The Influence of Stimulants on Truck Driver Culpability in Fatal Collisions

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A Thesis submitted to the Psychology Department

in partial fulfillment of the requirements

for the Master of Arts Degree (Clinical Psychology),

Department of Psychology

Lakehead University, Thunder Bay Ontario

September 1st, 2011

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Abstract

Given the monotony and extended driving periods inherent in transport truck driving, truck drivers might rely on stimulants to sustain attention and combat fatigue. Research indicates stimulants improve some cognitive functions but impair driving ability, and stimulant use is common among truck drivers. In addition, stimulant use is linked to collisions. Research to date on collision culpability among stimulant-positive truck drivers is sparse and presents with limitations due to small sample sizes and a lack of control over confounding variables. The present study investigated the influence of stimulants on unsafe driving actions (UDAs) in collisions. The odds of being stimulant-positive were expected to be statistically significantly higher for drivers who committed at least one UDA that led to a collision. Using the Fatality Analysis Reporting System (FARS) database, the author compared truck drivers who had at least one UDA recorded to a control group of drivers who had none. Logistic regression was used in order to account for the influence of confounding variables (age, previous driving record, and other drug-use) and to calculate the odds ratio of being stimulant-positive in the event of an UDA. Results indicate that the odds of being stimulant-positive are statistically significantly greater for truck drivers who committed an UDA (OR 2.29, 95% CI 1.7-3.0). In addition, Pearson's Chi-square models indicated stimulant-positive truck drivers were significantly more likely to have a history of infractions on their driving record and to have other drugs in their system. The results suggest stimulants negatively influence driving ability and truck drivers should not use stimulants while driving. In addition, the results support the inclusion of previous driving record and other drug use data as control variables for future studies. Despite this, the finding that 0.58% of truck drivers in the FARS database tested positive for stimulants suggests that stimulant use is not common.

Acknowledgments

I would like to thank my supervisor, Dr. Michel Bedard for having confidence in my ability to work independently, and for providing me with opportunities to present this research at conferences. In addition, I would like to thank Sasha Dubois for his dedication and hours of work planning and conducting statistical analyses, and for educating me a great deal on statistics. I would also like to thank Nadia Mullen for her contribution to planning this study as well as reviewing related conference presentation materials. I would also like to thank Bruce Weaver for providing input on statistical analyses and for reviewing related conference presentation materials. Lastly, but not least, I would like to thank Dr. Dwight Mazmanian and Dr. David Eby for taking the time to review this document and for providing excellent feedback.

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Failure to obtain adequate sleep is a well-documented problem among transport truck drivers (Hanowski, Hickman, Fumero, Olson, & Dingus, 2007; Hanowski, Wierwille, & Dingus, 2003). The cognitive deficits associated with sleep loss include impairment in memory, vigilance, attention, and psychomotor abilities (Dinges et al., 1997; Oginska & Pokorski, 2006) and this influences driving performance (Mills, Spruill, Kanne, Parkman, & Zhang, 2001; Roge, Pebayle, Hannachi, & Muzet, 2003; Ting, Hwang, Doong, & Jeng, 2008). In order to combat these detrimental effects, truck drivers report using both licit and illicit stimulants (Davey, Richards, & Freeman, 2007; Mabbot & Hartley, 1999). In addition, stimulant are frequently detected among truck drivers killed in work-related collisions (Brodie, Lyndal, & Elias, 2009; Drummer et al., 2003) as well as deceased drivers deemed to be at fault in collisions (Crouch et al., 1993; Drummer et al., 2004). Even though stimulants can enhance cognitive functions such as vigilance, attention, psychomotor functioning, memory, and visuospatial/visuomotor abilities (Camp-Bruno & Herting, 1994; Koelega, 1993; Silber, Croft, Papafotiou, & Stough, 2006), research suggests they create driving impairments (Logan, 1996; Logan, Fligner & Haddix, 1998; Silber, Papafotiou, Croft, & Ogden 2005). Despite the link between stimulants, collisions, and driving deficits, other research suggests stimulants might improve both cognitive performance and driving performance when used to combat fatigue (Caldwell, Caldwell, & Darlington, 2003; Logan, 2002; Moolenaar, 1999).

Given the complexities of the relationship between fatigue, stimulants, and collisions, research addressing collision culpability among transport truck drivers is needed. To ascertain the role of stimulants in transport truck driver collisions, research that establishes driver culpability and controls for confounding variables is required. In order to properly understand

the rationale for this need, a review of the literature is provided on the following: stimulants and classification, sleep patterns of transport truck drivers, the individual and combined effects of fatigue and stimulants on cognition and driving, and the relationship between stimulant use and culpability in collisions.

Sleep Loss and Fatigue among Transport Truck Drivers

In Canada the Commercial Vehicle Drivers Hours of Service Regulations controls the amount of driving and rest time required for transport truck drivers (Government of Canada, 2008). Similarly, the United States government recognized fatigue as an issue among transport truck drivers and implemented revised hours-of-service (HOS) regulations in order to increase sleep and rest time among drivers (Hanowski et al., 2003). Prior to the new guidelines Mitler, Miller, Lipsitz, Walsh, and Wylie (1997) found that drivers spent an average of 5.18 hours in bed per 24 hour day and averaged 4.78 hours of electrophysiologically verified sleep per day. Hanowski et al. (2003) found drivers who were deemed at fault in critical incidents received significantly less sleep (5.33 hours on average) in the 24 hours prior to the incident than drivers who were not at fault in critical incidents (6.08 hours on average). After the implementation of the revised HOS regulations in the United States, Hanowski et al. (2007) conducted a similar study. Similar to Hanowski et al. in 2003, data for this sample of truck drivers ($N = 82$) was collected with video recording equipment and sensors inside and outside of the truck for 16 weeks. Sleep data were also collected for 7 days with a sensor worn by participants. The average amount of sleep per night for all drivers was 6.28 ($SD = 1.42$) hours suggesting the possibility that sleep has increased among truck drivers since the revised HOS regulations came into effect. Matched-paired *t*-tests revealed that drivers who were deemed to be at fault in a

critical incident averaged 1.45 hours less sleep in the 24 hours prior to the incident ($M = 5.25$, $SD = 2.15$) compared to the overall average for at fault drivers ($M = 6.70$, $SD = 1.65$).

Although drivers might be getting more hours of sleep per night due to regulations, it still may not be enough. Research indicates that the optimal amount of sleep for adults is between seven and eight uninterrupted hours per night and this needs to be routine (Lee-Chiong, 2006). Although research suggests sleep has increased since the revised HOS regulations, drivers still might not be obtaining optimal amounts of sleep (for example, see Hanowski et al., 2007). Friswell and Williamson (2008) found that 89.4% of truck drivers reported fatigue (impaired driving, slowed reactions, decreased traffic awareness and attention to signs, and poorer steering) with 38.1% describing fatigue at least once per week. Insufficient sleep was identified as a contributing factor by 86.9% of the sample. In addition, 44.8% of this sample reported falling asleep at the wheel during the last year of work-related driving. Even if truck drivers did obtain optimal amounts of sleep they still face other fatigue inducing factors inherent in their work such as extended periods of driving and monotonous driving. For the Friswell and Williamson (2008) sample, long driving hours and monotonous driving conditions were identified as contributors to fatigue by 86.2% and 85.6% of drivers, respectively.

Monotonous driving conditions and extended driving periods. Highways and straight roadways with monotonous scenery are considered monotonous driving environments (Horne & Reyner, 1995; Ting et al., 2008). Research indicates highway driving creates fatigue and contributes to collisions, but stimulating scenery can alleviate this effect (Thiffault & Bergeron, 2003). In addition, switching from a complex to a monotonous road environment can reduce alertness and increase weariness and fatigue (Liu & Wu, 2009). Monotonous driving also

reduces vigilance and drivers are not adept at accurately identifying this decrement in ability (Schmidt et al., 2009).

Research shows that extended periods of driving can negatively influence driving ability (Nilsson, Nelson, & Carlson, 1997; Philip, Taillard, Quera-Salva, Bioulac, & Akerstedt, 1999; Ranney, Simons, & Masalonis, 1999) and this is exacerbated by monotonous driving conditions (Liu and Wu, 2009; Roge, et al., 2003). For example, a study by Ting, Hwang, Doong and Jeng (2008) suggests 90 minutes of driving is enough to create significant fatigue. Participants' subjective sleepiness ratings on a Likert scale increased significantly over 90 minutes from pre-test (*Mdn* = 2.37) to post-test (*Mdn* = 4.33). One-way repeated ANOVA with sequential ten minute periods revealed that reaction times significantly increased over 90 minutes. Reaction time increased 0.31 seconds from ten to 90 minutes of driving and this increase resulted in an additional eight meters of stopping distance while travelling at 100 kilometers per hour. Lastly, an overall performance index was calculated by combining data on car speed, headway, lateral position, and frequency of edge-line crossings. A repeated ANOVA indicated statistically significant decreases in overall performance over time. Other research indicates 60 minutes of driving creates fatigue and impairs performance (Liu & Wu, 2009). Specifically, Liu and Wu found drivers' feelings of fatigue on the psychological fatigue questionnaire (using a three point Likert-type scale) increased significantly from 30 to 60 minutes of driving in a monotonous driving environment (from approximately 1.4 to 2.5) and a complex driving environment (from approximately 1.5 to 2.7). Roge et al. (2003) found 30 minutes of monotonous driving was enough to impede driving performance as indicated by movement within the lane (lateral instability) and difficulty keeping distance from the lead vehicle (longitudinal instability). Although statistical significance was not attained, lateral and longitudinal instability were

negatively influenced by driving duration. Lateral instability during the second half hour (*M* = 0.32, *SD* = 0.12) was worse than in the first half-hour (*M* = 0.29, *SD* = 0.12). Longitudinal instability was also worse in the second half-hour (*M* = 7.299, *SD* = 5.60) than the first half-hour (*M* = 6.097, *SD* = 3.09). In addition, the results indicated the negative influence of driving duration on drivers' ability to locate peripheral stimuli was statistically significant. That is, during the first half-hour drivers successfully detected an average of 57.8% (*SD* = 21.2) of the peripheral stimuli compared to 47% (*SD* = 24.2) in the second half-hour.

It is well documented that fatigue has detrimental effects on driving performance (Mills et al., 2001; Roge et al., 2003; Ting et al., 2008) and truck drivers report fatigue as an issue (Friswell & Williamson, 2008). In addition, fatigue increases the chances a collision will be fatal (Bunn, Slavova, Struttmann, & Browning, 2005). Morrow and Crum (2004) suggest a myriad of factors inherent in transport driving that contribute to fatigue: work overload, schedule irregularity, sleep pattern disturbances, and insufficient recovery time between shifts. Taken together, the sleep patterns and work requirements of transport truck drivers is concerning when considering the negative influence these factors have on driving performance. It seems plausible that transport drivers are aware of these effects and search for means of overcoming fatigue. One way some truck drivers attempt to overcome the influence of fatigue is through use of licit and illicit stimulants (Brodie et al., 2009; Davey et al., 2007; Drummer et al., 2003; Mabbot & Hartley, 1999).

Stimulants and Classification

Although stimulants can be divided into four broad groups (behavioural or central nervous system [CNS] stimulants, clinical antidepressants, convulsants, and caffeine/nicotine) (Julien, 2005), only behavioural stimulants are directly relevant to the current study.

Specifically, only the behavioural class of stimulants are included in the FARS database, and the physiological effects of behavioural stimulants are most directly related to driving ability. By mimicking and/or augmenting the action of norepinephrine (as well as augmenting dopamine and serotonin), behavioural stimulants influence the CNS. This causes excitation of CNS functions, thereby increasing physiological activity (Julien, 2005). When considering sleep deprivation and vigilance performance, psychomotor stimulants are of interest given some of their effects: increased behavioural and motor activity, increased alertness, increased concentration, and wakefulness (Pleuvry, 2009). In addition to these effects, behavioural stimulants shift blood flow from skin and organs to muscles, increase body temperature, increase blood pressure and heart rate, and increase oxygen and glucose levels in the blood stream. This influence is similar to the fight or flight response, or our natural response to emergency situations (Julien, 2005). Illicit stimulants such as cocaine and methamphetamine, as well as large doses of licit stimulants can produce excitement and euphoria. Behavioural stimulants can be further subdivided into amphetamines, nonamphetamines, and cocaine and its derivatives (Julien, 2005).

Amphetamines. The amphetamines mimic and potentiate norepinephrine, and are structurally similar to this neurotransmitter. Although amphetamine and its derivatives (for example, dextroamphetamine and methamphetamine) vary in potency, they carry similar effects (Julien, 2005). Pharmacological effects of the amphetamines vary with dose. Even at low doses (for example, less than five milligrams of amphetamine, or 2.5 to 20 milligrams of dexamphetamine), increased alertness and excitement are observed. Even though this briefly provides a high boost of energy, dexterity and fine motor skills are impaired (Julien, 2005). At moderate doses (for example, five to 50 milligrams of amphetamine), respiration is stimulated, motor activity is increased, wakefulness is promoted, and appetite is suppressed. However,

restlessness, tremors, and agitation can be observed (Julien, 2005). Concerning wakefulness, there is a rebound fatigue phase after drug use is discontinued, and full recovery to normal sleep pattern can take weeks. At high doses (for example, 100 milligrams of amphetamine) and with chronic use, paranoia and mania can occur due to excessive levels of norepinephrine (Julien, 2005). In addition, fine motor skills and dexterity are further impaired.

In addition to clinical uses, amphetamines (especially methamphetamine) are often used illicitly because they can produce euphoria and because of their ability to improve psychomotor, intellectual, and athletic performance (Julien, 2005). The primary medical use for the amphetamines is for treating narcolepsy as well as some attention deficit/hyperkinetic disorders in children. To a lesser extent, amphetamines can also be used to treat petit mal epilepsy. Amphetamines also carry anorexic effects but are controversial in the treatment of obesity due to high abuse potential and rapid tolerance development (Julien, 2005; Pleuvry, 2009).

Nonamphetamines. Other behavioural stimulants such as ephedrine, methylphenidate, sibutramine, and modafinil are structurally very similar to amphetamines but lack the basic amphetamine nucleus (Julien, 2005). Although the effects of these stimulants are relatively mild compared to the amphetamines, physiological and behavioural patterns are similar, as these drugs also influence synaptic activity of norepinephrine (Julien, 2005). In addition, these drugs differ from one another in intensity of their physiological and behavioural effects. Despite the similarity to the amphetamine class, nonamphetamines might not influence the CNS as strongly as amphetamines. Ephedrine is used as a nasal decongestant and to treat hypotension during surgery (Julien, 2005; Pleuvry, 2009). Ephedrine is also detected in the majority of illicit amphetamine concoctions (Julien, 2005). Due to anorexic effects, sibutramine can be used for

weight loss. Lastly, some nonamphetamines (such as methylphenidate and modafinil) are used to treat attention deficit hyperactivity disorder (ADHD).

Cocaine and benzoylecgonine. Cocaine blocks the presynaptic reuptake of norepinephrine, thereby increasing the synaptic activity of this neurotransmitter (Julien, 2005). The effects of cocaine are similar to amphetamine, and extremely similar to methamphetamine. Despite this similarity, an average intranasal dose of cocaine (20 to 50 milligrams) is metabolized in five to 15 minutes, whereas a similar dose of amphetamine might last several hours. However, benzoylecgonine is the primary metabolite of cocaine and can carry mild CNS stimulation for several hours after cocaine use is terminated (Bloom & Kupfer, 1995). As with cocaine, benzoylecgonine carries similar effects as the amphetamines (Julien, 2005; Pleuvry, 2009), mostly because they produce similar norepinephrine synaptic actions. Cocaine is known for producing excitement and euphoria, as well as increasing mental awareness and ability. Although cocaine and its derivatives increase motor activity, coordination decreases as the dose increases (Julien, 2005). Even at low doses, cocaine can lead to undesirable reactions (increased blood pressure and heart rate, paranoia, sweating, anxiety) (Julien, 2005). Due to a high potential for abuse and dependency, cocaine is not recognized as clinically useful despite its strong local anaesthetic potential.

The Influence of Stimulants on Cognition and Driving.

The use of stimulants by transport truck drivers to combat fatigue is concerning when considering the link to fatal collisions (e.g., Brodie et al., 2009; Crouch et al., 1993). However, the exact nature of the relationship between stimulants and collisions is not clear. Despite being linked to collisions, stimulants can cause improvements in driving-related cognitive functions (e.g., attention, psychomotor functioning, memory, visuospatial and visuomotor abilities)

(Camp-Bruno & Herting, 1994; Elliott et al., 1997; Koelega, 1993; Rogers et al., 1999; Silber, Croft, Papafotiou, & Stough, 2006). For example, reaction times (in milliseconds) on the Inspection Time Task for drivers on d-amphetamine (M = 384.5, SD = 6.0) as well as methamphetamine (M = 379.4, SD = 8.7) were statistically significantly lower than the reaction time of drives given a placebo (M = 396.8, SD = 7.8; M = 395.0, SD = 8.8, respectively) (Silber et al., 2006). Methylphenidate also speeds reaction time. Using a computer generated stimulus identification task, Naylor, Halliday, and Callaway (1985) found statistically significant decreases in reaction time; low and high doses of methylphenidate decreased reaction time by 37 and 32 milliseconds, respectively.

Research indicates stimulants cause improvements in vigilance performance (Camp-Bruno & Herting, 1994; Rogers et al., 1999). Vigilance tasks (also known as monitoring tasks) require sustained attention in an attempt to identify randomly occurring unusual events. For example, Camp-Bruno and Herting (1994) used a computer generated reaction time task and found methylphenidate reduced reaction time by approximately 30 milliseconds after 25 minutes and 40 milliseconds after 4 hours. In addition to improving performance under normal vigilance conditions, stimulant use can return vigilance performance to baseline in fatigued participants even after lengthy periods of wakefulness (e.g., 22 to 85 hours without sleep) (Killgore et al., 2008; Ramsey et al., 2008; Wesensten, Killgore, & Balkin, 2005). For example, Killgore et al. (2008) compared dextroamphetamine users to a placebo control group and found that after 44 hours of wakefulness, reaction time remained at baseline for the treatment group but increased approximately 300% for the control group. In addition, speed improved slightly for the treatment group but dropped to less than 60% of baseline for the control group.

Some research suggests stimulants not only mitigate vigilance performance decrements by returning performance to baseline in fatigued participants, but also improve performance with time. For example, Moolenaar et al. (1999) compared ephedrine users to a placebo group and uncovered attentional and performance improvements over four hours using a divided attention task. Participants tracked a computer generated stimulus with a cursor. The time off-target decreased across the four hour period for the treatment group from approximately 26 seconds to 22.5. For the placebo group, this time increased from approximately 22 to 34 seconds. Participants simultaneously identified a peripheral signal. For this task, ephedrine users made statistically significantly fewer errors than the placebo group. A meta-analysis by Koelega (1993) reviewing the effects of amphetamine and methylphenidate on vigilance revealed improvements in reaction time and accuracy and this effect was not restricted to a return to baseline effect in fatigued participants. In addition, results of this meta-analysis show the usual decrement in vigilance with time is mitigated by stimulant use.

The above studies show improvements in cognition and vigilance performance with stimulant use. These findings relate to the influence of stimulants after a period of time has passed since ingestion (often based on half-life) in a controlled environment. However, research indicates that driving deficits are especially evident during the acute and withdrawal/rebound fatigue phase (Logan, 1996; Logan, 2002). Concerning long-term stimulant use, the majority of research shows cognitive deficits. For example, deficits in attention abilities as well as visual and working memory are evident in long-term cocaine users (Jovanovski, Erb, & Zakzanis, 2005). In 2002, Simon et al. investigated the cognitive performance of long-term methamphetamine and cocaine abusers, and both demonstrated impairments in memory, attention, and in the ability to ignore irrelevant information.

Aside from chronic stimulant use and the acute and withdrawal phases, research generally shows cognitive improvements with moderate amounts of stimulants. However, the exact nature of the relationship between these cognitive functions and actual driving is not clear. In addition, the use of stimulants in a controlled environment at low doses might not be applicable to real-world situations. Research also fails to address the different phases of stimulant intoxication and does not investigate large doses and/or "binges". In addition, there is an absence of *in situ* research. Although there is not a large body of research assessing the influence of stimulants on actual driving, a limited amount of research approaches this using simulated driving. Some studies demonstrate driving deficits such as swerving, speeding, erratic driving, and risk taking with stimulant use (Logan, 1996; Logan, Fligner, & Haddix, 1998; Silber et al., 2005).

Silber et al. (2005) used a driving simulator to examine the effects of amphetamines on driving performance on a freeway and in city traffic under both day and night conditions. Drivers received an impairment score based on the occurrence of 34 deleterious driving actions (e.g., collisions, improper signalling, dangerous action, wandering, speeding, decreased reaction time). In the treatment group 19 out of 20 participants were ranked as impaired, compared to 13 out of 20 of the placebo group. During day driving participants demonstrated decreased signalling adherence at intersections, when entering a freeway, and when changing lanes. Drivers also failed to stop at red lights more frequently and travelled at lower speeds on the freeway when emergency situations occurred. Aside from a night-time decrease in reaction time, drug-administered drivers demonstrated a reduction in driving performance for day-time conditions only. The authors pointed to perceptual narrowing or "tunnel vision" to explain the daytime driving deficits without concurrent night time deficits. Specifically, the sympathetic

arousal caused by dexamphetamine can create greater acuity where attention is focused with a loss of peripheral acuity. Therefore information falling outside a driver's focus could be lost thereby impairing driving performance. The authors suggested that this tunnel-vision effect is more important during the day because of the greater amount of relevant information and the need for drivers to selectively attend to stimuli.

The presence of stimulant-induced tunnel vision is supported by Mills et al. (2001). In this study researchers used a single-target and divided attention task across the visual field. Dextroamphetamine caused improvements in divided-attention and reaction time for stimuli at the center of the display. However, for stimuli at the outer limits of the monitors, deficits existed and increased with distance from the center of the screen. Therefore stimulant-induced arousal improved selective attention for the focal area but limited this ability for the periphery. The authors noted that the scanning of peripheral hazards required while driving creates a risk for drivers using stimulants due to a stimulant-induced tunnel-vision effect. Other research suggests that tunnel-vision occurs with extended driving periods and fatigue (Roge et al., 2003). In the Mills et al. (2001) study, stimulants did not return performance to baseline in fatigued participants. In addition, fatigue prevented the stimulant-induced enhancement in divided attention as seen in participants who were not experiencing fatigue.

Stimulant Use and Culpability in Collisions

Some research demonstrates stimulant use among commercial truck drivers involved in collisions. For example, using an Australian sample, Brodie et al. (2009) found almost ten percent of (six out of 61) heavy vehicle drivers killed in a collision tested positive for stimulants. Stimulants detected included amphetamine, methamphetamine, methylene-dioxymethamphetamine (MDMA), pseudoephedrine, and phentermine. In another Australian

study, Drummer et al. (2003) found even more stimulant users among a sample of 139 deceased truck drivers involved in fatal collisions. From this sample 32 truck drivers (23%) tested positive for stimulants (methamphetamine, MDMA, and various types of ephedrine). In 2004, Drummer et al. found 15.8% of a sample of Australian transport truck drivers tested positive for stimulants. In support of studies showing stimulant use among transport truck drivers, Crouch et al. (1993) found 22% of their sample (168) of United States truck drivers tested positive for stimulants; 8% cocaine or benzoylecgonine, 7% amphetamine or methamphetamine, and 7% phenylpropanolamine, ephedrine, or pseudoephedrine. Different results were attained by Longo et al. (2000a), in which case 1.8% of their Australian sample tested positive (1 out of 55 truck drivers). However, this study differed from the aforementioned culpability studies; Longo et al. investigated stimulant use among non-fatally injured drivers, whereas the above studies investigated stimulant use among fatally injured drivers.

In addition to the majority of studies finding high percentages of stimulant users among deceased collision victims, two self-report studies also reveal stimulant use with Australian truck drivers. Mabbott and Hartley (1999) conducted such a study and found 27.5% (65 out of 236) of truck drivers used stimulants as a fatigue countermeasure at an undisclosed time during their driving career. Of these drivers 16 reported using over-the-counter stimulants (caffeine pills, herbal drugs, pseudoephedrine), 28 used either prescription or illicit stimulants, and 21 used both prescription and illicit stimulants. Amphetamines were the most common stimulant reported followed by prescription appetite suppressants. Drivers were also asked about peers who use stimulants as a fatigue countermeasure, and 28.6% reported knowing one or more peers who used stimulants. In addition, 65.9% of those drivers stated that stimulants were used by their peer(s) on at least half of all transport trips. Davey, Richards, and Freeman (2007) found even

higher rates. In this study 32 out of 35 truck drivers reported previous and/or current stimulant use (on any occasion). Amphetamine was the most common (20 past users and 9 current users), followed by pharmaceutical stimulants such as ephedrine or duromine (9 past users and 3 current users), and cocaine (3 past users and 3 current users).

Although high percentages of stimulant use are detected in deceased collision victims and transport truck drivers report using stimulants to combat fatigue, this does not imply a causal relationship between stimulant use and collisions. Other research attempts to implicate stimulants by including information on culpability, however, research on culpability among stimulant positive truck drivers is limited; at the time of the present study, only one such study was found. In 2004 Drummer et al. found stimulants present in 15.8% (n = 22) of a sample of deceased truck drivers who were deemed at fault in the collision. Culpability was determined using a method called responsibility analysis (see Robertson & Drummer, 1994). This method determines culpability by considering eight factors: condition of the road, condition of the vehicle, driving conditions, type of crash, witnesses' observations, road law obedience, difficulty of task, and level of fatigue. The odds ratio (OR) of stimulants being present among collision culpable truck drivers was significant, OR 8.83, 95% CI 1.00–78.

The above study by Drummer et al. (2004) suggests collision culpability among fatally injured stimulant-positive transport drivers. However, this study presents with several limitations. In this study, stimulants had the strongest measured association with culpability. However, the CI (1.0-77.8) is wide and the inclusion of one in the CI represents marginal statistical significance. The sample size for this study also presents a major limitation: only 22 transportation truck drivers could be included after controlling for confounding variables such as alcohol. Sample size is an issue in other culpability research as well. Longo et al. (2000b)

investigated culpability among drivers testing positive for stimulants compared to those who tested negative. However, the sample for this study only included 55 truck drivers. Since this study calculated culpability among all motor vehicle drivers, the small number of truck drivers and the unique collision and drug-use patterns among this population prompted the researchers to remove truck drivers from the analysis.

In addition to small sample sizes, the above culpability studies do not control for driving-related risk taking behaviour and/or poor driving abilities. Specifically, drivers might be at an increased risk for collision culpability due to a general tendency to take risks while driving or simply because they are not good drivers. These factors might be reflected by higher instances of driving infractions on their driving record. Drivers' previous driving records were not controlled for thereby introducing unsafe driving tendencies as a potential confounder. Also, all of the drivers in these studies were killed as a result of the collision. Stimulant detection is higher among truck drivers who were killed in a collision (Brodie et al., 2009; Crouch et al., 1993; Drummer et al., 2003, Drummer et al., 2004) than those who were not (Longo et al., 2000a). Although this does not invalidate the results, culpability among stimulant positive at-fault transport truck drivers who were not killed during the collision could yield different results.

Another limitation in the available culpability research concerns the absence of information on specific driving actions related to culpability. That is, information on driving actions committed by stimulant users that lead to culpability could be useful towards understanding the influence of stimulants on specific driving actions.

Purpose of the Present Study

Little research exists on the rates of stimulant use among North American transport truck drivers. In addition, existing research uses samples of deceased drivers which bias the results by

inflating the findings. As a first goal, the percentage of truck drivers testing positive for stimulants will be presented both overall (from 1993 through 2008) and year-by-year. The second, and primary goal of the present study was to assess whether stimulant use increases the odds of performing unsafe driving actions (UDAs: a proxy measure for culpability) while improving on previous research by using a large sample, controlling for confounding variables, and including drivers who were or were not killed in the collision. Information on specific driving actions performed by stimulant positive drivers is also needed. Towards this end, UDAs committed by truck drivers in the present study were used as a proxy measure for determining culpability or crash responsibility. By using UDAs, the author was able to consider specific types of driver actions. It is hypothesized that drivers who commit an UDA will be at increased odds of being stimulant-positive.

Methods

Data Source

All analyses for the present study were calculated using the Fatality Analysis Reporting System (FARS) database. Since 1975 the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration in the United States compiled information on fatal traffic collisions for 50 states, Puerto Rico, and the District of Columbia. For inclusion in the FARS data base the crash must have occurred on a traffic way that is normally open to the public and the collision must have resulted in a death within 30 days. In addition, single vehicle crashes are not included in the FARS database. Trained FARS analysts gather, translate, and transmit the following data into standard FARS forms: police collision reports**,** state vehicle registration files**,** state driver licensing files**,** state highway department data**,** vital statistics**,** death certificates**,** coroner/medical examiner reports**,** hospital medical reports**,** and emergency medical

service reports. After FARS analysts enter a FARS form into the database an extensive quality control program ensures the entry is accurate. To ensure accuracy, the FARS forms are checked online for consistency, range, timeliness, completeness, and accuracy (FARS; National Center for Statistics and Analysis, 2006).

The FARS database includes three coded data forms: the accident form, the vehicle/driver forms, and the person form. The accident form contains crash information pertaining to time, location, the number of people and vehicles involved, weather, and several other variables. The vehicle and driver forms contain information on each vehicle and driver involved in the crash (for example, vehicle type, role in the crash, impact points, harmful events, driver's record and license status). Lastly, the person form contains specific data on people involved in the crash: demographic information, role in the crash, drugs and alcohol involvement, injury severity, *et cetera* (FARS; National Center for Statistics and Analysis, 2006).

Sample

The sample for the present study included FARS cases from 1993 until 2008 because specific drug types have been recorded in the FARS database since 1993. For inclusion in the final (restricted) sample drivers had to be male, 20 years of age and over, driving a truck tractor (cab only or with any number of trailing units; any weight), blood tested for drugs and alcohol, and alcohol free at the time of the collision (blood alcohol concentration of zero). Those excluded were driving a truck other than a truck tractor (semi-truck), were female or unknown sex, and/or tested positive for alcohol.

Cases in the FARS database that involved truck drivers (vehicle type listed in the FARS database as a truck weighing at least 10,000 pounds) involved in a fatal collision who were 20

years old and over and were blood tested for drugs and alcohol (N = 73,178) were subjected to exclusion criteria (see Figure 1). The sample was reduced by retaining only truck-tractor drivers (cab only, or with any number of trailing units; any weight), thereby leaving 52,282 cases; those who were driving any other type of truck were excluded. Female drivers (n = 1,226) and cases of unknown sex (n = 3) were then excluded which reduced the sample to 51,056 male drivers. Females were removed from the sample because only 3 stimulant-positive female cases were in the database; this did not provide sufficient power for statistical analysis and simultaneous control over sex differences. Previous studies demonstrate statistically significant differences between male and female drivers concerning the influence of drugs on driving (Dubois, Bedard, & Weaver, 2010) as well as the odds of committing an UDA (Dubois, Bedard, & Weaver, 2008). With 51,096 male drivers remaining, cases testing positive for any amount of alcohol were removed. After applying all the above exclusionary criteria, a restricted sample of 17,112 remained. This restricted sample included 16,982 stimulant-negative drivers and 220 stimulant-positive drivers.

Design

Drivers were classified as stimulant-positive or stimulant-negative. Cases were drivers who had at least one UDA recorded whereas controls had none. Those drivers who had no UDAs recorded were considered not to have contributed to the initiation of the collision. UDAs were used as a proxy measure of crash responsibility. FARS analysts use police collision reports to code up to three (four since 1997) UDAs that were considered to contribute to initiation of the collision (Blower, 1998). Blower (1998) suggests that UDAs are stronger than traffic violations at indicating crash culpability as not all contributing factors are chargeable offences. In addition, police officers are less likely to press charges for a traffic violation due to insufficient evidence.

By using UDAs, crash investigators' judgment is considered which provides a more complete picture of factors that contributed to the collision (Blower, 1998). Other studies demonstrate the usefulness of UDAs in assessing crash responsibility with the FARS database (Bedard, Dubois, & Weaver, 2007; Bedard & Meyers, 2004; Dubois, Bedard, & Weaver, 2010; Dubois, Bedard, & Weaver, 2008) and with other crash data (Silber et al., 2005).

Control variables. The FARS database allowed for control over age, other drugs, and past driving record. Previous research with the FARS database demonstrates age related differences pertaining to odds of committing an UDA (Dubois, Bedard, & Weaver, 2008; Dubois, Bedard, & Weaver, 2010). The influence of other drugs was accounted for in order to isolate the effects of stimulants on driving. For the drug test results only blood analysis or blood and urine analyses combined were relied upon as urine tests alone might not be accurate enough (Bendtsen, Hultberg, Carlsson, & Jones, 1999). The four stimulant types detected (amphetamine, methamphetamine, cocaine, and benzoylecgonine) were grouped together as they were all similar in classification: all four stimulants detected were illicit drugs with a half-life between approximately 3.8 and 12 hours (Cruickshank & Dyer, 2009; Scheidweiler et al., 2010). As previously discussed, alcohol was removed from the analysis entirely due to the overwhelming influence of alcohol on driving (e.g., Arnedt et al., 2001; Burian, Liquori, & Robinson, 2002). Past driving record infractions were included in order to control for high-risk driving as a potential confounding variables. The FARS database provides driving records for the previous 3 years and includes information on previous collisions, impaired driving offences, speeding convictions, other driving related convictions, and license suspension/revocation (Dubois, Bedard, & Weaver, 2010). Drivers younger than 20 years of age were excluded from the sample as they would not have sufficient time to develop a driving history.

Analysis. Analyses were conducted using both the entire sample (N = 73,178) as well as the restricted sample that remained after applying the exclusionary criteria (n = 17,112). The only analyses conducted for the entire sample of truck drivers (N = 73,178) involved descriptive statistics to calculate the rate of stimulant use overall (from 1993 through 2008) as well as a year by year analysis. For the restricted sample (n = 17,112) several analyses were conducted. An independent samples t-test was conducted to compare the age of stimulant-positive and stimulant-negative truck drivers. Pearson's Chi-square analyses were used as a screening test, and to provide population information for any UDA as well as the top five UDAs. To examine differences between stimulant-positive and stimulant-negative drivers in previous driving infractions (previous collisions, DWI convictions, other convictions, speeding, and suspensions), as well as the use of other drugs (narcotics, depressants, cannabinoids, and "other drugs"), and to validate previous driving record and other drugs as confounding variables, Pearson's Chi-square models were used.

For the main analysis, only the restricted sample was used (n = 17,112). Logistic regression was used in order to account for the influence of confounding variables (age, previous driving record and other drug-use) and to calculate predicted odds and odds ratios of being stimulant-positive in the event of an UDA. Firstly, an unadjusted odds ratio was calculated to examine differences in any UDA between stimulant-positive and stimulant-negative drivers without controlling for any other variables. The second model included age and the age squared term. The quadratic age term was used to account for the possibility of a curvilinear relationship between age and UDAs (driving performance might be worse for both the youngest and the oldest drivers). For the third model, other drugs were included in the analysis to control for the influence of narcotics, depressants, cannabinoids, and "other drugs" on driving performance. For

the fourth and final model, previous driving record infractions (previous collisions, DWI convictions, other convictions, speeding, and suspensions) were also included in order to account for poor driving skills or risky driving tendencies. At each step, interactions were examined and any significant interactions from previous models were included in the final model. Using this final model, logistic regression models were calculated for the top five individual UDAs (making an improper turn, failure to keep in proper lane, operating vehicle in an erratic or reckless manner, driving too fast for conditions, and failure to yield right of way or obey traffic signs). These models included the aforementioned control variables (age, other drugs, and driving record) as well as any interactions that were used in the final model which predicted any UDA.

Results

Descriptive statistics revealed that 0.58% (n = 429) of the entire sample (N = 73,178) tested positive for stimulants. For the year by year analysis, the percentage of drivers from the entire sample testing positive for stimulants appeared to increase, particularly after 1999 (see Figure 2). However, the rates of stimulant use are still at or below one percent from 1993 through 2008. After applying exclusion criteria, stimulant-positive truck drivers (n = 220) represented 0.12% of the restricted sample (n = 17,112). For the restricted sample, 150 cases tested positive for one stimulant, 69 cases tested positive for two stimulants, and one case tested positive for three stimulants. Stimulants detected included amphetemines (n = 78), benzoylecgonine (n = 47), cocaine (n = 52), and methamphetamine (n = 115). For those cases that tested positive for one stimulant (n = 150), 19 tested positive for amphetamines, 34 for benzoylecgonine, 39 for cocaine, and 57 for methamphetamine. Although age differences between stimulant-positive (M = 41.78, SD = 9.07) and stimulant-negative (M = 43.47, SD =

11.57) drivers were small, the independent samples *t*-test revealed a significant difference, indicating that stimulant-positive drivers tended to be younger, $t(17,110) = 2.1$, $p = .03$.

Concerning drugs other than stimulants (narcotics, depressants, cannabinoids, and other drugs), a Person's Chi-Square tests of independent samples revealed significant differences between stimulant-positive ($n = 220$) and stimulant-negative ($n = 16,892$) drivers (see Table 1). Stimulant-positive drivers were significantly more likely to also test positive for narcotics, depressants, cannabinoids, and other drugs. A Person's Chi-Square tests of independent samples revealed statistically significant differences in previous driving record infractions (previous collisions, DWI convictions, other convictions, speeding, and suspensions) between stimulant-positive ($n = 220$) and stimulant-negative ($n = 16,892$) drivers (see Table 1). Compared to stimulant-negative drivers, a significantly greater proportion of stimulant-positive drivers had previously recorded collisions, DWI convictions, other convictions, speeding infractions, and previous license suspensions. A Pearson's Chi-Square tests of independent samples revealed significant differences between stimulant-positive ($n = 220$) and stimulant-negative ($n = 16,892$) drivers for any UDA, as well as four of the top five most common UDAs (making an improper turn, failure to keep in proper lane, operating vehicle in an erratic or reckless manner, driving too fast for conditions); failure to yield right of way or obey traffic signs was not significant (see Table 2).

Main Analysis

An unadjusted odds ratio for being stimulant-positive in the event of performing an UDA was first calculated without accounting for any other factors. Results showed that the odds of being stimulant-positive were higher for drivers who committed an UDA than for those who did not, OR 2.52, 95% CI 1.9-3.3. To calculate the adjusted odds ratio, contributing factors were

included (see Table 3 for results of the final model). Firstly, age (centered at 45) contributed significantly, OR 0.97, 95% CI 0.94-0.99 which led to the addition of the age squared term in order to account for the curvilinear relationship between age and driving ability; the age squared term was also statistically significant (see Table 3). Next, other drugs (narcotics, depressants, cannabinoids, and *other* drugs) were introduced, all of which significantly contributed to the model. In addition, the interaction between stimulants and narcotics was also significant. Although this interaction might indicate a protective factor, whereby stimulant induced driving impairments are alleviated by narcotics, this finding should be interpreted with caution. Only 11 truck drivers tested positive for both stimulants and narcotics (5% of the stimulant group). Also, the odds ratio for stimulant and narcotic positive drivers committing an UDA is not statistically significant, OR 0.34, 95% CI 0.14-1.94. To complete the final model, previous driving record infractions all contributed (previous collisions, other convictions, speeding, and suspensions) with the exception of DWI convictions. However, given the Chi-Square results demonstrating a higher number of DWI convictions among stimulant-positive drivers (see Table 1) as well the significant influence of alcohol on driving ability, this variable was left in the final regression model. After all contributing variables were included, the resulting adjusted odds ratio demonstrates that drivers who committed an UDA had greater odds of being stimulant-positive than those who did not, OR 2.29, 95% CI 1.72-3.04.

The adjusted odds ratios for the top five most common UDAs (failure to keep in proper lane, driving too fast for conditions, operating vehicle in an erratic or reckless manner, making an improper turn, and failure to yield right of way or obey traffic signs), were all statistically significant with the exception of failure to yield right of way. The odds of being stimulant positive were statistically significantly higher for drivers who failed to keep in the proper lane

(see Table 4). Driving too fast for conditions was also statistically significant (see Table 5), as well as operating vehicle in an erratic or reckless manner (see Table 6). The final top five UDA that attained significance was making an improper turn (see Table 7). Lastly, the odds of being stimulant-positive for those who failed to yield right of way or obey traffic signs was not statistically significant (see Table 8).

Discussion

The hypothesis for the present study was supported: drivers who committed an UDA were at increased odds of being stimulant-positive, OR 2.29, 95% CI 1.72-3.04. This is in the same direction as the findings by Drummer et al. (2004) in which truck drivers were statistically significantly more likely to be deemed culpable in a fatal collision, OR 8.83, 95% CI 1.00–78. The present study also demonstrated increased odds of being stimulant-positive in the event of specific UDAs (making an improper turn, failure to keep in proper lane, operating vehicle in an erratic or reckless manner, driving too fast for conditions, and failure to yield right of way or obey traffic signs). This is consistent with driving simulator studies showing deleterious driving actions associated with stimulant use such as swerving, driving too fast or too slow, improper-use of turning signal, and running red lights (for example, see Logan, 1996; Logan, Fligner, & Haddix, 1998; Silber et al., 2005). The findings concerning specific UDAs must be interpreted while considering that there is a lack of exposure data. The findings reveal that 0.58% (n = 429) of the entire sample of truck drivers (n = 73,178) tested positive for stimulants for all the years combined, and stimulant detection rates never exceeded one percent for each individual year. These results run contrary to the majority of studies in Australia and the United States that demonstrate rates of stimulant use between 10% and 91% (Brodie, Lyndal, & Elias, 2009; Crouch et al., 1993; Davey, Richards, & Freeman, 2007; Drummer et al., 2003; Drummer et al., 2004; Mabbott & Hartley, 1999), and are more similar to the findings by Longo et al. (2000a) in

which 0.8% of a sample of Australian truck drivers tested positive for stimulants. As previously discussed, all the above studies utilized samples of truck drivers who were killed as a result of the collision with the exception of Longo et al. (2000a). In conjunction with the above studies, the results of the current study suggest that future research should consider populations of drivers who were not killed during a collision in order to determine alcohol and drug use. Deceased populations might bias findings by inflating the rates of drug and alcohol detection.

Results of the Pearson's Chi-square analyses support the inclusion of previous driving record and other drug-use as control variables, as these confounding variables were overrepresented among stimulant-positive drivers. The addition of these variables marks an improvement over the limitations of previous culpability research in which potentially risky driving tendencies and other drug-use were not accounted for.

The use of UDAs as a proxy measure for culpability enabled the investigation of specific unsafe actions that are linked to stimulant use. For stimulant-positive drivers in this sample, the odds of making an improper turn were highest (see Table 7). Failure to keep in the proper lane followed with the second highest odds ratio (see Table 4). It is interesting to note that these two UDAs were the biggest risk for stimulant-positive truck drivers. Given the need to use one's peripheral vision for turning a vehicle and for keeping between road lines (Summala, Nieminen, & Punto, 1996), these findings might support the possibility of a tunnel vision phenomenon. Both cognitive research (Mills et al., 2001) as well as driving-simulator studies (Silber et al., 2005) suggest tunnel vision is a factor associated with stimulants-use, extended driving periods and sleep deprivation (Roge et al., 2003).

For the present study, the lack of information on stimulant blood concentration may create a biasing effect whereby the overall effect is underestimated. Research demonstrates that

medium to high levels of stimulant blood concentrations are linked to culpability, and low levels are not, suggesting the impairing effects of stimulants might be restricted to higher levels (Drummer et al., 1994; Logan, Fligner, & Haddix, 1998; Terhune et al., 1992). In addition, driving deficits are especially evident during the acute and withdrawal/rebound fatigue phase (Logan, 1996; Logan, 2002). For the present study, the lack of information on stimulant blood concentration leads to the inclusion of drivers with low stimulant blood concentration levels. This could lead to an underestimation of the overall effect, as drivers with low levels of stimulants might not demonstrate driving impairments. Although this could imply an underestimation of the overall effect, this might add credence to the findings as removal of these drivers could increase the magnitude of the findings.

Overall, the results of this study demonstrate the importance of ensuring that transport truck drivers do not use stimulants while driving. It is important to conduct drug screening in order to ensure drivers are not relying on stimulants as a fatigue countermeasure. Employers and/or the government could conduct random drug screening on truck drivers. This could potentially be conducted by Ministry of Transportation Officers at weigh stations, or perhaps in conjunction with transport truck company owners at their main location.

Limitations

Although the inclusion of drivers who were not deceased as a result of the collision represents an improvement over previous research, use of the FARS database precludes the inclusion of collisions that did not involve a fatality. This carries several implications. Perhaps investigating officers implement a more vigorous means of investigation for fatal collisions. This could cause officers to more readily search for and assign UDAs to those involved in such a collision. When observing the Chi-Square results in regards to UDAs (see Table 2), it seems as

if a large number of both stimulant-positive and stimulant-negative drivers committed UDAs. Although this does not change the findings that stimulant-positive drivers were at greater odds for committing an UDA, it might indicate investigating officers are readily and perhaps overzealously assigning UDAs when a fatality is involved. In addition to missing data on collisions that did not involve a fatality, information on single vehicle collisions is also excluded. This could result in the exclusion of stimulant-positive drivers who crashed, but without the involvement of other vehicles.

Although the use of UDAs as a proxy measure of culpability allows for the investigation of specific driver actions, UDAs might not accurately reflect culpability. An accepted technique for determining collision culpability is responsibility analysis (for example, see Drummer et al., 2004, and Longo et al., 2000b). Responsibility analysis is a culpability determining technique developed by Robertson and Drummer (1994) in which each driver is scored on the presence of any of the following factors: road conditions, vehicle conditions, driving conditions, collision type, witness observations, road law obedience, difficulty of task, and level of fatigue. It is difficult to determine whether or not UDAs reflect culpability, or if culpability analysis itself is even preferable. Although all of the culpability analysis variables are likely factors in culpability, this type of culpability assessment introduces the possibility of inaccuracy. For example, witness observations can be inaccurate and are subject to bias. Establishing task difficulty and level of fatigue requires subjective assessments and is therefore prone to error. Lastly, this type of responsibility analysis also fails to consider the role of other drivers in the crash. Regardless, the present study did not use an established means of assigning culpability and instead relies on police records in which UDAs were recorded. For this reason, culpability

might not be established. Despite this, the results still demonstrate the negative influence of stimulants on driving.

There is no information on how drivers were or were not selected for drug testing within the FARS database. It is possible that truck drivers who appeared intoxicated were selected for drug testing, thereby creating a biased sample. That is, stimulant-positive drivers who did not appear intoxicated might not have been selected for drug testing, thereby leaving the more seriously impaired stimulant users for the current sample and artificially strengthening the results. Research does indicate that police officers are adept at identifying drivers impaired by stimulants, and that increasing blood concentrations result in increased impairment ratings (Gustavsen, Morland, & Bramness, 2005).

Concerning research that demonstrates cognitive and driving simulator improvements linked to stimulant use, the current study precludes any cases in which stimulants might have caused driving improvements. For example, only cases in which a collision occurred and resulted in a death are addressed in this study. This focus on negative outcomes associated with stimulant use and driving prevents the investigation of the possibility of driving improvements associated with stimulant use.

Future Directions

The present study demonstrates the importance of accounting for previous driving record and other drugs as confounding variables. Future research can strengthen the limited body of research by including information on blood concentration, and implementing culpability analysis as a means of determining culpability. Further research is needed to investigate the influence of stimulants on transport truck drivers as well as regular drivers.

Future research should not investigate drug use and collision culpability exclusively among samples of deceased truck drivers. The previously discussed tendency for biased results associated with deceased samples demonstrates the importance of including drivers who were not killed as a result of the collision. In addition, information on specific driving actions influenced by stimulants and other drugs should be investigated. Concerning stimulants and driving, researchers should investigate the possibility of a tunnel vision phenomenon.

The results also indicate relatively low rates of stimulant use among truck drivers. This could be due to increased scrutiny for truck drivers via drug testing. It might appear as if stimulants are not a significantly important area of concern among truck drivers. However, it is possible that truck drivers are relying on more acceptable and/or less easily detected stimulants. Given the recent trends in "energy drinks" containing caffeine, taurine, and guarana, future research should investigate the influence of these stimulants on driving as well as their use among transport truck drivers.

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Table 1

Chi-square Results for Drug-use and Driving Records

	Stimulant-positive *n* (%)	Stimulant-negative *n* (%)	χ^2	*p* value
Drugs				
Narcotics	11 (5%)	79 (0.5%)	85.29	<.001
Depressants	8 (3.6%)	61 (0.4%)	58.00	<.001
Cannabinoids	22 (10%)	107 (0.6%)	254.66	<.001
Other Drugs	11 (5%)	226 (1.3%)	21.32	<.001
Driving Record				
Collisions	53 (24.1%)	2,900 (17.2%)	7.29	<.001
DWI Convictions	5 (2.3%)	126 (0.7%)	6.66	<.001
Other Convictions	94 (42.7%)	4,057 (24%)	41.37	<.001
Speeding	104 (47.3%)	5,114 (30.3%)	29.60	<.001
Suspensions	48 (21.8%)	1,229 (7.3%)	66.50	<.001

Table 2

Chi-square Results for Any UDA and the Top Five UDAs

	Stimulant-positive *n* (%)	Stimulant-negative *n* (%)	χ^2	*p* value
Any unsafe driving action (UDA)	128 (58.2%)	5999 (35.5%)	48.54	<.001
Failure to keep in the proper lane	65 (29.5%)	2321 (13.7%)	45.21	<.001
Driving too fast for conditions	44 (20%)	1801 (10.7%)	19.68	<.001
Operating vehicle in an erratic or reckless manner	18 (8.2%)	526 (3.1%)	18.12	<.001
Making an improper turn	16 (7.3%)	257 (1.5%)	45.75	<.001
Failure to yield right of way or obey traffic signs	13 (5.9%)	1165 (6.9%)	0.33	0.565

Table 3

Final Regression Model Predicting Any UDA for Stimulant-Positive Drivers

	Adjusted Odds Ratio	95% CI	*p* Value
Stimulants	2.293	1.729 – 3.042	<.001
Age*	0.993	0.966 – 1.020	.549
Age²**	1.073	1.052 – 1.094	<.001
Other Drugs			
Narcotics	2.306	1.449 – 3.670	<.001
Depressants	1.699	1.035 – 2.789	.036
Cannabinoid	1.496	1.048 – 2.135	.027
Other	1.491	1.147 – 1.937	.003
Stimulant x Narcotic	0.234	0.063 – 0.875	.031
Prior Driving Record			
Collisions	1.291	1.189 – 1.402	<.001
DWI Convictions	1.044	0.728 – 1.497	.816
Other Convictions	1.248	1.158 – 1.344	<.001
Speeding	1.135	1.059 – 1.217	<.001
Suspensions	1.182	1.406 – 1.336	.007

*age was centered at 45 years

**age squared to account for curvilinear relationship between age and driving performance

Table 4

Final Regression Model Predicting Failure to Keep in Proper Lane for Stimulant-Positive Drivers

	Adjusted Odds Ratio	95% CI	*p* Value
Stimulants	2.420	1.781 – 3.288	<.001
Age*	1.035	0.998 – 1.074	.063
Age²**	1.057	1.030 – 1.084	<.001
Other Drugs			
Narcotics	2.485	1.518 – 4.067	<.001
Depressants	2.128	1.242 – 3.645	.006
Cannabinoid	1.211	0.771 – 1.903	.406
Other	1.979	1.466 – 2.671	<.001
Stimulant x Narcotic	0.177	0.034 – 0.928	.041
Prior Driving Record			
Collisions	1.252	1.122 – 1.397	<.001
DWI Convictions	0.998	0.616 – 1.618	.994
Other Convictions	1.262	1.142 – 1.394	<.001
Speeding	1.100	1.000 – 1.211	.051
Suspensions	1.114	0.946 – 1.310	.195

*age was centered at 45 years

**age squared to account for curvilinear relationship between age and driving performance

Table 5

Final Regression Model Predicting Driving Too Fast for Conditions for Stimulant-Positive Drivers

	Adjusted Odds Ratio	95% CI	*p* Value
Stimulants	2.073	1.470 – 3.924	<.001
Age*	0.969	0.930 – 1.010	.142
Age²**	1.042	1.012 – 1.074	.006
Other Drugs			
Narcotics	2.189	1.236 – 3.876	.007
Depressants	0.705	0.313 – 1.587	.398
Cannabinoid	1.390	0.859 – 2.247	.180
Other	1.197	0.817 – 1.755	.356
Stimulant x Narcotic***	-	-	-
Prior Driving Record			
Collisions	1.197	1.059 – 1.353	.004
DWI Convictions	0.786	0.437 – 1.415	.422
Other Convictions	1.223	1.094 – 1.367	<.001
Speeding	1.050	0.943 – 1.168	.372
Suspensions	1.063	0.885 – 1.276	.512

*age was centered at 45 years
**age squared to account for curvilinear relationship between age and driving performance
***no cases of stimulant and narcotic-positive drivers for this UDA

Table 6

Final Regression Model Predicting Operating Vehicle in Erratic or Reckless Manner for Stimulant-Positive Drivers

	Adjusted Odds Ratio	95% CI	*p* Value
Stimulants	2.320	1.364 – 3.943	.002
Age*	0.965	0.893 – 1.042	.358
Age²**	0.988	0.934 – 1.046	.684
Other Drugs			
Narcotics	2.182	0.851 – 5.597	.104
Depressants	0.945	0.280 – 3.195	.928
Cannabinoid	1.140	0.491 – 2.645	.761
Other	0.843	0.391 – 1.814	.661
Stimulant x Narcotic	1.287	0.200 – 8.284	.790
Prior Driving Record			
Collisions	0.814	0.640 – 1.035	.092
DWI Convictions	0.862	0.344 – 2.161	.752
Other Convictions	1.104	0.905 – 1.347	.330
Speeding	1.075	0.891 – 1.298	.448
Suspensions	1.606	1.212 – 2.128	<.001

*age was centered at 45 years

**age squared to account for curvilinear relationship between age and driving performance

Table 7

Final Regression Model Predicting Making an Improper Turn for Stimulant-Positive Drivers

	Adjusted Odds Ratio	95% CI	*p* Value
Stimulants	4.711	2.724 – 8.147	<.001
Age*	0.925	0.835 – 1.026	.139
Age²**	1.058	0.984 – 1.137	.127
Other Drugs			
Narcotics	4.013	1.369 – 11.762	.011
Depressants	0.997	0.223 – 4.450	.997
Cannabinoid	1.219	0.432 – 3.435	.708
Other	0.403	0.097 – 1.669	.210
Stimulant x Narcotic***	-	-	-
Prior Driving Record			
Collisions	1.791	1.368 – 2.346	<.001
DWI Convictions	1.226	0.432 – 3.482	.702
Other Convictions	1.603	1.237 – 2.078	<.001
Speeding	0.847	0.648 – 1.108	.226
Suspensions	1.366	0.924 – 2.019	.117

*age was centered at 45 years
**age squared to account for curvilinear relationship between age and driving performance
***no cases of stimulant and narcotic-positive drivers for this UDA

Table 8

Final Regression Model Predicting Failure to Yield Right of Way or Obey Traffic Signs for Stimulant-Positive Drivers

	Adjusted Odds Ratio	95% CI	*p* Value
Stimulants	0.877	0.495 – 1.554	.653
Age*	0.953	0.908 – 1.000	.048
Age²**	1.115	1.079 – 1.152	<.001
Other Drugs			
Narcotics	0.864	0.311 – 2.406	.780
Depressants	0.424	0.102 – 1.761	.238
Cannabinoid	1.295	0.690 – 2.428	.421
Other	0.797	0.452 – 1.405	.433
Stimulant x Narcotic***	-	-	-
Prior Driving Record			
Collisions	1.266	1.092 – 1.467	.002
DWI Convictions	1.047	0.553 – 1.983	.888
Other Convictions	0.991	0.861 – 1.141	.898
Speeding	1.155	1.014 – 1.314	.030
Suspensions	1.149	0.923 – 1.431	.213

*age was centered at 45 years
**age squared to account for curvilinear relationship between age and driving performance
***no cases of stimulant and narcotic-positive drivers for this UDA

Sample Flow-Chart With Inclusion and Exclusion Criteria

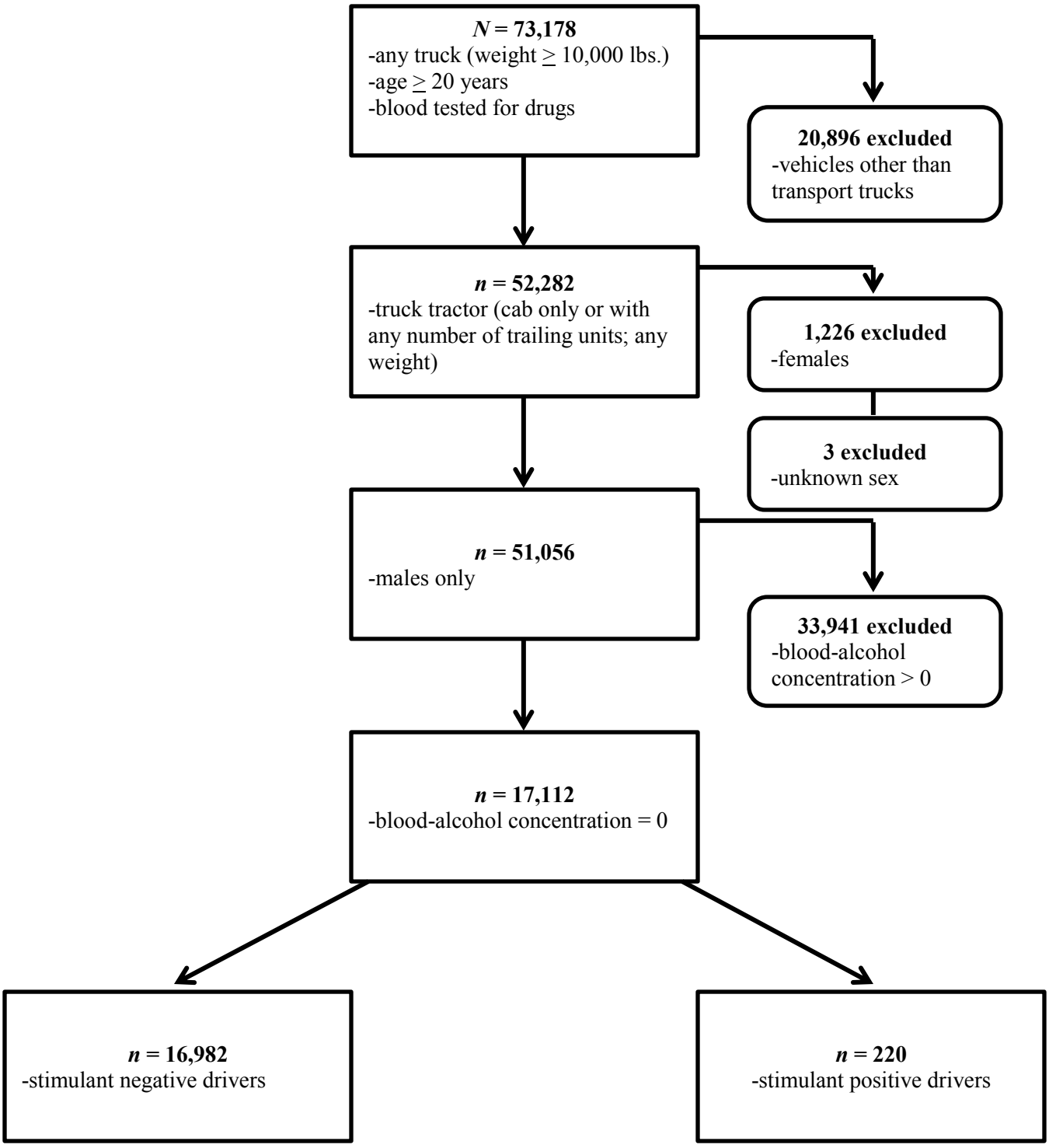

Figure 1. Flow chart of FARS cases selected for the present study with inclusion and exclusion criteria.

Stimulant Use by Year for the entire sample (73,178)

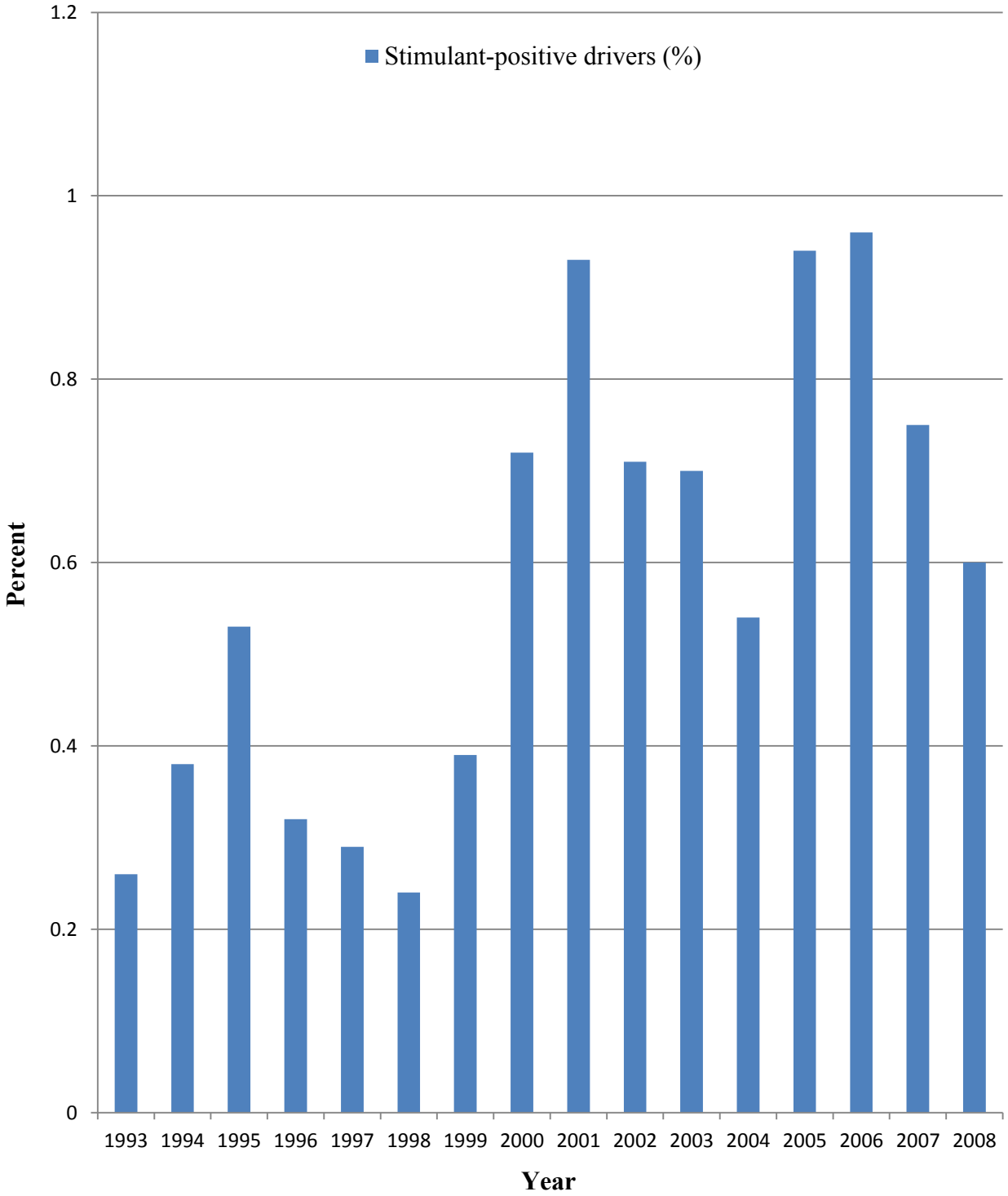

Figure 2. Percentage of total sample (*N* = 73,178) testing positive for stimulants based on analysis year (1993 through 2008).