Relationships between age, executive function and driving behaviour

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Abstract

This study investigates the relationships between executive function and driving behaviours within two samples of Australian drivers. A self-report, cross-sectional survey research design was employed on a sample of 92 provisionally licensed drivers aged 17-25 years enrolled in a local driver safety program, and 244 students aged 18-58 years from a Canberra university. Younger drivers were found to display poorer executive function and poorer effective executive function was associated with increased total negative driving behaviours including increased driving violations, mistakes and lapses. Regression analyses confirmed that executive function was an important influential predictor of driving behaviours over and above the effects of age and sex. The strength of the influence of executive function on driving behaviour was further demonstrated in the university sample by the partially mediating effect of executive function on the relationship between age and total negative driving behaviours. These results suggest that higher levels of executive function may partially buffer the negative influence of youth on driving behaviours. Implications of results are discussed with regards to future research in driver safety.

Keywords

Young Drivers, Executive Function, Driving Behaviour, Risk Factors

Introduction

Motor vehicle accidents are a major cause of fatality and injury in Australia and the primary cause of death amongst young Australians [1]. The skill of driving is complex and requires the integration of a broad range of information processing functions as well as motor and psychomotor coordination [2]. Researchers at the Monash University Accident Research Centre have identified four skills that are critical in moderating the crash involvement of young drivers [3]. These skills are: risk perception, attentional control, the ability to prioritise and share limited attention between multiple competing tasks, and the ability to moderate task demands according to one's own performance capabilities[3]. These skills can also be argued to be processes mediated by executive function.

Executive function is generally considered to be an umbrella term to encompass a collection of numerous neurocognitive processes necessary for purposeful, goal-directed activity. The term encompasses specific skills involved in goal-oriented processes such as: anticipation, deployment of attention, risk perception, decision making, planning, self regulation, and the utilisation of feedback [4]. Executive functions may also include or overlap with cognitive operations such as working memory, attentional control and inhibitory control (in particular the suppression of a habitual response in the face of novel situations) [5].

The frontal lobe, in particular the prefrontal cortex, is central to executive function [6]. The exact developmental trajectories of executive functioning is yet to be conclusively established, but it is generally argued that executive function component processes mature along a protracted course, beginning in early childhood and reaching maturity during adolescence [6]. However, for some executive processes recent literature suggests that development may continue into early adulthood [7-9].

Few studies have specifically investigated the influence of executive functioning on driving performance, and those which have done so have generally focussed on older drivers [10]. However, one such study was performed by Lundqvist and colleagues [11]. Using an advanced driving simulator, the driving performance of 29 socially well recovered brain lesion patients with confirmed reduced executive function, were compared with matched controls. No significant differences were evident between the two groups when the driving simulator replicated the conditions of predictable driving situations. However, in unpredictable driving situations patients demonstrated longer reaction times and safety margins, as well as difficulties in allocating processing resources to a secondary task. When tested again in an on-road

test, the patients displayed significantly poorer attention, worse traffic behaviour and less risk awareness when driving in real traffic than the control group. Together these findings suggest that executive functioning plays a pivotal role in managing novel experiences on the road and this may influence driving performance in unexpected traffic situations.

Attention Deficit Hyperactivity Disorder (ADHD) research also provides support for the role of executive functions in driving behaviours, as several studies have provided evidence of a link between ADHD and increased road injury risk [12]. It has been suggested that the common executive dysfunction features of ADHD such as deficiencies in attention, persistence, activity regulation, motor control, reaction time and rule-following behaviour, may significantly impact on the tactical operations of a motor vehicle driver in traffic [12].

There is abundant evidence that youth and driving accidents are related [2]. Young novice drivers are typically 2-4 times more likely to be involved in motor vehicle accidents across Australia and abroad [13]. The reason for the difference between younger verses older drivers is unclear. Currently, there exists minimal research investigating systematic differences between younger and older drivers [14]. However, it is suspected that a major causal factor for this overrepresentation is a lack of driving experience in young drivers [15]. As a consequence, this may contribute to an inadequate ability to cope with deviations from 'normal' driving conditions (such as adjusting to differential traffic flows or weather conditions) [14, 15]. As the findings of Lundqvist and colleagues [11] suggest, executive functioning may be influential in an individual's ability to cope in driving conditions which deviate from normality. Poor executive functioning may therefore be detrimental to the safety of young inexperienced drivers and represent an additional risk factor.

Another influential factor in driving behaviour and accident prediction is sex. The Department of Transport and Regional Economics [16] report that in 2006 the fatality statistics for male drivers aged 17-25 years were more than three times higher than for female drivers of the same age. However the above findings do not suggest that females are necessarily safer drivers than males. In a review of the research literature performed by Over [17] on sex differences behind the wheel, it was reported that, due to both methodological and conceptual deficiencies in studies to date, there was not enough strong or consistent evidence to reach a conclusion about the relative safety of male compared to female drivers.

The purpose of the current study was to explore the relationships between executive function and driving behaviours, while also examining the influences of age and sex. As it was anticipated from the literature that age and sex would influence driving behaviour it was hypothesised that after controlling for these effects decreased executive function would be associated with increased total negative driving behaviours including: increased driving violations, mistakes and lapses due to inattention and inexperience. It was also expected that executive function would partially mediate the effects of age on total negative driving behaviours.

The current study will explore the aforementioned relationships among two different participant samples. One sample is drawn from young drivers participating in a local road safety course. This group was chosen because it is expected to be more representative of the general population however; there was limited access to participant numbers. To obtain a larger number of participants, an additional sample was collected from a more accessible but potentially less representative sample, consisting of university students.

Methods

Participants

The first group of participants discussed are those drawn from a sample of young drivers enrolled in a local driver safety education program called Road Ready Plus. Approximately 105 Road Ready Plus students were offered a small cash incentive to complete an anonymous self-report questionnaire. Of the 92 respondents, 54 were male (58.7%) and 38 were females (41.3%), aged 17 to 25 years (M = 18.57, SD = 1.85).The second group of participants consisted of 244 students, 183 females (75%), and 61 males (25%) aged from 18-58 years (M = 25.06, SD = 8.94) enrolled in an undergraduate psychology course at a Canberra University.

Measures

The survey used in this study consisted of three self-report sections, reflecting participant's demographic characteristics, executive functioning and driving behaviour.

Executive function. The adult self-report version of the Behaviour Rating Inventory of Executive Functioning (BRIEF-A) [17] was used to assess executive functioning. The BRIEF-A is comprised of 75 self-report items designed to measure behavioural manifestations of executive function. Participants indicate how often they had a problem with the described behaviours within the last month by circling *never*, *sometimes* or *often*.

The BRIEF-A provides nine overlapping theoretically and empirically derived clinical scales, two indices (meta-cognitive and behavioural regulation) and one composite global score (global executive function) comprised of the summation of both indices. The subscales which contribute to global and index scores include: inhibit, shift, emotional control, self-monitor, initiate, plan/organise, task monitor, working memory and organisation of materials. Total scores were obtained by the summation of representative subscale questions, with higher scores indicating poorer functioning within that domain of executive function.

Previous studies have demonstrated that the BRIEF-A displays solid psychometric properties including reliability, validity and clinical utility [18]. In the current study high levels of internal consistency were achieved, with Cronbach's alpha coefficients for index scores ranging from .91 to .95.

Driving behaviour. A version of the Driving Behaviour Questionnaire (DBQ) developed by Aberg and Rimmo [19], which had been modified by Senserrick and Swinburne [20] to apply to Australian roads, was employed in this study. This measure is comprised of 36 self-report items that identify four factors: violations (deliberate deviations from practices believed necessary to maintain the safe operation of a motor vehicle, such as speeding), mistakes, (dangerous errors resulting from departures from planned actions, such as misjudging the speed of an oncoming vehicle when overtaking), inattention lapses (general driving errors due to lapses of attention such as failing to notice when a traffic signal turns green), and inexperience lapses (general driving errors such as switching on windscreen wipers when one intended to switch on the indicator) [19,20]. Participants respond to statements describing everyday driving situations and are asked to indicate on a seven-point scale the extent to which each of the statements apply to them from 1 (*Not at all*) to 7 (*Always*). Total scores for each factor are obtained by the summation of factor questions, and a summary score is created (total negative driving behaviours) by the summation of all four factors scores. In all instances higher scores indicate higher frequencies of that behavioural domain.

Previous studies have demonstrated good test retest reliability as well as strong confirmatory evidence for a predictive relationship between factors of the DBQ and an individual's history of dangerous driving and crash involvement [21-23]. In the current study the DBQ demonstrated strong reliability with Cronbach's alpha coefficients ranging from .82 to .94.

Procedure

The present study employed a cross-sectional survey design. A purposive sample of young drivers was recruited from a local road safety education training course called Road Ready Plus. This potential sample was felt to be more representative of young drivers in the general population, as this course targets all young drivers in the Australian Capital Territory who are aged less than 27 years and who have held a provisional licence for six months or more. This course costs $70 and takes five hours to complete. This course features a range of individual and facilitated group activities designed to enhance driver safety. Following completion of this course students are rewarded for furthering their driver education with increased licence demerit points and the capacity to legally drive without displaying a provisional licence plate. Completion of the Road Ready Plus course is optional. However, without completing this course provisionally licensed drivers in the Australian Capital Territory are required to display their provisional plates for three years or until the age of 26 and have a reduced number of licence demerit points [24]. Information and an invitation to participate in the present study were mailed out alongside course information, to all persons enrolled during the months of September and October 2007. Participants were informed that participation in the study was voluntary, anonymous and confidential. Participants were offered $10 cash to complete the attached survey and return it during their scheduled Road Ready Plus class. Participants completed the survey before engaging in the Road Ready Course.

The second participant sample was recruited from students enrolled in four undergraduate psychology subjects utilising a convenience sampling technique. All participants were offered course credit for their participation. The separation of samples was retained for analysis as it was considered they may represent different driver characteristics which may, in turn, yield additional insights. For instance the Road Ready Plus sample was felt to be potentially more prone to negative driving behaviour than the university sample (see Discussion). All research was conducted under full approval of the University of Canberra Committee for Ethics in Human Research.

Results

The means and standard deviations of scores are presented in Table 1.

Table 1: Descriptive Statistics

Variable	*M*	*SD*
Road Ready Sample[a]		
Total Negative Driving Behaviour	61.77	24.70
Global Executive Function	118.43	24.46
Age	18.57	1.85
University Sample[b]		
Total Negative Driving Behaviour	53.41	25.57
Global Executive Function	111.85	20.30
Age	25.06	8.94

[a]$N = 92$, [b]$N = 244$.

Pearson's product moment correlation analyses revealed that all subscales and index measures of executive function were found to hold a medium to large significant positive relationships with driving behaviours in both sample populations, $r = .31$ to $.51$, $p < .05$ [25]. This indicated that drivers with poorer executive function were more likely to exhibit increased total negative driving behaviours including committing more driving violations, mistakes and lapse due to inattention and inexperience. As all subscale and index scores of executive function and driving behaviour were shown to relate in a similar manner, in the interest of parsimony, summary results presented here will rely on the scores of global executive function and total negative driving behaviours.

The Road Ready sample correlation analysis revealed that neither age nor sex significantly correlated with any measure of executive function or driving behaviour. Among the university sample however, age was found to hold a small negative association with total negative driving behaviour $r = -.24$ $p < .01$, and a small negative association was also demonstrated for age and global executive function $r = -.14$, $p < .01$. No significant relationships were demonstrated between sex and executive function or driving behaviour. In the Road Ready sample the lack of correlation between age and other measures is likely to be due to the restricted range of ages relative to the university sample (see Discussion).

To determine whether executive function contributed significant unique variance to the outcome variable of total negative driving behaviours, over and above the effects of age and sex, a two-step hierarchical multiple linear regression analyses was conducted on both samples. For both samples, all necessary assumptions of regression were met and order of entry was consistent with the hypothesis and previous research [19]. A summary of the analysis results of both samples can be seen in Table 2. Within the Road Ready sample, the variables of age and sex were entered in the first step. Both age $t(89) = -0.94$, and sex, $t(89) = -0.08$, failed to contribute significantly to total negative driving behaviours, $p > .01$. In this model, age and sex accounted for a non significant 1% of the variance in total negative driving behaviours, $F(2,89) = 0.45$, $p > .01$. However, the addition of global executive function in the final step made a significant independent contribution, $t(88) = 5.67$, $p < .01$ and explained an additional 26% of the variance in total negative driving behaviours $F(1,88) = 32.11$, $p < .01$. The variables of age $t(88) = -0.21$, and sex $t(88) = 0.25$, retained their status of non significance, $p > .01$. The final regression model significantly explained 27% of the variance in total negative driving behaviours, $F(3,88) = 11.10$, $p < .01$.

These findings suggest that amongst this sample neither age nor sex significantly predicted total negative driving behaviours. However, executive function scores explained over one quarter of the variance in total negative driving behaviour scores.

The same analysis procedure was repeated using the university sample data. To control for the effects of age and sex these variables were again entered at the first step. Age was found to significantly predict total negative driving behaviours $t(240) = -3.86$, $p < .01$, while sex failed to contribute significantly. In this model, age and sex accounted for 7% of the variance in total negative driving behaviours $F(2,240) = 8.62$, $p < .01$. The addition of global executive function scores in the final step, made a significant contribution, $t(239) = 5.42$, $p < .01$ and explained an additional 11% of the variance in total negative driving behaviours $F(1,239) = 29.38$, $p < .01$. Age retained significance $t(239) = -3.33$, $p < .01$, and the contribution made by sex increased marginally but remained non significant ($p = .07$). In the final model, 17% of the variance in negative driving behaviour was explained by age, sex and executive function, $F(3,239) = 16.22$, $p < .01$.

Table 2: Summary of Regression Analysis for Predictors of Total Negative Driving Behaviours

Variable	*B*	*SE B*	β	sr^2	R^2	ΔR^2
Road Ready Sample						
Step 1.						
Age	-1.35	1.44	-.10	.00		
Sex	-0.40	5.39	-.01	.00	.01	.01
Step2.						
Age	-0.26	1.25	-.02	.00		
Sex	1.17	4.65	-.02	.00		
Global Executive Function	0.53	0.10	.53*	.24	.27	.26*
University Sample						
Step 1.						
Age	-0.68	0.18	-.24*	.06		
Sex	5.66	3.66	.09	.01	.07	.07*
Step2.						
Age	-0.56	0.17	-.19*	.03		
Sex	6.38	3.46	.11	.01		
Global Executive Function	0.41	0.07	.32*	.10	.17	.10*

* $p < .01$.

As previous analyses of the Road Ready Plus data revealed age failed to be significantly associated with driving behaviours, the following analysis therefore only includes university sample data. In determining the presence of a mediating relationship, the method suggested by Baron and Kenny [26] was employed. Barron and Kenny require three criteria be met before a mediating relationship can be confirmed. Firstly, the independent variable must be shown to significantly affect both the dependent and the mediating variable. Secondly, the mediating variable must significantly affect the dependent variable whilst holding the independent variable constant. Finally, the affect of the independent variable must be no longer significant or is considerably attenuated when the mediating variable is included in the regression model. Once the criteria set out by Barron and Kenny has been met, Sobel's [27] method has been employed to verify the presence of a significant mediating relationship. Following Baron and Kenny's recommendation an initial linear regression analysis was performed. This indicated that age was a significant negative predictor of total negative driving behaviour scores $\beta = -.24$, $t(242) = -3.84$, $p < .01$. A linear regression of age on global executive function also indicated a significant negative relationship $\beta = -.14$, $t(242) = -2.14$, $p < .05$. In the final linear regression model, global executive function was found to be a significant predictor of total negative driving behaviours $\beta = .32$, $t(241) = 5.32$, , $R^2 = .16$, $F(2. 240) = 22.40$, $p < .01$. However, the addition of global executive function in this model caused the β value of age to change from -.24 to -.19, $t(241) = -3.31$, $p < .01$, which by Sobel's method was proven to be

significant, z = -3.11, p <.01. This suggests that the relationship between age and total negative driving behaviour is partially mediated by global executive functioning.

Discussion

The focus of this study was to explore the relationships between executive function and driving behaviour while also examining the influence of age and sex among young drivers. Significant associations were revealed between executive function and driving behaviours, suggesting that generally drivers with poorer executive functioning are more likely to exhibit increased total negative driving behaviours including committing more driving violations, mistakes and lapses of attention and inexperience. Results from both hierarchical regression analyses revealed that executive function was an important influential predictor of driving behaviour that contributed independent to the effects of age and sex. These results lend support to the essential findings of Lundqvist and colleagues [11] that executive functioning plays a pivotal role in managing driving behaviour.

The strength of the influence of executive function was further demonstrated by the partially mediating effect of executive function on the relationship between age and total negative driving behaviours present in the university sample. This result suggests that increased executive function may partially buffer the effects of age and contribute to safer driving behaviours. That is, while young drivers are generally more at risk of negative driving behaviours than older drivers, this may be less the case for younger drivers with strong executive function. Together these findings indicate that younger drivers with increased executive function are less likely to commit negative driving behaviours such as committing driving violations than their peers with poorer executive function.

The lack of significant effects for sex observed in all analyses was an unexpected finding, and conflicts with previous reports of male drivers being more likely to commit driving violations than their female counterparts [18]. Reasons for the aforementioned differential findings are unclear. It is possible that the university sample was limited to detect sex differences due to the predominantly female sample population. However the Road Ready Plus sample demonstrated a more balanced gender ratio. One possible explanation for the lack of effects for sex may lie in the suggestion from Moore [28] that the risky driving behaviours of females are becoming increasingly similar to males. Another possibility may reflect participant motivations for enrolling in the Road Ready Plus course. Perhaps because an incentive for completing the Road Ready Plus course is that participants receive extra licence demerit points, this course may therefore attract drivers who are more likely to commit driving violations than other populations, reducing the covariance of sex. A final possible explanation put forth for the differential finding reflects results from a study performed by Dobson *et al.* [29]. This study investigated the driving behaviours of young women and found that young female drivers demonstrated almost twice the mean driving violations of middle aged women [29]. Therefore, perhaps the young mean age of Road Ready Plus females contributed towards limiting the relationship between sex and driving violations that would otherwise have been evident in a sample with a wider female age range.

The expectation that younger drivers would be associated with increased negative driving behaviours was not supported in the Road Ready Plus sample. The results from the Road Ready Plus sample conflicts reports from the university sample and previous studies that have demonstrated younger drivers to be more likely to commit driving violations, and driving mistakes than their older counterparts [19, 21]. The reason for this differential finding is not clear, although a likely explanation may lie in differing sample size and populations studied. As the Road Ready Plus sample targeted only young drivers within a narrow age range of 17-25 years, the design therefore may have been limited to detect an association between age and driving behaviour.

When interpreting the results of this study there are several limitations which should be noted. The self-report design of this study renders it subject to potential social desirability bias and or other inaccuracies. For instance measures such as the BRIEF have been criticized for being "too directed towards psychopathology and less sensitive to … executive deficits" [6]. Sample size is another area of the research design to potentially impose limitations. The sample size employed in the current study is only sufficient for detecting medium to large effect sizes [30]. It could be possible that some of the variable interactions in the present study were small and therefore went undetected due to an insufficient number

of respondents. A final limitation of this study is the extent to which results can be applied generally. Thus conclusions based on this limited research must be tentative.

Future research could endeavour to improve on the type of measures employed, samples size and generalisability of the findings. Given the complexity and the multi-component nature of executive function and driving behaviour, further investigations utilising a variety of different executive function and driving behaviour measures may be beneficial. For instance, more direct measures of executive function (e.g. neuropsychological tests) and driver behaviour (e.g. observed behaviour in driving simulators) may reduce the potential errors associated with reliance only on self-report measures. Additionally, future studies could consider a prospective or longitudinal design to help explore the developmental path of executive function maturation and track driving behaviours.

The present study contributes to the limited research in this area. Further understanding the relationships that the present study has indicated between age, executive functioning and driving behaviour could prove to be very useful for driver education, safety and training. An increased focus in driver training on improving skills of executive function could help minimise driver risks of motor vehicle accidents. This study's findings may encourage efforts leading to the development of a screening tool to identify young drivers of increased risk of motor vehicle accidents and traffic violations due to less effective executive functioning. Once identified, risk management programs could employ strategies such as additional training to enhance 'at risk' drivers' executive skills.

In summary, findings from the present study indicate that executive function is an important influential predictor of driving behaviour that contributes over and above the effects of age and sex. The findings of this study suggest that executive function plays a pivotal role in managing driving behaviour and that generally, younger drivers with increased executive function are less likely to commit total negative driving behaviours including driving violations, mistakes and lapses of inattention and inexperience than their peers with poorer executive function. The present study contributes to the limited research in this area. Understanding the relationships that the present study has indicated, between executive functioning and driving behaviour could prove to be very useful for driver education, and training.

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