BRIEF REVIEW

Biological and behavioral factors affecting driving safety

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Key words

Biological factors • Behavioral factors • Driving safety

The European Commission estimates that car crash-related costs in Europe are around 160 billion euros, approximately 2% of the Gross Domestic Product [1]. In several countries, car crashes are the first cause of death among subjects aged 15-30, with a direct heavy impact on the years of life lost; in young subjects car crashes also represent one of the major causes of disability [2].

Several driver characteristics and driving behaviors due to age, diet, alcohol consumption, circadian rhythms, drug intake and diseases may contribute to a reduced alertness and induce drowsiness with dangerous consequences on driving ability thus increasing the risk of car crashes. It can be estimated that human factors concerning the psychophysical condition of the driver are involved in 60-80% of road accidents [2].

Crash involvement rates on a population basis are higher among males than females in all age groups [3]. This observation may be related to the fact that females drive fewer kilometres/year, drive mainly in town and for short journeys, rarely in bad weather and usually drive small engine cars. Males drive for a higher number of kilometres/year, on motorways for long distance driving and drive trucks or large engine cars.

Most accidents involve subjects under 25 years (35%), whereas subjects aged over 70 years are involved in approximately 3% of car crashes, as expected considering that the percentage of drivers over 70 years of age is small compared to other age groups [3].

Taking into account the distance travelled (Fig. 1), crash rates in older subjects are higher than in the middle-aged and comparable to those of young subjects; crash rates in females are slightly higher than in males in all age groups [3].

Our study on truck drivers disclosed that the reaction times worsen ($r_S = 0.337$; $p = 0.034$) and the number of correct answers decreases as age increases ($r_S = -0.354$; $p = 0.025$) even in a limited age-range (Fig. 2) (unpublished data).

Socioeconomic factors such as low social class and low educational level, family conditions (divorced or with divorced parents), job loss and social isolation and several behavioral and psychophysical factors are considered predisposing factors to traffic accidents [4].

Several psychotropic substances taken for recreational (alcohol and illicit drugs) or medical purposes can impair driving performance either by disturbing the information processing mental function, promoting risk taking behaviour, or by increasing response time [4]. Commonly administered therapeutic drugs, such as antihistaminics, antihypertensives, cardiac glycosides, diuretics, antidiabetic agents and antibiotics may cause

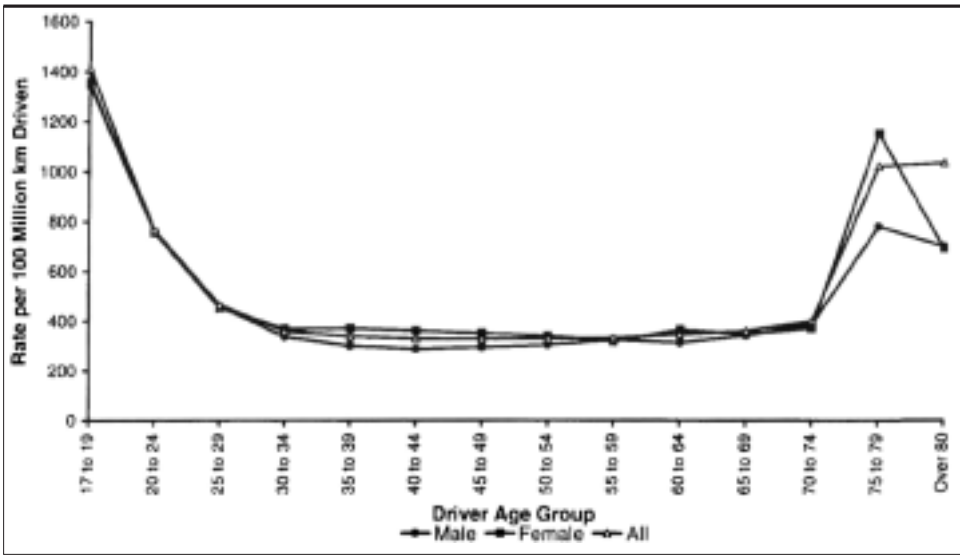
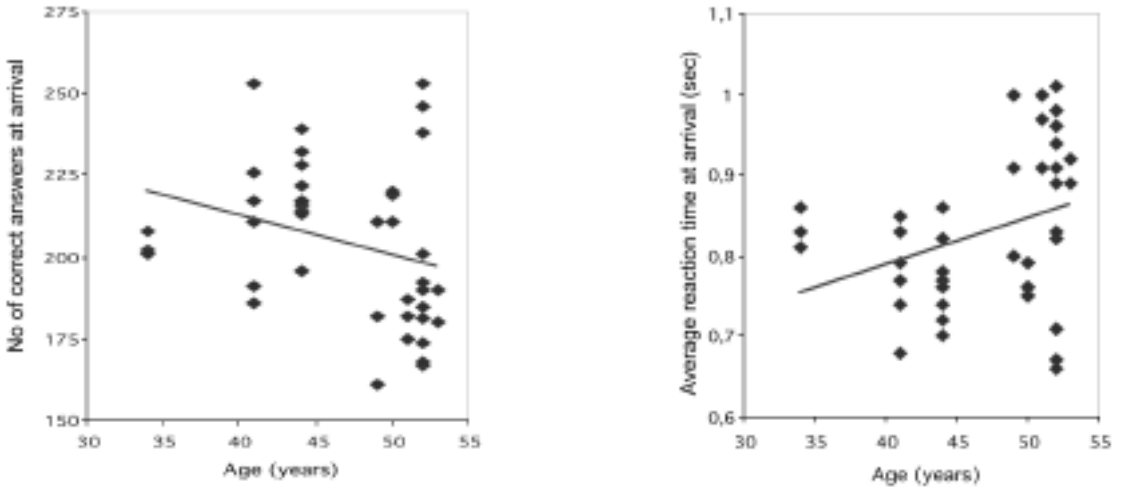


Fig. 1. Driver crash involvement by age and sex, Western Australia 1989-1992 (crashes per 100 million km driven) [3]. Reprinted from Accid Anal Prev 1998;30:379-87, with permission from Elsevier.

Fig. 2. Relationship between age and driver performance (reaction time and number of correct answers) by Vienna Determination Test.



weakness or other side effects, thereby increasing the risk of a road accident [4]. Although relatively few reports have addressed the role of medical conditions in road accident involvement, it has been suggested that several diseases and disabilities may impair driving performance [4].

Among behavioral factors, alcohol plays an important role in car crashes, and accidents involving alcohol are more likely to result in injuries and deaths than crashes where alcohol is not a factor [4-6]. A large proportion of accidents are attributable to alcohol (in Europe about 20%) mainly in young people: the intake of alcoholic beverages when associated with narcotics use may represent the most dangerous combination that when is increases the risk of serious crashes [4].

Sleepiness while driving and/or falling asleep at the wheel are other important risk factors for injuries from car crashes, though the exact role of these factors has yet to be fully elucidated [7]. Estimates of the proportion of road traffic accidents due to sleepiness while driving vary widely between nations, ranging from 1% to 33% [7]. This contribution is most likely underestimated, due to the lack of a standardised definition of "sleep-related vehicle accidents" and/or due to insurance-related problems. The percentage of road traffic accidents ascribed to sleepiness in Italy has been estimated at around 21% [8].

Individuals at highest risk of sleep-related accidents are generally young subjects, particularly males, individuals with undiagnosed or untreated sleep disorders, subjects who use sleep-inducing drugs, shift workers or truck drivers with long periods of driving, a high frequency of night driving and lack of adequate rest (< 6 hours of sleep) [9, 10].

Sleep loss is also an important risk factor in city accidents occurring on short trips and the main reasons for sleep loss (Fig. 3) are work and partying/social events [11].

As regards the distribution of sleep-related vehicle accidents by time of day, Figure 4 shows three peaks, two during the early morning (at around 02-03, and 06-07) when traffic flow rates are low, and another one in the mid-afternoon (16-17) at a time of high traffic density [12].

Sleepiness decreases performance, reducing the vigilance level and impairing attention and reaction times [13]. Even a low and generally 'safe' level of alcohol consumption may exacerbate driving impairment due to sleepiness [14].

A poorly investigated aspect of road accidents is the role of the driver's chronotype in the induction of sleepiness. Several studies have shown interindividual differences in the spontaneous sleep-wake cycle and it has been suggested that this variability may influence individual levels of performance. In particular it has been observed that performance differences between the two chronotypes (morning-type or evening-type) are related to the time of day [15].

Recent studies have shown that peaks of melatonin synthesis occur on average three hours earlier among individuals with morning chronotype compared with evening chronotypes [16-18]. The phase and magnitude of the melatonin secretion cycle, at the beginning or

Fig. 3. Reasons for sleep loss [11]. Reprinted from Accid Anal Prev 1997;29:463-9, with permission from Elsevier.

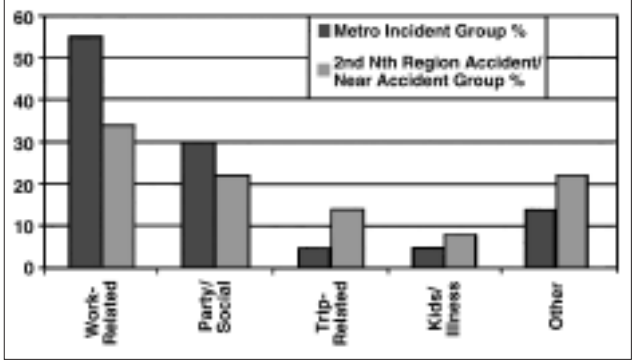
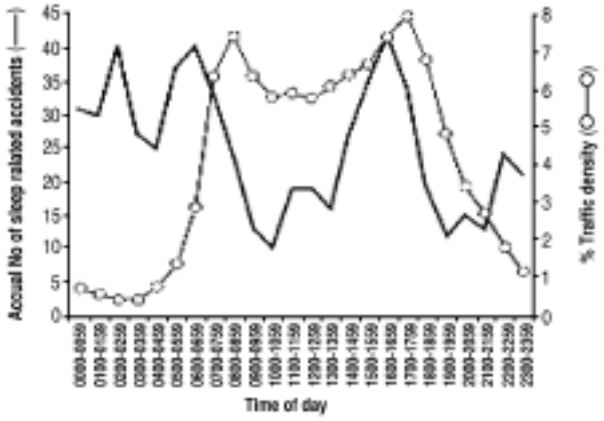


Fig. 4. Incidence of sleep related vehicle accidents and traffic flow rates by hour of day [12]. Reprinted from BMJ 1995;310:565-7, with permission from the BMJ Publishing Group.



end of the work shift, may represent a marker of maladjustment and stress condition among vehicle drivers [19, 20].

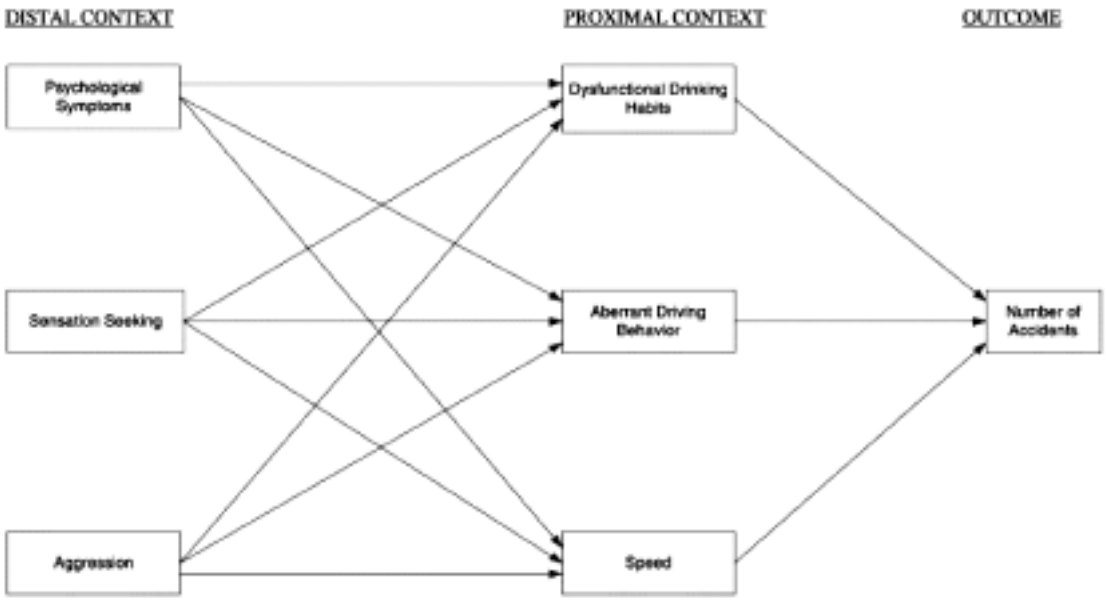
Among the human risk factors of road accidents, several psychological and behavioral factors seem to be associated with an increased risk of motor-vehicle accidents [4, 21]. Several attempts have been made to analyse the role of these factors in triggering accidents and it has been suggested that certain personality traits can affect "driving style". To shed more light on the relative contribution of personality factors and driving behaviors in accident involvement, a model distinguishing distal (i.e. personality factors) and proximal (i.e. aberrant driving behaviors) predictors of traffic accidents has been proposed (Fig. 5) [21].

Some personality traits, such as impulsiveness and sensation seeking have been implicated as major factors in the risk-taking disposition. In particular, the "Sensation Seeking" trait related to pursuit of "strong" sensations and of an adventurous and hazardous life, seems to increase the risk of road traffic accidents. "Sensation Seeking", a personality trait that seems to be geneticall-y based, is more pronounced among young males, and is related to behaviors such as reckless driving, sometimes associated with excess alcohol consumption [22, 23]. "Sensation Seeking" is directly correlated to hazardous driving behaviours such as high speed, infringement of safety distance and other rules of the highway code, driving after excess alcohol intake, etc. [24, 25]. It has been hypothesized that the interaction between stable personality factors and transient elements such as stressful events, fatigue or drinking might play a major role in crash causation [26].

Normal car driving on the road, especially under difficult conditions, is considered one of the most significant stressors of everyday life and is influenced by several individual and environmental factors. Consequently, the driver's performance, as well as road safety, may be affected by the stress induced by driving. Significant changes in stress hormones, such as catecholamines (in particular adrenaline) and cortisol or both, have been detected in studies carried out on bus, truck and racing car drivers [27-33]. The finding that adrenaline excretion rates were significantly correlated to anxiety scores in both truck and racing car drivers suggests that the degree of adrenergic response is influenced by the psychological profile [31, 33].

Driving motor-vehicles under stressful environmental conditions (long-distance driving, traffic or weather conditions) may trigger a major activation of the car-

Fig. 5. Proposed contextual mediated model [21]. Reprinted from Accid Anal Prev 2003;35:949-64, with permission from Elsevier.



diovascular system. Our study on truck drivers showed an increase in heart rate and onset of supraventricular extrasystoles during conditions of traffic jams and fog [31]. In addition, the marked increase in urinary levels of thromboxane B_2 found in truck drivers at the end of the working-shift suggests that the stressful conditions of long distance driving might interact with the release of this modulator of platelet function [32].

In conclusion, among the human factors related to driving safety, some individual characteristics such as age and gender and lifestyle features such as alcohol and drug intake increase the risk of being involved in motor-vehicle crashes.

Young male subjects with particular personality traits (aggressiveness, sensation seeking) are likely to have aberrant driving behaviors (driving speed, violations, alcohol abuse) that increase the probability of road accidents.

A large proportion of traffic accidents can be ascribed to drowsiness or falling asleep that usually hit the driver in the early morning hours.

Among the factors affecting sleepiness, driver chronotype may influence driving safety, mainly at certain times of day, since individual variability related to the sleep-wake cycle has been associated with changes in performance rhythms. Although the large literature data on traffic accidents, the potential causative role of several factors overviewed in this paper (personality traits, chronotype and others) needs to be clarified in future researches.

A better understanding of the human factors affecting motor-vehicle accidents is required to adopt appropriate measures to increase driving safety.

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■ Received on June 17, 2005. Accepted on January 5, 2006.

■ This paper was presented at the *Fourth European Conference on Travel Medicine*, Rome, 29-31 March 2004.

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