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Driving under the influence of cannabis: Links with dangerous driving, psychological predictors, and accident involvement

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ABSTRACT

Driving under the influence of cannabis (DUIC) has become a growing concern. Studies investigating the impact of DUIC on traffic safety have shown evidence that, during the acute period of cannabis intoxication, cannabis diminishes driving faculties and is associated with an elevated risk of collision. However, DUIC drivers seem to exhibit a general reckless driving style that may contribute to an over-estimation of DUIC-related collisions among this group. In this study, we investigated DUIC drivers with respect to self-reported dangerous driving habits (e.g., risky driving, aggressive driving and negative emotional driving), behaviours observed in a driving simulator, psychological predictors and crash involvement. Results suggest that DUIC is associated with self-reported and observed risky driving and negative emotional driving. We also found that sensation seeking and impulsivity are independent psychological predictors of DUIC. Finally, a trend suggests that self-reported DUIC is associated with an increased risk of being involved in a car accident, after controlling for dangerous driving and demographic variables. Implications for interventions are discussed.

1. Introduction

Cannabis is the most frequent consumed illegal drug worldwide and its use appears to be increasingly common in many industrial and developing countries (Hall and Degenhardt, 2007; Patton and Adlaf, 2005; World Drug Report, 2007). Therefore, the detrimental social consequences related to cannabis consumption, such as the impact of the substance on driving skills and traffic safety, warrant serious consideration. Cannabis is the second most frequently found psychoactive substance found in body fluids of drivers involved in a collision after alcohol (Kelly et al., 2004). Furthermore, a trend suggests that the incidence of driving under the influence of cannabis (DUIC) is on the rise. For example, self-reported driving after using cannabis rose from 2.1% in 1988 to 4.8% in 2004 in Canada (Beirness and Davis, 2006).

1.1. Driving under the influence of cannabis and accident involvement

Experimental studies have shown that in the acute period of intoxication, cannabis negatively affects driving skills deemed necessary for safe driving. Laboratory research measuring basic cognition and psychomotor functions demonstrated that delta9 tetrahydrocannabinol (THC), the active metabolite of cannabis, induces dose-related decrements in short-term memory, divided attention and vigilance, reaction time, tracking, and coordination (Kurzthaler et al., 1999; Moskowitz, 1985; Sexton et al., 2000; Smiley, 1999). More ecologically valid research using driving simulators, in closed and open driving circuits, indicated that moderate and high concentrations of THC diminish the ability to maintain stable driving, as measured by deviation of lateral position and headway variability (reviews: Kelly et al., 2004; Ramaekers et al., 2004). A meta-analysis completed by Berghaus et al. (1995) indicated that cannabis-related impairment in cognition, psychomotor functions and driving performance is highest during the first hour following consumption. Experimental studies show that DUIC drivers are aware of the effects of cannabis impairments therefore they adopt compensatory behaviours such as lower speed and diminish lane changes (Smiley, 1999). It is not clear if those adaptive behaviours observed in laboratory settings can overcome deficits on real roads. For example, on monotonous roads and in situations were multiple behaviours need to be executed rapidly and simultaneously.

In the past, studies looking at the risk of collision associated with DUIC have yielded contradictory results. Moreover, according to Bates and Blakely (1999), methodological shortcomings in many studies make findings difficult to compare and interpret. However, recent epidemiological studies have shown that the presence of THC in a driver's body fluids is associated with an increased risk of being injured or killed in a road accident (Brault et al., 2004; Mura et al., 2003) and of being responsible for an on-road collision

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(Drummer et al., 2004; Laumon et al., 2005; Longo et al., 2000). Furthermore, results from a study using self-reported measures of accident involvement indicated that cannabis use is associated with an elevated risk of traffic crashes (Mann et al., 2007a).

1.2. Dangerous driving among cannabis users

Dangerous driving can be defined as deliberate deviations from safe driving (Malta, 2004). It includes a wide range of on-road violations, such as running red lights, speeding, dangerous overtaking, tailgating, among others. As all these behaviours are linked with accident involvement, they deserve attention from a traffic safety perspective (Blows et al., 2005). Dangerous driving is associated with demographic variables such as gender, age and driving exposure. Younger males tend to drive more dangerously in comparison with older drivers and females (Asbridge et al., 2003; Blows et al., 2005). Also, frequent exposure to driving, in terms of kilometers driven per year, is linked with more frequent manifestations of dangerous on-road behaviours (Harding et al., 1998; Wells-Parker et al., 2002).

Dangerous driving includes a broad variety of behaviours, which are often identified as aggressive driving. However, a single on-road behaviour may be triggered by different emotions and underlie distinct motivations and intentions. For example, dangerous overtaking may be employed as a means to show annoyance towards a slow driver (aggressive intention), and it can also serve to enhance high and intense sensations (risk-taking motivation). Therefore, Dula and Geller (2003) emphasized the need to establish distinct definitions of aggressive driving, negative emotional driving and risky driving. They developed a questionnaire, the Dula Dangerous Driving Index (DDDI; Dula and Ballard, 2003), in order to measure these three distinct constructs. They proposed that aggressive driving be defined as "any behaviour emitted by a driver while driving that is intended to cause physical and/or psychological harm to any sentient being." On-road overt aggressive behaviours are associated with an elevated collision risk (Mann et al., 2007b; Wells-Parker et al., 2002); these behaviours thus pose a serious concern for traffic safety. Furthermore, negative emotional driving is related to irritability and anger while driving and a tendency to become annoyed with other drivers. However, this emotional state does not necessarily translate into aggression (Galovski et al., 2006). Risky driving, on the other hand, denotes a careless style of driving and can be defined as deliberate on-road risk-taking not intended to harm other drivers. Risky driving differs from aggressive driving in the intent and the psychological function underlying the behaviour. Indeed, in contrast to aggressive driving, risky driving has been shown to be positively related with self-regulation tendencies aimed at escaping self-awareness and reducing tension, or in order to compensate for low self-esteem or to maintain a particular self-image (Richer et al., 2007). Most studies related to dangerous driving have used self-reported measures of driving behaviours. However, self-reports may suffer methodological weaknesses, such as memory bias and social desirability, and may share method variance with other self-reported questionnaires (Nesbit et al., 2007; Schwebel et al., 2006). Common method variance refers to a variance that is attributed to the measurement method and is observed when variables are measured with the same method. Share method variance may inflate artificially the true relationship between theoretical constructs (Lindell and Whitney, 2001). As a result, complementary methodologies for measuring dangerous driving, such as direct observation of behaviours on a driving simulator or driving logs, are warranted.

Previous studies indicate that cannabis consumption is correlated with dangerous on-road behaviours such as driving under the influence of alcohol (DUIA), inadequate use of the seat belt (Everett et al., 1999) and speeding (Vassallo et al., 2008). Furthermore, there is evidence that cannabis use predicts verbal expressions of anger while driving (Butters et al., 2005). Since DUIC appears common among cannabis users (Fischer et al., 2006; Ogborne and Smart, 2000), it may be part of a general deviant lifestyle including dangerous driving. Collision-related behaviours, such as driving under the influence of drugs or alcohol, speeding, and dangerous overtaking, tend to covary (Shope and Bingham, 2002). Researchers have suggested that dangerous driving represents a single factor defined as a "general driving problem" associated with a risky lifestyle (Fergusson et al., 2003; Jessor, 1986; Jonah, 1990). It would therefore be interesting to verify whether DUIC is associated with different manifestations of dangerous driving, such as aggressive driving, negative emotional driving or risky driving. The driving problem behaviour theory, an extension of the *problem behaviour theory* (Jessor et al., 1991), explains that these dangerous driving behaviours serve similar psychological functions and have common psychosocial risk factors (Jonah, 1990). As mentioned by Jonah (1990), the driving problem behaviour theory was first developed in order to explain interrelations between deviant behaviours in adolescents; however, this conceptual framework does have relevance for understanding problem driving behaviours in young adults. Indeed, longitudinal studies have shown continuation of problem behaviours from adolescence into young adulthood (Bingham and Shope, 2004; Jessor et al., 1991). Few studies have supported the problem driving behaviour theory with samples including middle-aged adults (Galovski et al., 2006).

Individuals driving under the influence of cannabis seem to exhibit a general dangerous driving style, which puts them at a higher risk of being involved in traffic crashes (Bédard et al., 2007; Everett et al., 1999; Fergusson and Horwood, 2001). For this reason, it is necessary to control for dangerous driving habits when assessing the association between DUIC and accident involvement. Many studies failed to control for this confounding factor; therefore, the role of cannabis consumption in traffic collisions is unclear and the causal link between cannabis and traffic crashes remains to be established.

1.3. Psychological and demographic predictors of driving under the influence of cannabis

Evidence from the literature indicates that DUIC is associated with gender and age. Indeed, young men are more likely to drive under the influence of cannabis than are young women (Beirness and Davis, 2006; Jones et al., 2007). Also, previous studies have shown that DUIC is related to psychological correlates. Self-reported driving within 6 h of taking drugs has been found to be moderately correlated ($r = .24$) with sensation seeking (Armstrong et al., 2005), which refers to the desire for engagement in varied, novel, complex, and arousing sensations and experiences (Zuckerman, 1994). Also, low self-constraint in late adolescence, which includes dimensions of personality related to impulsivity, as measured by the Multidimensional Personality Questionnaire (Patrick et al., 2002), is associated with persistent driving of a car within 2 h of using cannabis in males between ages 18 and 26 (Begg et al., 2003; Gulliver and Begg, 2007). However, to our knowledge, no previous studies have investigated the relative contribution or the multiplicative effect of these personality factors in the prediction of DUIC. Personality characteristics influence the way people drive and are predictors of collision-related behaviours (Dahlen et al., 2005; Schwebel et al., 2006). It is therefore important to take personality into account when conceptualizing preventive interventions, as it can affect the outcome of an intervention. Moreover, by defining high-risk personality profiles, it is possible to identify individuals who are more likely to drive under the influence of cannabis and, in turn, tailor intervention programs to be more effective among those individuals.

1.4. Objectives and hypotheses

This study aims at investigating the relationship between self-reported DUIC and dangerous driving by means of self-reported measures and direct observations made in a driving simulator. It was hypothesized that DUIC would be a significant predictor of various forms of dangerous driving (i.e., risky driving and aggressive driving) even after controlling for age and driving exposure. We also looked at whether DUIC was associated with negative emotional driving; however, no specific hypothesis could be drawn from the research literature. A second objective was to verify the relative contribution of sensation seeking, impulsivity, age and driving exposure in the prediction of DUIC. It was hypothesized that sensation seeking and impulsivity would be significantly and positively associated with DUIC, and that age would be significantly and negatively associated with DUIC. No specific hypothesis could be made on the relationship between driving exposure and DUIC. Finally, the relationship between DUIC and the probability of being involved in a collision while controlling for potential confounding variables (i.e., age, driving exposure, dangerous driving, and driving under the influence of alcohol) was examined. Given that previous studies conducted on the link between DUIC and traffic crashes have produced inconsistent results, the last objective was explorative.

2. Method

2.1. Sample

In total, 83 men took part in the study. Only men were recruited, as men tend to be more often involved in dangerous driving and/or DUIC than women (Beirness and Davis, 2006; Blows et al., 2005). Due to missing data or uncompleted tasks, analyses were performed on a total of 72 participants for driving simulation tasks and 75 participants for self-reported dangerous driving behaviours measured by the DDDI. Inclusion criteria required that participants hold a valid driver's license issued by the province of Quebec and drive at least once a week. These prerequisites were necessary to ensure knowledge homogeneity of the Quebec Highway Safety Code and a minimum driving exposure among participants. The mean age of the sample was 27 years old (S.D. = 8.4, range 17–49). The sample was composed primarily of students (53%), but 39.8% were workers and 7.2% were unemployed at the time of the study. As regards level of education, 26.5% had an undergraduate degree, 42.2% a college diploma and 30.1% a high school diploma; one lone participant had only finished elementary school. In terms of driving exposure, 15.7% averaged less than 5000 km/year, 28.9% between 5000 and 10 000, 30.1% between 10 000 and 20 000 km/year, 20.5% between 20 000 and 40 000 km/year, and 4.8% over 40 000 km/year.

2.2. Measures

2.2.1. Driving under the influence and substance use scales

Cannabis consumption was measured by the relative frequency of cannabis use over the previous 12 months. Answers were based on a seven-point Likert scale ranging from 0 for "never" to 6 for "everyday". DUIC was measured by the relative frequency of driving in the hour following smoking cannabis over the previous 12 months. The 1-h time frame was chosen because studies have demonstrated that cannabis intoxication is highest during this period (Berghaus et al., 1995). Answers were given on a five-point Likert scale ranging from 1 for "never" to 5 for "always". Driving under the influence of alcohol was measured by the number of times a participant, over the course of the previous 3 years, had driven a car when he thought that perhaps he had consumed too much alcohol to be able to drive safely.

2.2.2. Personality scales

The French version of the *NEO Personality Inventory-Revised* (NEO-PI-R) (Rolland et al., 1998) was used. This scale is a self-report inventory based on the five-factor model of personality and is well validated cross-culturally. Responses are recorded on a five-point Likert scale ranging from "strongly disagree" to "strongly agree". For the purpose of the study, the impulsivity facet from the neuroticism construct was used. In this study, this measure presents a satisfying internal consistency ($\alpha = 0.63$). The construct of impulsivity from the NEO-PI-R refers to the "tendency to act on cravings and urges rather than reining them in and delaying gratification (Costa and McCrae, 1992)." Only the impulsivity facet was used instead of the broad domain of neuroticism in order to predict DUIC. According to Paunonen (1998), using aggregate personality facets such as the NEO-PI-R neuroticism construct instead of specific traits in order to predict behaviours reduces predictive accuracy.

Sensation seeking was assessed with the French version of the *Sensation Seeking Scale Form V* (SSS-V) (Bergeron and Prud'homme, 1999; Zuckerman, 1994). This self-report scale is composed of 40 items measured with dichotomous choice and yields four constructs: boredom susceptibility, disinhibition, thrill and adventure seeking, and experience seeking. For the purpose of the study, the overall score was used. The total scale presented an excellent internal consistency ($\alpha = 0.82$).

2.2.3. Driving habits and dangerous driving scale

The *Dula Dangerous Driving Index* (Dula and Ballard, 2003) was developed to measure the frequency of dangerous driving based on drivers' self-reported driving behaviours and emotions while driving. Responses were made on a five-point Likert scale ranging from 1 for "never" to 5 for "always". The scale yields a total score in addition to three sub-constructs: aggressive driving, negative emotional driving and risky driving. The French version of the scale, developed by the authors of the present paper, was found to have good internal consistency for each construct as well as for the total score: aggressive driving ($\alpha = 0.74$), negative emotional driving ($\alpha = 0.80$), risky driving ($\alpha = 0.76$), and dangerous driving total score ($\alpha = 0.88$).

Self-reported number of traffic collisions involving at least material damage occurring in the previous 3 years was also noted. The 3-year period was selected in order to limit memory bias and to ensure enough variance, as accidents are rare events (Elander et al., 1993).

2.2.4. Dangerous driving measures observed on the driving simulator

The maximum speed reached on the driving simulator was used as an observed measure of dangerous driving. Speeding is one of the most common on-road behaviours leading to traffic crashes and represents 72% of traffic violations in the province of Quebec (Société de l'assurance automobile du Québec, 2006). Dangerous driving was also measured by an aggregate score of behaviours demonstrated by participants in the driving simulator. The aggregate score included tailgating, dangerous overtaking, and omitting a stop. All these behaviours are identified in literature as dangerous driving (Blows et al., 2005).

2.2.5. Demographic variables

Participants completed a questionnaire assessing socio-demographic variables such as age, education level and occupation. Driving exposure was measured by the relative annual mileage in kilometers on a five-point scale which yielded the following distribution: (1) less than 5000 km/year; (2) between 5000 and 10 000 km/year; (3) between 10 000 and 20 000 km/year; (4) between 20 000 and 40 000 km/year; (5) more than 40 000 km/year.

2.3. Procedure

Informed consent was obtained from each participant before beginning the tasks of the study. A brief description of the study was given and confidentiality of all information and observations gathered was assured. Each participant was administered self-report questionnaires and asked to complete tasks in a driving simulator. At the end, participants were debriefed and awarded $30.00 in compensation. Participants completed tasks in a fixed-based driving simulator designed to conduct research on road safety (Baumberger et al., 2007; Bergeron et al., 2001, 2002; Thiffault and Bergeron, 2003). It consisted of a Honda Civic placed in the centre of a room facing a (3 m by 2.45 m) curved screen. A projector was used to display an interactive virtual driving environment on the screen. The environment consisted of a straight road viewed in perspective with lane division lines. Surrounding scenery consisted of grass, bushes, tress and houses. The entire simulator controls (steering wheel, gas and brake pedals) and indicators (speed) were fully operational and interactive. The simulator was also equipped with a vibration device and sound system designed to enhance the participants' driving experience.

2.3.1. Practice condition

Participants were first asked to drive for about 10 min to become familiar with handling the simulator in the interactive environment. Participants encountered intersections and road signs and markings, but no specific responses were requested of them during the trial run.

2.3.2. Condition T1

In condition T1, participants were asked to drive in the same environment as during the practice run, but an "intelligent" vehicle was positioned ahead of the participant's car in the virtual environment. The "intelligent" vehicle was programmed to decelerate when participants were behind, as a way to slow them down, and to accelerate when participants were trying to pass. No specific response was asked of participants during this trial. Dangerous driving was measured by the maximum speed reached during the trial. This measure represents a natural tendency for speeding.

2.3.3. Condition T2

Time pressure constitutes the main situational factor inducing aggressiveness among drivers (O'Brien et al., 2004; Shinar, 1998). Consequently, time pressure was added in T2 condition. Participants were told that they had to make it to a bogus meeting on time. Time pressure came in the form of a message at the top of the screen. The message indicated to participants that they were late in completing the task and appeared when participants were confronted with the "intelligent" vehicle. The experimenter observed dangerous driving behaviours by means of a detailed checklist listing tailgating, illegal overtaking in the left lane, overtaking in the right lane, and omitting a stop.

3. Results

This section presents inter-correlations and descriptive statistics of main variables, followed by relationships between dangerous driving and DUIC. As well, correlations between self-reported measures of dangerous driving and behaviours observed in the driving simulation tasks are presented. Results related to psychological and demographic predictors of DUIC are further reported and, finally, the association between DUIC and accident involvement is presented.

3.1. Correlations between self-reported dangerous driving and driving under the influence of cannabis

In total, 30 participants were cannabis users, 80% of whom reported at least one incidence of DUIC in the previous 12 months. The mean age of DUIC drivers was 24.13 (standard deviation [S.D.] = 6.67, range 19–45), which was younger than the mean age of the total sample. Two-tailed Pearson product-moment correlations showed that DUIC was significantly and negatively associated with age ($r(83) = -0.23$, $p < 0.05$). Therefore, age was statistically controlled in all analyses associated with DUIC. Inter-correlations between main self-reported variables are presented in Table 1. DUIC was found to be significantly and positively linked to risky driving ($r(75) = 0.42$, $p < 0.01$), negative emotional driving ($r(75) = 0.27$, $p < 0.05$), dangerous driving total score ($r(75) = 0.32$, $p < 0.01$), DUIA ($r(83) = 0.25$, $p < 0.05$), sensation seeking ($r(83) = 0.50$, $p < 0.01$) and impulsivity ($r(83) = 0.29$, $p < 0.01$). Finally, DUIC was not significantly correlated with the DDDI aggressive driving subscale. Table 2 presents descriptive statistics and internal consistency for all key variables.

3.2. Hierarchical regression analyses predicting dangerous driving

Hierarchical linear regression analyses using the "enter" method were performed in order to verify whether DUIC adds a significant contribution, beyond age and driving exposure, in predicting aggressive driving, negative emotional driving, risky driving and dangerous driving. These variables were controlled because of their theoretical and actual association with dangerous driving subscales and the total score, as well as DUIC (Asbridge et al., 2003; Blows et al., 2005; Wells-Parker et al., 2002). In all regression models, age and driving exposure were entered in Step 1, and DUIC was entered in Step 2.

Results indicated that driving exposure is a significant predictor of aggressive driving ($\beta = 0.38$, $p < 0.01$) and negative emotional driving ($\beta = 0.30$, $p < 0.01$). Furthermore, negative emotional driving

Table 1
Inter-correlations among all self-reported variables.

Variables	1	2	3	4	5	6	7	8	9	10
(1) Age	–									
(2) Driving exposure	0.30**	–								
(3) Cannabis use	−0.22*	−0.13	–							
(4) DUIC	−0.23*	−0.12	0.86**	–						
(5) DUIA	−0.08	0.12	0.21	0.25*	–					
(6) Risky driving DDDI	−0.19	−0.03	0.27*	0.42**	0.43**	–				
(7) Aggressive driving DDDI	0.03	0.35**	−0.03	0.07	0.18	0.43**	–			
(8) Negative emotional driving DDDI	−0.13	0.20	0.13	0.27*	0.27*	0.68**	0.56**	–		
(9) Dangerous driving total score DDDI	−0.13	0.19	0.16	0.32**	0.36**	0.87**	0.75**	0.90**	–	
(10) Sensation seeking	−0.42**	−0.27*	0.53**	0.50**	0.12	0.37**	0.09	0.37**	0.35**	–
(11) Impulsivity	−0.02	0.18	0.18	0.29**	0.26*	0.43**	0.13	0.19	0.32**	0.05

* $p < 0.05$.
** $p < 0.01$.

Table 2
Descriptive statistics and internal consistency of principal variables.

Variables	*n*	*N* items	Range	α	*M*	S.D.
Self-reported variables						
Cannabis use	83	1	0–6		1.12	1.8
DUIC	83	1	1–5		1.67	1.16
DUIA	83	1	0–10		0.77	1.84
Traffic crashes	83	1	0–3		0.48	0.75
Dangerous driving DDDI						
Risky driving	75	12	1–5	0.76	20.04	5.55
Aggressive driving	75	7	1–5	0.74	12.83	4.02
Negative emotional driving	75	9	1–5	0.80	21.1	5.02
Dangerous driving	75	28	1–5	0.88	53.96	12.34
Personality variables						
Sensation seeking	83	40	0–1	0.82	20	6.4
Impulsivity	83	8	1–5	0.63	23.55	4.9
Observed variables						
Behaviours observed on the driving simulator						
Maximum speed T1 (km/h)	72	1	59–183		93.03	17.37
Aggregate score T2	72	3	0–9		2.33	2.69

Table 3
Hierarchical regression analyses ($n = 75$).

Variables	Aggressive driving DDDI				Negative emotional driving DDDI			
	β	t	R^2	ΔR^2	β	t	R^2	ΔR^2
Step 1								
Age	−0.07	−0.6			−0.17	−1.46		
Driving exposure (km/year)	0.38	3.3**	0.13		0.3	2.52**	0.085	
Step 2								
DUIC	0.1	0.91	0.14	0.01	0.27	2.44**	0.15	0.07*

* $p < 0.05$.
** $p < 0.01$.

was predicted by DUIC ($\beta = 0.27$, $p < 0.01$), which contributed significantly to total variance (ΔR^2 0.07, $p < 0.05$), beyond age and driving exposure (see Table 3).

Risky driving was associated with DUIC ($\beta = 0.40$, $p < 0.01$) even after controlling for demographic variables. DUIC predicted a significant part ($\Delta R^2 = 0.15$, $p < 0.01$) of the risky driving subscale. Finally, dangerous driving was predicted by driving exposure ($\beta = 0.27$, $p < 0.01$) and DUIC ($\beta = 0.33$, $p < 0.01$), which contributed greatly ($\Delta R^2 = 0.10$, $p < 0.01$) to the observed variance (see Table 4).

3.3. Correlations between observed behaviours and self-reported measures

The behaviours observed in the T2 condition (i.e., tailgating, dangerous overtaking and omitting a stop) were analysed using the method of principal component analysis, to create an aggregate score of dangerous driving. A single factor (Eigen Value = 1.83) could be extracted, which explained 61.3% of total variance. The construct validity of behavioural measures was tested by correlating maximum speed in the T1 condition and the aggregate score in the condition T2 with self-reported measures of dangerous driving. The correlations presented in Table 5 show an association between maximum speed in the T1 condition and risky driving ($r(72) = 0.46$, $p < 0.01$), negative emotional driving ($r(72) = 0.46$, $p < 0.01$), and the DDDI total score ($r(72) = 0.46$, $p < 0.01$). The aggregate score of dangerous driving in the T2 condition was marginally associated with aggressive driving and negative emotional driving. Furthermore, the aggregate score was significantly correlated with risky driving ($r(72) = 0.27$, $p < 0.05$) and the DDDI total score ($r(72) = 0.30$, $p < 0.05$). The results suggest that people who admit more to committing dangerous driving behaviours in real life reached higher maximum speed and demonstrated more dangerous driving behaviours on the driving simulation tasks. The strength of correlations between self-reports and observed behaviours is higher for maximum speed than for the aggregate score of dangerous behaviours. The low number of behaviours observed in T2 might have induced a lack of variance, affecting the analyses.

Table 4
Hierarchical regression analyses ($n = 75$).

Variables	Risky driving DDDI				Dangerous driving DDDI			
	β	t	R^2	ΔR^2	β	t	R^2	ΔR^2
Step 1								
Age	−0.13	−1.1			−0.15	−1.29		
Driving exposure (km/year)	0.06	0.57	0.03		0.27	2.40**	0.07	
Step 2								
DUIC	0.40	3.71**	0.19	0.15**	0.33	2.96**	0.17	0.10**

* $p < .05$.
** $p < .01$.

Table 5
Two-tailed Pearson product-moment correlations ($n = 72$).

Variables	Maximum speed T1	Aggregate score T2
Cannabis use	0.25*	−0.03
DUIC	0.24*	0.04
DUIA	0.10	0.15
Dula dangerous driving index		
Risky driving	0.46**	0.27*
Aggressive driving	0.19	0.23†
Negative emotional driving	0.46**	0.23†
DDDI total score	0.46**	0.30*
Individual differences		
Sensation seeking	0.34**	−0.03
Impulsivity	−0.02	−0.07

* $p < 0.05$.
** $p < 0.01$.
† $p < 0.10$.

Cannabis use ($r(72) = 0.25$, $p < 0.05$) and DUIC ($r(72) = 0.24$, $p < 0.05$) were related to maximum speed in the T1 condition. These findings corroborate the associations between DUIC and self-reported risky driving. Sensation seeking was also related to maximum speed in the T1 condition ($r(72) = 0.34$, $p < 0.01$). Other correlations were not statistically significant (see Table 5).

3.4. Predictors of driving under the influence of cannabis

A hierarchical linear regression analysis using the "enter" method was performed in order to distinguish specific predictors and their relative contribution to self-reported DUIC (see Table 6). Age and driving exposure were entered in Step 1. Thereafter, psychological predictors, sensation seeking and impulsivity were included in the model followed by the interaction term between the two variables. The purpose of this analysis was to verify whether individuals scoring high on sensation seeking and impulsivity might drive more frequently under the influence of cannabis than individuals who scored high on only one of the personality determinants. The final model was statistically significant ($F(5, 77) = 8.10$, $p < 0.01$) and accounted for 32% ($R^2 = 0.32$) of total variance. The interaction effect between sensation seeking and impulsivity was not significant, suggesting that individuals who score high on either of these personality factors would drive more frequently under the influence of cannabis than individuals who report lower scores on sensation seeking and impulsivity scales. Among psychological traits, sensation seeking appeared to be a more important predictor of DUIC ($\beta = 0.44$, $p < 0.01$) than impulsivity ($\beta = 0.23$, $p < 0.05$).

3.5. Predictors of accident involvement

In total, 35% of the sample ($n = 29$) reported one or more road crashes involving at least material damage in the previous 3 years. Accident involvement presented a skewed distribution; therefore, this variable was dichotomized (0 = absence; 1 = presence). A logistic regression was conducted in order to verify the relative risk of collision for DUIC while adjusting for confounding effects of age, driving exposure, dangerous driving, and driving under the influence of alcohol (see Table 7). The model was statistically significant ($\chi^2(5) = 11.49$, $p < 0.05$), but it presented a modest adjustment (R^2 Nagelkerke = 0.20). Results showed that driving exposure was positively associated with accident involvement (odds ratio [OR] = 1.81; 95% confidence intervals [95% CI] = 1.06–3.08, $p < 0.05$), whereas age was marginally negatively associated with the outcome variable (OR = 0.93; 95% CI = 0.86–1, $p = 0.08$). Neither dangerous driving nor DUIA was a significant predictor of self-reported traffic crashes. DUIC was associated with an increased risk of traffic collisions (OR = 1.58; 95% CI = 0.98–2.54, $p = 0.06$); however, the association was marginally significant. This trend suggests that DUIC may constitute a risk factor for accident involvement after controlling for confounding factors.

4. Discussion

To our knowledge, this is the first study to investigate the association between DUIC and a wide range of dangerous driving behaviours including risk-taking and aggressive reactions on the road. The results show that self-reported DUIC is related to self-reported risky driving, negative emotional driving, and dangerous driving measured by the DDDI. Indeed, DUIC explains a significant part of construct variance, even after controlling for age and driving exposure. Also, DUIC is positively correlated with DUIA. The association between self-reported DUIC and speeding observed in a driving simulation task corroborates findings based on self-reports. However, the correlation between DUIC and self-reported risky driving

Table 6
Predictors of driving under the influence of cannabis ($n = 83$).

Variables	b	SE	β	t	R^2	ΔR^2
Step 1						
Age	−0.006	0.01	−0.04	−0.41		
Driving exposure (km/year)	−0.04	0.10	−0.04	−0.39	0.05	
Step 2						
Sensation seeking	0.08	0.02	0.44	4.27**		
Impulsivity	0.05	0.02	0.23	2.38*	0.32	0.26**
Step 3						
Interaction sensation seeking × impulsivity	0.005	0.003	0.15	1.55	0.34	0.02

* $p < 0.05$.
** $p < 0.01$.

Table 7
Logistic regression analysis predicting accident involvement ($n = 75$).

Variables	b	Standard-error	p	Odds ratio	Confidence intervals (95%)
Age	−0.068	0.04	0.08	0.93	0.86–1
Driving exposure (km/year)	0.6	0.27	0.03	1.81	1.06–3.08
Dangerous driving DDDI	0.006	0.02	0.79	1	0.96–1.05
DUIA	−0.24	0.18	0.19	0.78	0.55–1.13
DUIC	0.47	0.24	0.06	1.58	0.98–2.54

is higher than the direct observation of risky driving by speeding in the driving simulator. This finding may be caused by a shared method error between self-reported measures. It is also possible that risky driving was more accurately assessed by the DDDI with the inclusion of multiple manifestations of on-road risk-taking, in comparison with the single behaviour of speeding observed in the driving simulator. Taken together, these results indicate that self-reported DUIC is associated with a risky driving style, including a broad range of dangerous on-road behaviours, and they support the problem driving behaviour theory (Fergusson et al., 2003; Jessor, 1986; Jonah, 1990) and give support to the initial hypothesis. Studies conducted in order to verify this problem behaviour syndrome mainly used samples of adolescents and young adults. In the present study, the mean age of participants was 27 years old, but ranged from 17 to 49, and we observed that dangerous driving behaviours were interrelated. These results suggest that some middle-aged men may also exhibit a deviant driving style that may be explained by problem driving behaviour theory. Future studies should investigate whether psychological functions and psychosocial risk factors related to proneness to problem driving behaviour are similar among older individuals as compared with adolescents and young adults.

The results showed an association between DUIC and self-reported negative emotional driving, but not one with aggressive driving. Therefore, the hypothesis asserting that DUIC is positively related to aggressive driving could not be corroborated. DUIC drivers reported higher levels of anger while driving; nevertheless, they do not admit to being more aggressive towards other drivers. These results support previous studies showing that anger on the road does not always lead to aggressive driving (Galovski et al., 2006). However, these findings partially contradict results obtained by Butters et al. (2005), who indicated that verbal manifestations of aggressive driving is significantly linked with cannabis use. Differences between aggressive driving measures may have contributed to this inconsistency. The aggressive driving construct included in the DDDI yields only one item regarding verbal aggressiveness towards other drivers. These results demonstrate the need to maintain a consistent definition and measure of the aggressive driving concept among scholars.

The second objective of this study was to verify the relative contribution of age, driving exposure, sensation seeking and impulsivity in the prediction of DUIC. The interaction between sensation seeking and impulsivity was also considered. The results showed that, beyond age and driving exposure, both sensation seeking and impulsivity are psychological predictors of DUIC, supporting the hypothesis. These personality factors have an independent contribution in explaining self-reported driving under the influence of cannabis; however, sensation seeking seems to be a more important factor. Thus, individuals scoring high on sensation seeking or impulsivity show an elevated risk of driving under the influence of cannabis. These findings corroborate the literature on psychological predictors of driving under the influence of drugs (Armstrong et al., 2005; Begg et al., 2003; Gulliver and Begg, 2007) and confirm the importance of considering sensation seeking and impulsivity when intervening with DUIC drivers. Age is negatively correlated with DUIC, supporting the fact that younger drivers will drive after consuming cannabis more often than do older drivers (Adlaf et al., 2003; Beirness and Davis, 2006; Walsh and Mann, 1999). However, when entered in the regression model, neither age nor driving exposure is a significant predictor of DUIC. This result may be due to the inter-correlation between age and sensation seeking or to a lack of statistical power.

The final objective consisted in verifying whether DUIC is associated with an elevated risk of traffic crashes after controlling for identified confounding factors. The findings showed that heavier driving exposure is associated with an increased risk of collision. This particular result supports previous knowledge regarding predictors of on-road accidents (Summala, 1996). Furthermore, age was marginally negatively associated with accidents. Thus, younger drivers tended to be more at risk for involvement in a collision. This trend is consistent with previous knowledge on demographic predictors of traffic crashes (Evans, 1987; Mayhew et al., 2003). Furthermore, results show no relationship between DUIA and traffic crashes. DUIA has been largely sanctioned by authorities and has received substantial attention from mass media interventions. Attitudes towards DUIA are generally very negative; thus, this behaviour is associated with strong social desirability. Also, self-reported measures assessing DUIA have been found to be unreliable (Bond and Cherpitel, 2004; Chang and Lapham, 1996). Given these facts, it is possible that participants underreported DUIA episodes, contributing to the lack of association with collision involvement. In this study, dangerous driving, measured with the DDDI, was also not associated with self-reported accidents. The DDDI total score is in part composed of risky driving and negative emotional driving, which are not always associated with traffic crashes. Indeed, risky drivers might also have good driving skills and reflexes and therefore avoid collisions (Zuckerman, 2007). A trend suggests that, beyond confounding factors, DUIC is a risk factor for traffic collisions involving at least material damages. Even if the odd ratio associated with DUIC (OR = 1.58; 95% CI = 0.98–2.54) is not statically significant ($p < 0.05$), this result is consistent with previous findings that self-reported DUIC is a risk factor for motor vehicle accidents (Mann et al., 2007a). However, this result does not shed light on the specific effect of cannabis on driving skills, nor does it suggest a causal link between DUIC and collisions.

4.1. Implications and applications of findings

Self-reported DUIC is associated with specific personality determinants, namely sensation seeking and impulsivity. This allows for propositions to be made with respect to adapting intervention strategies for DUIC drivers. Media campaigns promoting traffic safety tend to emphasize rational decision-making processes involved in driving. However, personality factors such as sensation seeking and impulsivity can modulate these cognitive processes, leading high-risk individuals to be insensitive to such interventions. Based on the individual difference model of information exposure, high sensation seekers tend to be more receptive and more attentive to messages with high sensation value or inducing high stimulation (Donohew et al., 2000). Clearly, intervention messages addressed to high sensation seekers should include an arousing and unconventional format. Impulsive individuals tend to make decisions on the basis of affective and physiological cues. This kind of “irrational” decision-making may lead to risk-taking such as DUIC. In order to target impulsive individuals, interventions should focus on a very simple sequence of behaviours which must become automatic; in this way, rational thinking would not be necessary to achieve these behaviours. However, for impulsive and high sensation seekers, this kind of behavioural skills intervention can become redundant and boring. It is therefore important to strike a balance between arousing and educational messages. Finally, on-road risky behaviours tend to be inter-correlated, so interventions should focus on a broad range of dangerous behaviours.

4.2. Strengths and limitations

This study’s strength lies in the multi-faceted approach used to measure dangerous driving that is self-reported questionnaires and direct observation of behaviours in a driving simulator. Most traffic safety studies investigating dangerous driving used only retrospective self-reported measures. However, self-report scales are sensitive to recall biases, misreporting, and they share measure error with other self-report measures (Schwebel et al., 2006). Although this study provides interesting results, it has limitations that demand consideration. A larger sample size would have increased statistical power; therefore, analyses that did not reach statistical significance at a 95% confidence level may have done so with additional cases. Furthermore, due to the sample size and recruitment method, the sample cannot be labelled as representative of the entire studied population. The sample included men only and, although they varied widely in age, occupation and level of education, future research should include both men and women and investigate gender differences. Collision involvement was assessed by retrospective self-reported number of traffic crashes. Measuring this variable by official records would have increased the validity of the measure. The study was based on cross-sectional self-reported data. Therefore, it is impossible to assume causality between accident involvement and studied predictors. The DUIC measure represents another limitation. The question asked to participants was stated as follows: "How often did you drive within the hour following cannabis use in the past 12 months?" Clearly, this measure does not control for the concomitant use of other substances. Finally, behaviours observed on driving simulation tasks may lack in ecological validity. Nevertheless, in this study, associations between self-reported real-life driving and observed behaviours support the validity of these measures.

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