung, E. (2001). Sensation seeking, risky driving and behavioral adaptation. *Accident; Analysis and Prevention, 33*(5), 679–684.

Kua, A., Korner-Bitensky, N., Desrosiers, J., Man-Son-Hing, M., & Marshall, S. (2007). Older driver retraining: A systematic review of evidence of effectiveness. *Journal of Safety Research, 38*(1), 81–90.

Lajunen, T. (2001). Personality and accident liability: Are extraversion, neuroticism and psychoticism related to traffic and occupational fatalities? *Personality and Individual Differences, 31*(8), 1365–1373.

Larsen, R. J., & Buss, D. M. (2008). *Personality psychology*. New York: Mc Grew-Hill.

Lee, H. C., Cameron, D., & Lee, A. H. (2003). Assessing the driving performance of older adult drivers: On-road versus simulated driving. *Accident; Analysis and Prevention, 35*(5), 797–803.

Lewin, I. (1982). Driver training: A perceptual-motor skill approach. *Ergonomics, 25*(10), 917–924.

Machin, M. A., & Sankey, K. S. (2008). Relationships between young drivers' personality characteristics, risk perceptions, and driving behaviour. *Accident; Analysis and Prevention, 40*(2), 541–547.

Matthews, G., Dorn, L., & Ian Glendon, A. (1991). Personality correlates of driver stress. *Personality and Individual Differences, 12*(6), 535–549.

McCrae, R. R., & Costa, P. T. (1995). Trait explanations in personality psychology. *European Journal of Personality, 9*(4), 231–252.

McCrae, R. R., & Costa, P. T. (2003). *Personality in adulthood: A five-factor theory perspective*. Guilford Press.

McGwin, G., Jr, & Brown, D. B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. *Accident; Analysis and Prevention, 31*(3), 181–198.

McGwin, G., Owsley, C., & Ball, K. (1998). Identifying crash involvement among older drivers: Agreement between self-report and state records. *Accident Analysis and Prevention, 30*(6), 781–791. https://doi.org/10.1016/S0001-4575(98)00031-1.

Owsley, C., McGwin, G., Jr, & McNeal, S. F. (2003). Impact of impulsiveness, venturesomeness, and empathy on driving by older adults. *Journal of Safety Research, 34*(4), 353–359.

Public Health Agency of Canada (2012). Injury in review, 2012 edition: spotlight on road and transport safety. <http://www.parachutecanada.org/downloads/research/reports/InjuryInReview2012_EN.pdf>.

Schwebel, D. C., Ball, K. K., Severson, J., Barton, B. K., Rizzo, M., & Viamonte, S. M. (2007). Individual difference factors in risky driving among older adults. *Journal of Safety Research, 38*(5), 501–509.

Stanney, K., Salvendy, G., Deisinger, J., DiZio, P., Ellis, S., Ellison, J., et al (1998). Aftereffects and sense of presence in virtual environments: Formulation of a research and development agenda. *International Journal of Human-Computer Interaction, 10*(2), 135–187.

Statistics Canada (2010). Population projections for canada, provinces and territories. Catalogue no. 91-520-X.

Sümer, N., Lajunen, T., & Ozkan, T. (2005). Big five personality traits as the distal predictors of road accident involvement. *Traffic and Transport Psychology: Theory and Application: Proceedings of the ICTTP, 2004*, 215.
Tabachnick, B. G., & Fidell, L. S. (2001). Using multivariate statistics.
Tellegen, A. (1991). Personality traits: Issues of definition, evidence, and assessment.
Transport Canada (2011). In *Road Safety in Canada.* <http://www.tc.gc.ca/eng/motorvehiclesafety/tp-tp15145-1201.htm>.
Transport Canada (2015). In *Canadian motor vehicle traffic collision statistics: 2013.* <https://www.tc.gc.ca/media/documents/roadsafety/cmvtcs2013_eng.pdf>.
Trimpop, R., & Kirkcaldy, B. (1997). Personality predictors of driving accidents. *Personality and Individual Differences, 23*(1), 147–152.
Turcotte, M. (2012). Profile of seniors' transportation habits. Statistics Canada. Retrieved from: <http://www.statcan.gc.ca/pub/11-008-x/2012001/article/11619-eng.pdf>.
Weaver, B., & Koopman, R. (2014). An SPSS macro to compute confidence intervals for Pearson's correlation. *The Quantitative Methods for Psychology, 10*(1), 29–39.
Whitfield, R. A., & Fife, D. (1987). Changing patterns in motor vehicle crash mortality: 1940–1980. *Accident; Analysis and Prevention, 19*(4), 261–269.
Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. Cambridge University Press.