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Effects of stimulant and opiate drugs on driver behavior during lane change in a driving simulator

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ABSTRACT

The fact that alcohol use impairs driving has been known since many years ago; however, the influence of other drugs on driving behavior is rather new. Driving behavior under the influence of amphetamine and opium has not been fully explored yet. Some researchers have shown that such drivers suffer from an incorrect estimation of distance to the lead vehicle, high risk-taking, and high lateral position deviation.

In this paper, the subjects were categorized in three groups: stimulant-drug users; opiate-drug users; and non-drug users. 6 amphetamine-user drivers (average 25 years old in the range of 22–35), 6 opium-user drivers (average 32 years old in the range of 22–45), and 6 non-drug users (average 27 years old in the range of 22–35) were tested in the CI003 driving simulator.

They drove in lane-changing scenario. The values of the mean absolute value of the steering wheel angular velocity, integral of path curve, the mean absolute value of the transverse velocity of the vehicle in the lateral direction, The average and standard deviation of duration of lane-changing and the minimum lateral acceleration of optimized Bezier curve were computed in lane-changing scenario.

For classifying of these groups, we decided to use artificial neural network to separate features. An artificial neural network with higher than 83% of accuracy was trained to distinguish the features.

1. Introduction

The European Monitoring Centre for Drugs and Drug Addiction estimates that 5% of people in Europe and 0.1–15.3% of people in other countries use amphetamine permanently. Amphetamines are a group of brain stimulants in the form of white powder or brownish white. They are associated with neurotransmitter norepinephrine, epinephrine, and dopamine. They are also known as imitative sympathetic drugs or stimulants of the central nervous system.

Amphetamines include methylphenidates, dextroamphetamines, and methamphetamines (Kim et al., 2013). These drugs enter the central nervous system causing a sudden release of chemical dopamine mediators of the brain (Kleijn et al., 2012). It stimulates brain cells (Zhou et al., 2010), disrupts depth perception, reaction time, and attention, increases self-confidence in exaggerated form, intensifies aggressiveness and uncontrollability (Cherek et al., 1987), and causes an increase in physical movements and the focus (Silber et al., 2012). Consumption of these drugs aggravates the risk of driving. There are significant relationship between using amphetamines and risky driving and occurrence of accidents (Mura et al., 2006; Mørland et al., 2011), as amphetamine users tend to undertake high risks (McIntosh et al., 2008; Soderstrom et al., 2001) due to impaired judgment (Vaez and Laflamme, 2005).

Opiate drugs reduce the sensitivity of the Central Neural System (CNS). Opiates are mimic endogenous opioid peptides (endorphins). Various effects of opiates include inhibition of response to painful stimuli, memory loss, and hallucination. Narcotics are those substances that act on opioid receptors. Some people use opiates because of analgesic effects, which are medically and legally prescribed, and some others abuse them without medical prescriptions. In both cases, the risk factor for driving is increased.

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There are some conventional methods to examine drivers via common drug tests (Mieczkowski, 2010). They include oral fluid screening tests (Zancanaro et al., 2012; Wille et al., 2010) and urine tests (Nakanishi et al., 2012). However, these tests have many disadvantages; they are intrusive and unreliable. For instance, drinking vinegar causes incorrect results (Jaffee et al., 2007). Thus, it is essential to develop nonintrusive and reliable monitoring methods for detecting drug-using drivers.

Driving simulators have become popular for detection and evaluation of addicted drivers (Stough et al., 2012). Driving simulators have three advantages such as: (a) Evaluation of risky behavior of addicted drivers in a safe environment; (b) A controlled environment for conducting experiments with adequate excitation signals and few disturbance inputs; (c) Availability of precise measurement instruments such as steering wheel angle encoders and pedal potentiometers.

There are several research works, e.g. (Dastrup et al., 2010), based on car following scenarios to identify and assess the behavior of drug-addicted drivers. The current paper has three advantages over the previous works: (a) the previous papers have used only car following scenarios for analysis. We have added lane change scenario to obtain high precision in algorithm; (b) Most papers have used statistical approaches to analyze drug addiction, but this paper applies model-based and feature-based methods simultaneously; (c) In the previous research works, healthy subjects were tested once in a state of one-time drug use (amphetamine or opium), and once again in the normal state of no-drug use. But, in this paper, subjects with a long history of drug addiction have been tested. Conducting experiments on such subjects guarantees that the long-term effects of addiction are considered. Healthy subjects, who use amphetamine or opiate drugs just for the test, do not necessarily behave similar to long-time addicts; (d) this paper studies both stimulant and opiate drugs.

Our subjects are classified in three groups of amphetamine, opium, and non-drug users. We know about the exact amount of their daily consumption and even their consumption hour by self-reported questionnaires and also the medical records in their therapy institute – Congress 60 Human Revivification Society (Congress 60). To isolate the driving pattern of the subjects, a driving scenario is designed in order to show the effects of these drugs on driving behavior. The scenario used in this paper is lane change. The subjects are asked to drive on a lane-changing scenario in the driving simulator. A few variables such as time, longitudinal and lateral position, longitudinal and lateral velocity, and the steering wheel angle are measured. These variables are analyzed by feature-based and model-based methods and finally the driving patterns of these groups are identified.

In Section 2, the theoretical model of lane-changing features are mentioned. In Section 3, specifications of the driving simulator used as the experimental setup and also the design procedure of the lane-changing scenario are presented. In Section 4, test results are illustrated and the paper is concluded in Section 5.

2. Lane-changing features

Lane-changing maneuver is a movement from one lane to another in the same direction to create more freedom for drivers (Naseri et al., 2015). Driving style plays a major role in performing lane-changing maneuver. The three driver groups studied in this paper, *i.e.* stimulant-drug users, opiate-drug users, and non-drug users, exhibit distinguishable paths throughout the maneuver.

The lane-changing maneuver consists of two phases. The first phase starts from the moment the driver starts to turn the steering wheel and ends at the maximum heading angle of the vehicle. The second phase starts from the end of the first phase and ends when the wheel angle returns to zero. Note that the maximum steering wheel angle occurs before the end of phase 1.

There are at least three parameters in the lane-changing maneuver for classifying drivers in terms of their drug use.

The first parameter is the timing interval between these two events: (a) The moment a driver feels less space for her/his freedom; (b) The moment s/he starts to change lane. This interval is representative of driver's patience (Naseri et al., 2015) .

The second parameter is the time headway between the driver's vehicle and the lead vehicle at the onset of lane change (Naseri et al., 2015). This parameter is representative of driver's caution.

The third parameter is how aggressive the driver changes lane. This parameter is summarized in driver's mean absolute longitudinal and lateral acceleration during maneuver. To calculate these two components of acceleration, variables including steering wheel angle, heading and the speed of the vehicle during lane change are used.

As shown in Table 1, in our study, the elapsed time, position and velocity of the driver's vehicle, the yaw rate of the driver's vehicle, and steering wheel angle are used.

2.1. Steering wheel angle features

The steering wheel angle is directly related to the driver's control action. Drivers, who use amphetamines, show severe reactions in their steering patterns (Mura et al., 2006; Mørland et al., 2011; McIntosh et al., 2008; Soderstrom et al., 2001; Vaez and Laflamme, 2005). Thus, the steering wheel angle feature is an appropriate parameter for clustering of these groups. The steering signal contains higher frequencies than the signals from the heading of the car. In fact, the car heading is proportional to the time integral of the steering wheel angle. Some highly dynamic features of the steering wheel angle are filtered out by this integration. Thus, the direct use of the steering wheel angle is very helpful in detecting high-frequency oscillations of driver's input, which are essential in detecting stimulant-drug users. The steering angle is obtained using an encoder attached directly to the shaft of the steering wheel. The steering wheel angular rate is obtained by differentiating the steering wheel angle after having passed through a low-pass filter.

2.2. Lane-based features

Lateral lane position and the area under the path curve are analyzed.

2.2.1. Lane position

There are a few features associated with the vehicle's lateral deviation (Friedrichs and Yang, 2010). LNCHGVEL and LNCHGACC

Table 1
Variables used to study lane-changing maneuver.

Variables	Variable symbol	Description	Unit
Time	T	Elapsed time from the beginning of test	S
Lateral and longitudinal position	x and y	Instantaneous coordinates of the vehicle in the directions of x and y	M
Velocity	v_x and v_y	Instantaneous velocity of the vehicle in the directions of x and y	m/s
Heading	φ	The angle between vehicle's direction and the road and its derivative	deg. and deg./s
Steering angle	ϕ	Steering wheel angle	deg.