Do drinking and riding mix? Effects of legal doses of alcohol on balance ability in experienced motorcyclists

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Abstract

The appropriateness of applying drink driving legislation to motorcycle riding has been questioned as there may be fundamental differences in the effects of alcohol on these two activities. Several psychomotor and higher-order cognitive skills underpinning riding performance appear to be significantly influenced by low levels of alcohol. It has been suggested that alcohol may redirect riders' focus from higher-order cognitive skills to more physical skills such as maintaining balance. The effects of low doses of alcohol on balance ability were investigated in a laboratory setting. The static balance of ten experienced riders was measured while they performed either no secondary task, a visual search task, or a cognitive (arithmetic) task following the administration of alcohol (0; 0.02, and 0.05% BAC). Subjective ratings of intoxication and balance impairment increased in a dose-dependent manner; however, objective measures of static balance were negatively affected only at the .05% BAC dose. Performance on a concurrent secondary visual search task, but not a purely cognitive (arithmetic) task, improved postural stability across all BAC levels. Finally, the .05% BAC dose was associated with impaired performance on the cognitive (arithmetic) task, but not the visual search task, when participants were balancing, but neither task was impaired by alcohol when participants were standing on the floor. Implications for road safety and future 'drink riding' policy considerations are discussed.

Key words

Motorcycles; impaired driving; human factors; dual-task paradigm; cognitive psychology

1. Introduction

The high crash involvement of motorcyclists is well documented. While motorcycles account for only 4.5 percent of all Australian passenger vehicle registrations and 0.9 percent of vehicle-kilometres travelled, motorcycle riders account for approximately 15 percent of all road fatalities and a higher proportion of serious injuries (Johnston, Brooks & Savage, 2008). Riding a motorcycle is much more likely to result in death or serious injury than is travelling in a car. In Australia, the rate of motorcycle rider deaths per distance travelled is approximately 30 times the rate for occupants of passenger vehicles, and the rate for serious injuries is approximately 41 times greater (Johnston et al., 2008). These patterns are not unique to Australia—similar estimates have been reported for other developed countries (Jamson & Chorlton, 2009; Liu, Hosking & Lenné, 2009).

There is much evidence relating alcohol consumption to motor vehicle crashes and, more specifically, to motorcycle crashes (Lin & Kraus, 2009; Mau-Roung & Kraus, 2009; Kasantikul, Ouellet, Smith, Sirathranont & Panichabhongse, 2005; Sun, Kahn & Swan, 1998; Soderstrom, Dischinger, Kerns & Trifillis, 1995; Colburn, Meyer, Wrigley & Bradley, 1993; Soderstrom, Dischinger, Ho & Soderstrom, 1993). Alcohol is implicated more frequently in the fatal crashes of motorcycle riders than in the fatal crashes of car drivers (Soderstrom et al., 1993), a finding that is often attributed to the importance of coordination and balance in motorcycle riding. A recent empirical test track study (Creaser, Ward, Rakauskas, Shankwitz, & Boer, 2009) demonstrated significant decrements in riding performance following low levels of alcohol intoxication (0.02 and 0.05% BAC [blood alcohol content]). When intoxicated, participants' response times on a hazard avoidance task were slower, which led to more task performance errors. The authors postulate that the decrements in response times may have resulted from the effect of alcohol on relevant functions such as riders' ability to attend to their environment or their attempts to compensate for impaired balance while performing the complex, multi-task activity of motorcycle riding.

Low doses of alcohol may affect riders' ability to maintain balance. Body sway parameters are used in the context of clinical, sports and research settings to measure an individual's ability to maintain a balanced body posture to prevent falling (Sarabon, Rosker, Loefler & Kern, 2010; Winter, 1995). Static balance tasks involve quiet standing on one or both legs and are generally easy for healthy individuals (Kitabayashi, Demura, Noda, & Yamada, 2004). A simple method to measure body sway during static balance involves the use of a device known as the Lord "Swaymeter", which is attached at waist level and records body displacement in the anterior-posterior and the lateral directions (Lord, Clark, & Webster, 1991).

Body sway is a sensitive measure of the depressant effects of alcohol on the central nervous system (Franks, Hensley, Hensley, Starmer & Teo, 1976), with the sensitivity to detect changes at alcohol doses (.043% BAC) that are too low to significantly affect fine motor activity (Mangold, Läubli & Krueger, 1996). When alcohol is consumed, the degree of body sway when standing in a vertical position is increased in both males and females in a significant linear relationship with dose (Lipscomb & Nathan, 1980; Mills & Bisgrove, 1983). Stance stability is most affected at peak BAC levels and, because of the involvement of the vestibular and oculomotor systems (both important in the maintenance of postural stability), continues to be impacted even as alcohol is cleared from the system and BAC decreases (Lukas, Lex, Slater, Greenwald & Mendelson, 1989).

If balance is affected by low doses of alcohol, riders may adapt their riding behaviour to compensate for the psychomotor impairment of alcohol by focusing more on maintaining bike stability, an adaptation that may decrease the level of attention available to perform other, higher order tasks (Creaser et al., 2009). Because other skills, such as cornering judgment and hazard perception ability, are necessary for safely riding a motorcycle while navigating the shared road environment, any balance impairment would be of concern. A dual-task paradigm that includes the assessment of balance in conjunction with performance of a concurrent higher-order cognitive task can be used to investigate these possibilities.

The current laboratory study used a dual-task paradigm to examine the effects of alcohol on static balance both alone and in conjunction with two secondary tasks: a visual search task and a purely cognitive (arithmetic) task. It was hypothesised that subjective ratings of intoxication and balance impairment, as well as objective measures of body sway, would increase in a dose-dependent manner following the ingestion of low doses of alcohol. It was also hypothesised that maintenance of static balance when intoxicated would be more affected when participants were required to concurrently perform the secondary tasks.

2. Method

Study design

A 3 x 3 within-subjects design with alcohol dose (0, 0.02, 0.05% BAC) and secondary task (none, visual, cognitive) was used.

Participants

Ten experienced riders (9 male) aged between 23 and 53 years (mean = 38.6, SD = 10) participated in the study. To be eligible, participants were required to have held a full driver's licence for at least five years *and* a full (unrestricted) motorcycle licence (mean = 17.4 yrs of licensure, SD = 11.7), to be "social drinkers" (drink between 2-3 standard drinks per week, on average), and to have ridden regularly during the past five years (mean = 9.4 hrs/week, SD = 8.9). Participants were recruited from the University and local community by means of advertisements and were reimbursed for their time. The research was approved by the Monash University Human Ethics Committee.

Equipment

Lord "Swaymeter". Balance assessment was conducted using the Lord Swaymeter to record body displacement at waist level (Lord et al., 1991). This device consists of a firm belt attached around the waist and a 40 cm metal rod extending horizontally behind the participant. A vertically mounted pen was affixed to the end of the rod. Behind the participant, graph paper (with a 1 mm square grid) was placed on top of a height-adjustable table so that the pen would record movement of the participant onto the paper.

Breathalyser. A Lion Alcolmeter SD-400 unit (Lion Laboratories, Glamorgan, UK) was used to measure alcohol exhaled in the breath and to convert it to a BAC reading using a 1:2100 partition coefficient. To ensure accurate performance, the breathalyser was calibrated by Victoria Police prior to study commencement.

Secondary tasks

Visual search task. The Surrogate Reference Task (SuRT; © 2004 DaimlerChrysler AG) was used as the visual search task. The SuRT was presented on a laptop computer positioned within easy view in front of the participant on a height-adjustable table. The participant was required to visually search for a slightly larger target circle among visually similar distracter circles and state aloud whether the target circle appeared on the left or the right of the screen (Figure 3). The experimenter keyed in the participant's response and the software automatically presented the next circle display. Performance on the SuRT was scored on the basis of the number of circle presentations correctly solved within the 30 second time period.

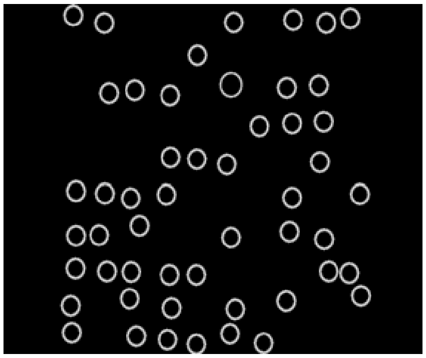

Figure 1. Screen shot of the visual search task (Surrogate Reference Task; SUrT)

Cognitive task. The Serial Sevens Subtraction Test (SSST; Hayman, 1942) has been widely used in neurological examinations of mental function as a measure of concentration (Karzmark, 2000; Smith, 1967). It involves a person performing mental calculations to successively subtract the number seven from a given starting number, usually 100 (Karzmark, 2000). For the current study, instructions were given as such: "Start immediately from the number I give you and continue to subtract the number seven out loud. You can go as slow as you like and remember that maintaining your balance is the primary task". The starting number was stated (using a different starting number for successive trials) at the same time as the 30 second balance assessment began. Verbal responses were recorded using a digital voice recorder and later scored according to the number of correct subtractions. If the participant made an error by subtracting an amount other than seven, any subsequent subtractions could be scored as correct so long as they involved the subtraction of the number seven from the previously stated number.

Procedure

Alcohol administration. Alcohol doses for each BAC condition were calculated using a BAC calculator that estimates total body water based on height, weight and gender to determine the volume of alcohol required to reach a desired peak BAC level (Hume & Weyers, 1971). Doses were prepared to achieve the target BAC of .either .02% or .05% using a vodka (37.5% alcohol) and chilled orange juice mixture made up to a total of 480 ml and presented to participants in an acrylic tumbler.

All participants were tested under each of the three conditions (sober, 0.02% and 0.05%) and the order of alcohol administration was counterbalanced. Participants were 'blind' to which dose they received on each occasion. For the sober condition, a nominal amount (1 ml) of alcohol was floated atop the beverage using an eye dropper.

Participants were instructed to consume a sip (approximately 30 ml) of the beverage every minute for 16 minutes. After dosing, participants drank a glass of water, and were instructed to rinse their mouth of any residual alcohol. To allow peak BAC levels to be reached, a 20-minute period was then allowed to pass before BAC analysis and balance testing was conducted.

Subjective measures. In all BAC conditions, subjective ratings of intoxication and balance impairment were collected 20-minutes following consumption of the beverage. Participants were asked to circle a number from 0 to 10 to indicate how intoxicated they felt and how much they thought their balance might be impaired after having consumed an unknown dose of alcohol, with the number 0 on the left being "completely sober/not affected at all" and the number 10 on the right being "extremely intoxicated".

Balance assessment. Trials were conducted with participants standing on a wooden beam (80cm long x 7 cm wide x 4.5 cm high) on the floor with their eyes open. The decision to use this stance was based on results of a pilot study of six participants tested in 19 different stances. Participants were asked to remove their shoes and stand as still as possible with arms hanging loosely by their side. They were permitted to raise their arms slightly to regain their balance, if necessary. Instructions specified that the participant should keep their eyes open and fixated on a point towards a laptop computer positioned within easy view in front of them (Figure 2).

Figure 2. Measurement of balance using the Lord "Swaymeter"

All participants completed three 30-second trials of the balance assessment across each secondary task condition (none, visual search, and cognitive) and under each BAC level. To assess the effects of alcohol on secondary task performance, participants were also required to perform three repetitions of each secondary task at each dose of alcohol while sitting comfortably. If a participant was not able to remain standing for a three 30-second trial period, their test score was extrapolated as per the method used by Lord, Clark and Webster (1991). For example, if they were able to maintain their balance for only 15 seconds and the product of the maximal anterior-posterior and lateral sway in this period was 100 mm^2, then this was coded as having swayed 200 mm^2 during that particular trial.

Data analysis. The degree of sway in each trial was measured by the log of the product of maximal sway in the lateral and anterior-posterior directions (Lord et al., 1991). Stance duration was the length of time that a participant maintained the stance, up to a maximum of 30 seconds. The average of three trials in each stance was used in the analysis. Performance on both the visual and cognitive secondary tasks was the number of correct responses made, averaged across all trials in each particular condition. A repeated measures analysis of variance (ANOVA), with dose (3 levels) and task (3 levels) as factors was performed using the statistical program PASW 18.0. Pairwise comparisons assessed the significance of any differences between conditions. An alpha level of .05 was used to determine statistical significance.

3. Results

Blood alcohol content (BAC) readings. The average BAC reading attained for all participants just before the balance assessment was 0.0236 percent (SD = .0005) for the 0.02% dose, and 0.0537 percent (SD = .0011) for the 0.05 percent dose.

Subjective ratings of intoxication and balance impairment. A repeated measures ANOVA revealed a significant effect of Dose on subjective ratings of intoxication, $F(2,18) = 20.52$, $p < .001$, and on ratings of balance impairment, $F(2,18) = 19.38$, $p < .001$, with the 0.02% BAC condition resulting in significantly higher ratings of intoxication than the Sober condition, and the 0.05% BAC condition resulting in significantly higher ratings of intoxications than the 0.02% BAC condition (Figure 3).

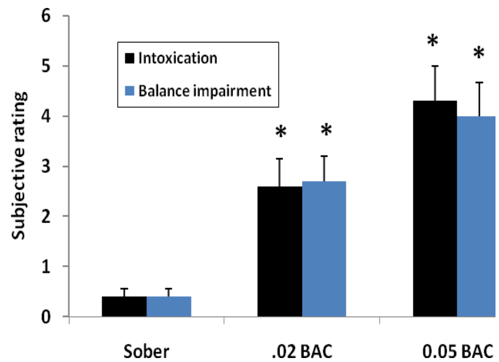

Figure 3. Subjective ratings of intoxication and balance impairment (out of 10)

Static balance. A repeated measures ANOVA conducted on the static balance data revealed a significant main effect of Dose, $F(2,18) = 5.1$, $p < .05$, and a marginally significant main effect of Task, $F(2,18) =$ 4.6, $p = .061$. Pairwise comparisons revealed that postural sway increased in the .05% BAC condition compared to both the sober (+59%) and the 0.02% BAC (+66%) conditions (Figure 4, left panel). Interestingly, postural sway decreased (improved) when participants performed the visual search secondary task compared to when performing either no task (-40%) or the cognitive task (-57%) (Figure 4, right panel). There was no significant Dose x Task interaction.

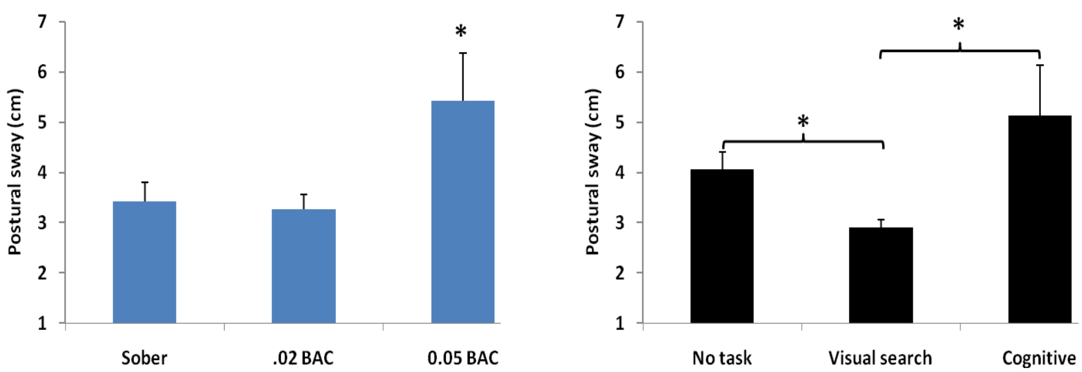

Figure 4. Effects of alcohol (left panel) and secondary task (right panel) on postural sway (log of anterior-posterior deviation x lateral deviation)

For mean stance duration, a repeated measures ANOVA revealed a significant main effect of Dose, $F(2,18) = 5.6$, $p < .05$, with pairwise comparison indicating a shorter mean stance duration in the .05% BAC condition (by 11%) compared to the sober condition (Figure 5).

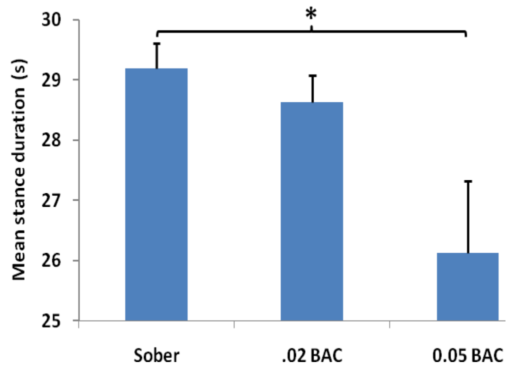

Figure 5. Effects of alcohol on mean stance duration (maximum possible is 30 s)

Secondary task performance. To assess whether ingestion of alcohol had any effect on secondary task performance irrespective of balance ability, participants performed the visual search and cognitive tasks while sitting comfortably. Repeated measures analysis failed to reveal any effects of alcohol dose, $F(2,18) = .84$, $p > .05$ on secondary task performance (number of responses per trial) (data not shown).

Secondary task performance while performing the static balance tasks was evaluated to ascertain whether focusing on the balance tasks while under the influence of alcohol affected visual search or cognitive processes. A repeated measures ANOVA revealed a significant interaction between Task and Dose, $F(2,18) = 4.53$, $p < .05$, so data from each secondary task were analysed separately. A repeated measures ANOVA conducted on the visual search data failed to reveal any differences among the three doses on this task (Figure 6, left panel); however, analysis of the cognitive task data revealed a significant main effect of Dose, $F(2,18) = 4.9$, $p < .05$, with pairwise comparison revealing that participants responded correctly significantly less often on the cognitive task in the .05% BAC condition compared to the .02% BAC condition. A trend for participants to respond correctly less often in the .05% BAC condition than when sober ($p < .10$) was also observed (Figure 6, right panel).

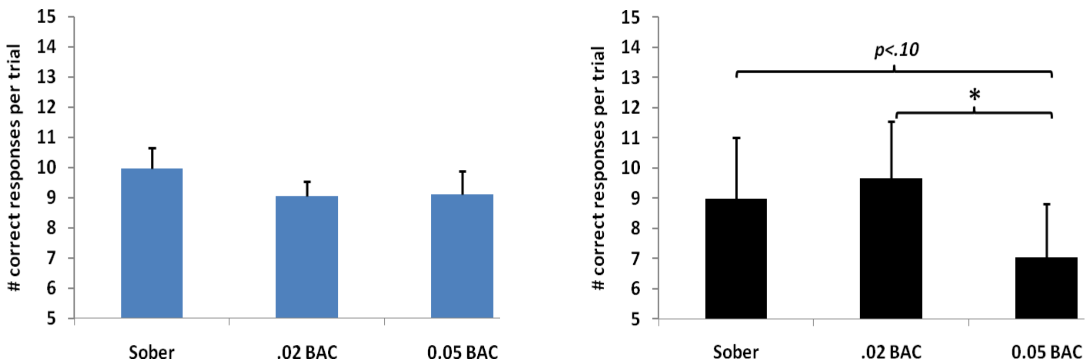

Figure 6. Effect of alcohol on visual search (left) and cognitive (right) secondary task performance..

4. Discussion

The ingestion of legal (0, .02% and .05% BAC) doses of alcohol by experienced motorcycle riders resulted in a dose-dependent increase in subjective ratings of intoxication and balance impairment. At the same time, objective measures of balance ability were negatively affected only at the highest (.05% BAC) dose. These findings provide partial support for the hypothesis that subjective ratings of intoxication and balance impairment, as well as objective measures of body sway, would increase in a dose-dependent manner following the ingestion of low doses of alcohol, and are in accordance with previous research on the effects of low doses of alcohol on static balance (Mangold et al., 1996). The results also demonstrate that riders are aware of being intoxicated after consuming even low doses of alcohol, even when they are unaware of the dose. This is a promising result; since participants predicted that their balance would be impaired in real world conditions, "perceived impairment of balance" may be used to assist riders when they are faced with the decision of whether or not they are fit to ride.

Previous test-track research found that low doses of alcohol do not affect riders' balance but do contribute to other, higher order, deficits (Creaser et al., 2009). This suggests that low levels of alcohol may result in riders adapting their attentional strategies to compensate for psychomotor impairment, which may concomitantly detract their attention away from other, higher-order cognitive skills. The present study was designed to test this hypothesis—that maintenance of static balance following ingestion of low doses of alcohol would be more affected when participants were required to concurrently perform either a visual search or a purely cognitive (arithmetic) secondary task. Objective balance and secondary task data do not support this hypothesis. In fact, analysis of postural sway data from all BAC levels combined indicates that performance of the visual search task was actually associated with *improvements* in static balance ability over baseline levels, as evidenced by reduced postural sway. It is possible that the nature of the visual search task—to actively search for a visual target amongst other, background, visual stimuli—may have compelled participants to focus their attention more precisely than they would have otherwise. Interestingly, results from several studies (Creaser et al., 2005; Kasantikul et. al., 2005) suggest that alcohol may have selective detrimental effects on attention while riding. Based on the present data, though, it would seem that this is not always the case, as alcohol at the doses tested failed to impair performance on the visual search task, which by its very nature, involves attentional resources.

The trend towards decrements on the purely cognitive secondary task at the .05% BAC dose when participants were not required to maintain balance, which also resulted in significantly greater postural sway than the visual search task, suggests that if riders were to devote significant cognitive resources to a non-visual secondary task while riding, such as a mobile phone conversation, talking on a headset to a pillion passenger, or inattention from the forward scene, then they would put themselves at a greater risk of being involved in a collision due to impairments in their ability to maintain motorcycle stability. This possibility is supported by crash data showing that the majority of alcohol-related motorcycle crashes are single-vehicle, run-off-the-road crashes that occur on curves, at night, on weekends, and while riders are on their way home—crash types that were attributed to alcohol-induced rider inattention (Kasantikul et al., 2005)..

Several aspects of the present study design may limit the relevance of the results. First, the participant sample included only experienced riders who were also experienced car drivers. It is possible that less experienced riders would behave differently when tested under the BAC levels administered herein.

Research is currently planned to include a sample of inexperienced motorcycle riders to test this possibility. The requirement for significant (> 5 years) car driving experience was made in order to be able to quantify and isolate the effects of alcohol that relate only to motorcycle riding experience.

Another limitation of the present study is the laboratory setting and artificial circumstances in which it was conducted, which required participants to sit, by themselves, in a windowless room while consuming a drink and to perform prescribed balance tasks in the presence of an experimenter. It is possible that the effects of alcohol on balance and higher order cognitive processes would be different if they were evaluated under real world circumstances—for example, in participants following an evening of drinks at the local pub. To more closely simulate real conditions, a medium fidelity motorcycle riding simulator study is currently underway. Further, individual differences in tolerance to the effects of alcohol may have resulted in some participants' balance ability being more affected than others by the doses of alcohol used in this study. That tolerances for alcohol were as similar as possible across participants, however, was made more likely by the requirement that participants be 'social' drinkers (e.g., consume between 2-3 standard drinks, on average, per week).

Stance duration was shown to decrease significantly by low level alcohol, under experimental conditions with a balance task that required participants to stand still for 30 seconds. This is a much shorter duration than that required for balance maintenance during motorcycle riding. As such, it is possible that impairment of balance would have been greater if a longer task duration had been used. Although this was not possible to assess under the current laboratory conditions, extended balance would be a key area of interest for future research in this area.

Results from the present study have implications for real world motorcycle riding and related road safety policy. Increases in subjective intoxication and balance impairment, as well as decreases in objective measures of balance ability, indicate that even legal doses of alcohol may have adverse effects on riding performance that may be associated with increased crash risk. Riders should be advised to avoid drinking alcohol before riding or to limit their alcohol intake to no more than one standard drink. For riders who may have already ingested alcohol before riding, postural sway and secondary task data indicate that it would be of benefit to actively and continually scan the visual scene while riding, rather than focusing on one point on the forward scene. Finally, policy makers are encouraged to continue to support research into the effects of legal (low) doses of alcohol on motorcycle riding and car driving performance, with a view towards informing policy decisions using relevant, reliable, and robust empirical data.

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