# Drinking and riding: is subjective workload related to performance?

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**Abstract**

**Introduction:** Within the context of road safety it is important that workload (the portion of a driver's resources expended to perform a task) remains at a manageable level, preventing overloading and consequently performance decrements. Motorcyclists are over represented in crash statistics where the vehicle operator has a positive, low blood alcohol concentration (BAC) (e.g., ≤0.05%). The NASA task load index (NASA-TLX) comprises sub-scales that purportedly assess different aspects of subjective workload. It was hypothesized that, compared to a zero BAC condition, low BACs would be associated with increases in workload ratings, and decrements in riding performance.

**Method:** Forty participants (20 novice, 20 experienced) completed simulated motorcycle rides in urban and rural scenarios under low dose BAC conditions (0.00%, 0.02%, 0.05% BAC), while completing a safety relevant peripheral detection task (PDT). Six sub-scales of the NASA-TLX were completed after each ride. Riding performance was assessed using standard deviation of lateral position (SDLP). Hazard perception was assessed by response time to the PDT.

**Results:** Riding performance and hazard perception were affected by alcohol. There was a significant increase in SDLP in the urban scenario and of PDT reaction time in the rural scenario under 0.05% BAC compared to 0.00% BAC. Overall NASA-TLX score increased at 0.02% and 0.05% BAC in the urban environment only, with a trend for novices to rate workload higher than experienced riders. There was a significant main effect of sub-scale on workload ratings in both the urban and rural scenarios.

**Discussion:** 0.05% BAC was associated with decrements in riding performance in the urban environment, decrements in hazard perception in the rural environment, and increases in overall ratings of subjective workload in the urban environment. The workload sub-scales of the NASA-TLX appear to be measuring distinct aspects of motorcycle riding-related workload. Issues of workload and alcohol impaired riding performance are discussed.

**Key words:** blood alcohol concentration (BAC), road safety, simulation, novice, experience

## 1 Introduction

Motorcyclists experience higher crash rates than other road users; in Australia motorcycles account for only 0.9 percent of vehicle-kilometres travelled but account for approximately 15 percent of all road fatalities and a higher proportion of serious injuries (Johnston, Brooks, & Savage, 2008). In Queensland in 2008, motorcycles represented approximately four percent of vehicle registrations but accounted for over 20 percent of road fatalities. The heightened vulnerability of motorcyclists identifies them as a specific road user group deserving particular research attention.

Alcohol consumption is well known to impair driving and riding performance and is implicated more frequently in fatal crashes than non-fatal crashes (Siskind *et al.* 2011). Additionally motorcyclists are involved in crashes more often at lower BAC than car drivers (Sun, Kahn, & Swan 1998). Several studies have shown impairment at motorcylce riding under the influence of low dose (≤ 0.08%) blood alcohol concentration (BAC). Impairment in riding performance under low dose BAC has been reported using both simulators

(Filtness *et al.*, in press; Colburn *et al.* 1993) and test track (Creaser *et al.* 2009) protocols; in particular, standard deviation of speed and variability of lane positioning increase and reaction time slows.

Workload can be defined as having three components; physiological, procedural and perceptual (subjective) (Weinger *et al.* 2000). Subjective workload is assessed using rating scales in order to measure a participants' perceived workload. Subjective workload measures are often preferred to physiological and procedural measures as they are less invasive, easier and less expensive to administer and results are more easily reproduced (Young, Lyubov, & Hooper 2008). Subjective workload may be considered the portion of resources expended in order to perform a task. Within the context of road safety it is important that workload remains at a manageable level preventing vehicle operators from being overloaded and consequently suffering performance decrements. One possible contributor to an increase in riders' subjective workload is alcohol consumption, even at low doses (e.g., BACs ≤ 0.05%).

The NASA task load index (NASA-TLX) (Hart & Staveland, 1988) comprises six sub-scales that purportedly assess different aspects of subjective workload. The NASA TLX is a well-known, multidimensional assessment tool that measures six dimensions of workload: mental demand, physical demand, temporal demand, performance, effort and frustration. The NASA-TLX has been demonstrated to be a sensitive and reliable measure of subjective workload both as a totalled score (Hill *et al.*, 1992) and as the six separate subscales (Jahn *et al.*, 2005) in sober participants. Although initially developed for use in flight simulation, it has been applied, extrapolated and modified by researchers in various disciplines outside of aeronautical research, including in road safety research (e.g. Edquist, Rudin-Brown, & Lenné, 2012; Kim & Son 2011; Kim, Jeong & Suh 2011). Within road safety research it is generally reported that increases in workload are associated with decrements in performance. The multidimensional approach of the NASA-TLX allows for analysis of both overall workload and its specific components.

The NASA-TLX has previously been used to investigate the effect of positive BAC on subjective workload. Kim *et al.* (2007) compared simulated ship bridge operation in a small sample of eight deck officer cadets. Where alcohol significantly affected task performance, subjective workload was also rated as significantly higher (0.08% BAC compared with sober). Lower dose, 0.05% BAC was also investigated but in this case neither simulator performance nor subjective workload was significantly affected. Although Kim et al. (2007) provide graphical breakdown of the six subscales of the NASA-TLX, suggesting that "mental demand" and "effort" are particularly affected by BAC; no statistics are provided. The lack of statistics makes it difficult to verify that the independence of scale items is sustained with intoxicated participants.

The NASA-TLX has also been used to monitor changes in workload as participants become more experienced at a task. This is most commonly applied to training of surgeons, for instance practice at simulated brain surgery is associated with decrease in workload ratings (Dixon *et al.* 2011), although the method of training may affect any reductions in workload (Muresan *et al.* 2010). As workload decreases with gains in experience it is possible that experienced motorcycle riders will report lower workload levels than novice riders.

The aim of the current study was to investigate if subjective workload (as measured by the NASA-TLX) is related to impairments of motorcycle simulator riding performance under low dose BAC. This study also provided opportunity to investigate the impact of low dose BAC on the separate subscales of the NASA-TLX and verify the independence of the subscale items in relation to positive BAC. It was hypothesized that, compared to a zero BAC condition, low BACs would be associated with increases in subjective workload ratings, as well as decrements in riding performance, and that novice riders would report a higher workload than experienced riders.

# 2 Method

## 2.1 Design

A 3 x 2 mixed design was utilised with alcohol dose ('Dose') as the within-subjects factor (0, 0.02% BAC and 0.05% BAC) and riding experience ('Experience') as the between-subjects factor (experienced, novice). Order of alcohol dose administration was counterbalanced across participants. The research was approved by the Monash University Human Research Ethics Committee.

## 2.2 Participants

Participants were twenty experienced riders (two female) aged 23 to 54 years (mean = 37.1 y, SD = 9.9) with an average of 14.15 y (SD 10.3 y) riding experience, and twenty novice riders (two female) aged 18 to 53 years (mean = 27.2 y, SD = 10.8) who were learners or within the first two years of passing their motorcycle licence test. Experienced participants were classified as riding regularly over the past five years covering at least 5,000 km total. Participants were compensated $40 per session for their time.

## 2.3 Riding Simulator

The MUARC advanced driving simulator was reconfigured as a motorcycle riding simulator for the purposes of the research program. The interactive riding simulator used a real Honda NSR 150 motorcycle. Participants were able to realistically control the throttle, hand and foot brakes, and steering. The simulated scenario was displayed on a curved projection screen providing a 180° horizontal and 40° vertical field-of-view with an additional screen for the rearward view. The motorcycle was fixed in a vertical position to allow participants to have both feet on the foot pegs, emulating a real riding position.

### *2.3.1 Scenarios*

Participants were presented with urban and rural road scenarios under each alcohol condition. The order of presentation was counterbalanced across participants, and remained consistent across the alcohol conditions. For both scenarios, oncoming traffic was presented at pre-determined intervals. Each scenario lasted approximately 6 - 10 minutes, depending on participants' speed. The rural scenario consisted of a winding single carriageway, with an 80 km/h speed limit. The urban scenario consisted of a straight dual lane road passing through six blocks of buildings, with a 60 km/h speed limit.

### *2.3.2 Peripheral detection task (PDT)*

While riding, participants were required to simultaneously perform a safety-relevant peripheral detection task (PDT). This task required participants to signal the location of an icon which appeared intermittently to the far left or right of the centre of the screen. The icon was programmed to appear at randomised intervals of 200, 300, 400, 500 or 600 m (12-36 s at 60 km/h) and disappeared after 100 m (6 s) if a rider failed to respond..

## 2.4 Blood alcohol content measurement

BACs were measured using a Lion Alcolmeter SD-400 unit (Lion Laboratories, Glamorgan, UK) which measures alcohol exhaled in the breath and converts 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.

## 2.5 Procedure

All participants completed all three test sessions, with each test session separated by at least one day. Participants were instructed not to drink alcohol the night before and not to eat for at least two hours prior to testing. Participants were instructed to take a complimentary taxi to and from each test session. Upon arrival at the laboratory, participants were breathalysed to ensure that no alcohol had been consumed. After completing a demographic and riding experience questionnaire, participants completed a five minute practice ride on the simulator to familiarise themselves with the controls of the riding simulator and the PDT.

The alcohol dose (vodka, 37.5% alcohol) was administered as a beverage made up to 480 ml with chilled orange juice. Alcohol doses for each BAC were determined using a BAC calculator based on the Hume-Weyers formula (Hume & Weyers 1971), which estimates total body water based on height, weight and gender to determine the volume of alcohol required to reach a desired peak BAC level. Participants were blind to the BAC condition. In the zero alcohol condition a nominal amount (1 ml) was floated atop the beverage to make it smell like it might contain alcohol. Participants were required to drink 30 ml (a "sip") of liquid every minute for 16 minutes. Twenty minutes after drinking (to allow peak BAC to be reached), participants were breathalysed again. Each test session lasted approximately two hours in total.

### 2.6 NASA-TLX

After each scenario, participants scored their subjective workload on a modified version of the NASA TLX (Hart and Staveland 1988) immediately after the scenario had concluded (while still seated on the motorcycle). The NASA TLX is a well-known, multidimensional assessment tool that measures six dimensions of workload: mental demand, physical demand, temporal demand, performance, effort and frustration. The modified version used in the present study did not include the physical demand item, and instead included an item assessing safety. This adapted scale assesses workload in the six dimensions, each on a scale from 1 to 10. The scores were totalled to give a composite NASA-TLX score. This adapted scale has been used in previous simulator research (e.g., Edquist, Rudin-Brown, & Lenné, 2012; Young, Mitsopoulos-Rubens, Rudin-Brown, & Lenné, 2012).

### 2.7 Data analysis

All statistical analyses were conducted using PASW 18.0 statistical software. An alpha level of .05 was used to determine statistical significance. Dependent variables were analysed using a mixed measures ANOVA with the within-subjects factor of alcohol Dose (3 levels: zero alcohol, 0.02% BAC and 0.05% BAC) and the between-subjects factor of riding Experience (2 levels: experienced and novice). The scores from each sub scale of the NASA-TLX were analysed using mixed measures MANOVA with Dose (3 levels), Scale item (6 levels: mental demand, pace, success, hard work, irritation and safety) and Experience (2 levels: experienced and novice) as factors; results are reported using Pillai-Bartlett trace. In the case of a significant MANOVA, individual mixed measures ANOVAs with Dose (3 levels: zero alcohol, 0.02% BAC and 0.05% BAC) and Experience (2 levels: experienced and novice) as factors were conducted. Post hoc pairwise comparisons were conducted using Bonferroni tests. To supplement the interpretation of the results, partial $\eta^2$ was used as an estimate of effect size. Where required, square root transformations were used to correct for skewness. Where Mauchley's test indicated that the assumption of sphericity had been violated, degrees of freedom were corrected using Huynh-Feldt estimates of sphericity, epsilon values are listed accordingly.

## 3 Results

### 3.1 Participant characteristics

Experienced participants were on average significantly older than novice participants (37.1 *vs.* 27.2 years), and had significantly more riding experience both in terms of years they had held a licence, average riding hours per week and riding trips per month. Descriptive and inferential statistics for participant riding characteristics are presented in Table 1.

**Table 1: Participant riding characteristics, comparison between experience levels by independent T test**

| | Experienced Mean (SD) | Novice Mean (SD) | t value (degrees of freedom) | p value |
|---|---|---|---|---|
| Age | 37.1 (9.9) | 27.2 (10.8) | 3.02(38.0) | 0.004* |
| Years held a motorcycle licence | 14.2 (10.3) | 1.7(3) | 5.21(22.3) | <0.001* |
| Years held a car licence | 18.6 (10.3) | 9.1 (10.4) | 2.91(38.0) | 0.006* |
| Hours ridden per week | 8.2 (6.7) | 3.4 (2.4) | 3.06 (23.9) | 0.005* |
| Times ridden per month | 21.6 (13.5) | 12.2 (12.8) | 2.23 (37.0) | 0.032* |

*denotes statistical significance at the $p < 0.05$ level

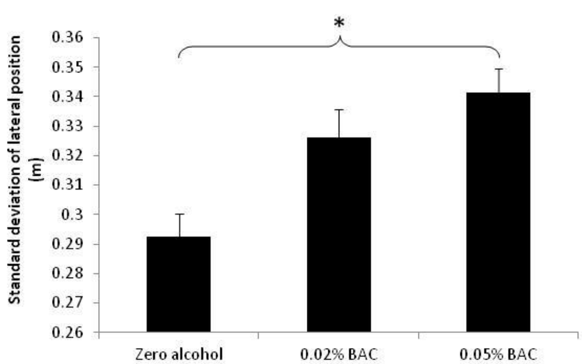
### 3.2 BAC readings

There were no significant differences in BAC readings between the two experience groups at test session midpoint under either 0.02% BAC or 0.05% BAC. There was no significant change in BAC readings over time in the 0.05% BAC condition. However, BAC readings did decrease slightly over time in the 0.02% BAC condition (from 0.028% BAC at the beginning of the test session to 0.017% BAC at the conclusion, $p < .05$).

### 3.3 Riding performance

There was a significant main effect of Dose on the standard deviation of lateral position (SDLP) in the urban scenario $F(2,76) = 6.633$, p <.01, partial $\eta^2 = 0.149$. Pairwise comparisons showed the 0.05% BAC condition to be associated with significantly greater deviation within the lane than the zero alcohol condition ($p$<.01), regardless of participants' experience level (Figure 1). There was no effect of Experience on SDLP in the urban environment. There were no significant effects of Dose or Experience on SDLP in the rural scenario.

**Figure 1: Effect of Dose on standard deviation of lateral position (SDLP) in the urban scenario (error bars represent standard error)**

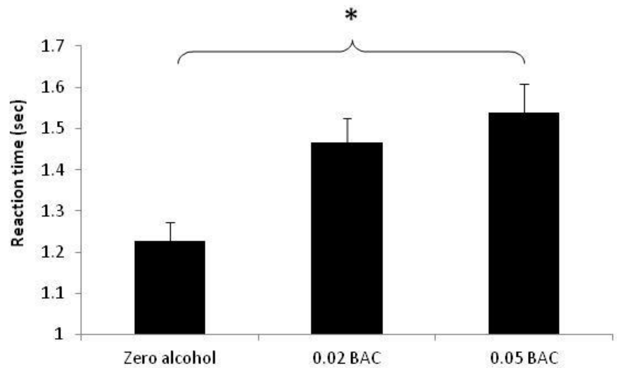



*denotes statistical significance at the 0.05 level

While riding, participants were required to simultaneously perform a safety-relevant peripheral detection task (PDT). In calculating average PDT reaction times, missed stimuli (3.9% of all PDT presentations) were not included; as such PDT results should be interpreted as indicating the mean time to react of all PDT presentations where a response was made. The proportion of missed PDT responses across Dose occurred as follows: Zero alcohol – Urban 2.9%, Rural 3.8%; 0.02% BAC – Urban 4.23%, Rural 4.0%; 0.05% BAC – Urban 2.8%, Rural 8.2%. There was a significant main effect of Dose on PDT reaction time in the rural scenario, $F(2,74) = 3.64$, $p$ <.05, partial $\eta^2 = 0.090$ (Figure 2). Pairwise comparisons revealed a significantly slower reaction time at the 0.05% BAC dose compared with zero alcohol, but no significant difference between 0.02% BAC dose and zero alcohol or between 0.02% BAC and 0.05% BAC. There was no effect of

Experience on PDT reaction time in the rural environment. There were no significant effects of Dose or Experience on PDT reaction time in the urban scenario.

**Figure 2: Effect of Dose on reaction time to the peripheral detection task in the rural scenario (error bars represent standard error)**

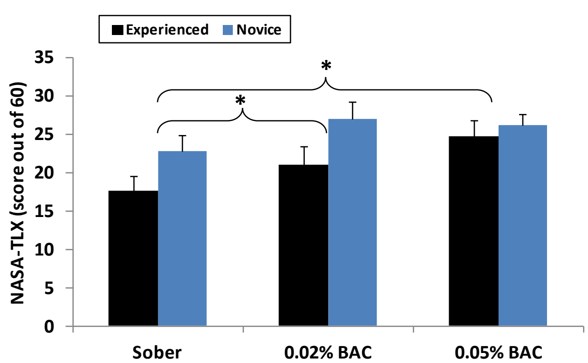



*denotes statistical significance at the 0.05 level

### 3.4 Subjective workload

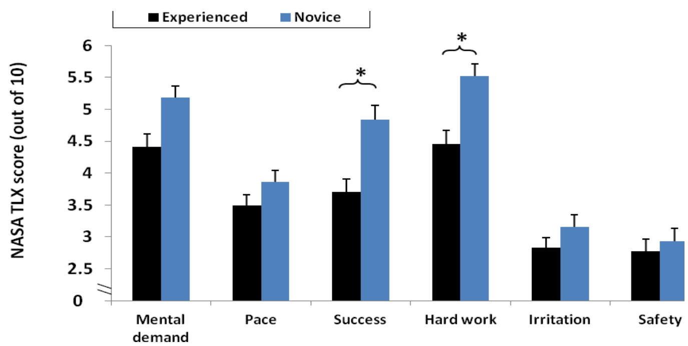
Scores on the modified NASA-TLX were used an indicator of subjective workload. Results were totalled across the six subscales (out of 60) for each participant to provide an overall subjective workload score. There was a significant main effect of Dose on overall subjective workload in the urban scenario, $F(2,76) = 8.30$, $p < .01$, partial $\eta 2 = 0.179$, (Figure 3). Pairwise comparisons showed both alcohol conditions to be associated with significantly greater workload than the zero alcohol condition ($p < 0.05$); however, workload scores for the two alcohol doses did not differ significantly from one another. There was also a non-significant trend towards a main effect of Experience on workload, $F(1,38) = 3.34$, $p = .076$, partial $\eta 2 = 0.081$, suggesting that novice participants (mean = 25.3, s.d. = 7.7) may have experienced greater subjective workload than experienced participants (mean 20.5, s.d.8.8) in this scenario (or they may have simply rated the workload as higher).

**Figure 3: The effect of Dose on subjective workload in the urban road environment (error bars represent standard error)**



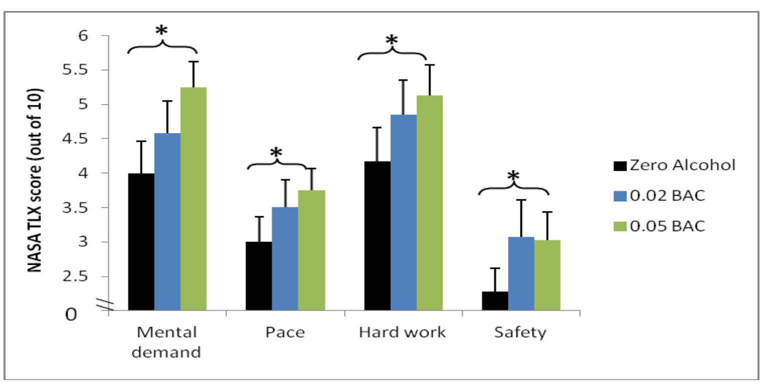

To test any differences in scores on individual NASA-TLX items across the three alcohol doses and between the two experience groups, scores from each road environment were analysed using mixed measures MANOVA**.** In the urban environment, there was a near-significant interaction between Scale and Experience on workload ratings, $F = 0.244$, $p = 0.077$, partial $\eta^2 = 0.244$. Mixed measures ANOVA conducted on each scale item revealed 'success' ($F$ = 8.879, $p$ < .01, partial $\eta^2$ = 0.189) and 'level of hard work to accomplish performance' ($F$ = 4.605, $p$ < .05, partial $\eta^2$ = 0.108) were rated significantly lower (more successful and easier) by experienced riders compared to novice riders (Figure 4).

**Figure 1: Average rating for each NASA-TLX scale item by experience level in the urban environment (bars represent standard error of the mean)**




Main effect results of the MANOVA mirrored those of the overall ANOVA for the urban environment with a main effect of Dose $F$ = 7.61, $p$ <0.01, partial $\eta^2$ = 0.292. Pairwise comparison showed the two alcohol conditions to be associated with significantly higher workload ratings than the sober condition, but not to each other. Mixed measures ANOVA demonstrated Dose to have a significant effect on 'mental demand', $F(2,76)$ = 11.312, $p$ <0.01, partial $\eta^2$ = 0.292, 'pace of the task', $F(2,76)$ = 4.777, $p$ <0.05, partial $\eta^2$ = 0.112, 'hard work' level, $F(2,76)$ = 5.562, $p$ <0.01, partial $\eta^2$ = 0.128, and 'safety', $F(2,76)$ = 4.092, $p$ <0.05, partial $\eta^2$ = 0.097, results are displayed for the significant findings in figure 5.

**Figure 5: Average rating for NASA-TLX scale item by alcohol dose in the urban environment (bars represent standard error of the mean)**




In addition, there was a significant main effect of Scale, $F$ = 17.36, $p$ <0.01, partial $\eta^2$ = 0.719, demonstrating independence of the sub-scale items. Pairwise comparison of scale items showed mental demand not to be significantly different from success or hard work. The pace of the task was different to all other items and safety was not significantly different from irritation.

There were no significant interactions and no significant main effects of Dose or Experience on workload ratings in the rural environment. There was, however, a significant main effect of Scale, F = 17.879, $p$ <0.01, partial $\eta^2$ = 0.730. In this case, pairwise comparison revealed all scale items to be significantly different from one another, apart from: mental demand (which was not significantly different from hard work level), pace of the task (which was not significantly different to success) and irritation (which was not significantly different to safety).

## 4 Discussion

The ingestion of low doses of alcohol (0.02%, and 0.05% BAC) by novice and experienced riders resulted in increases in impairment of some measures of vehicle handling skills and hazard perception compared to a zero alcohol condition. Both novice and experienced participants deviated within the lane significantly more under the 0.05% BAC condition in the urban environment compared to when sober. Response times to a safety-relevant PDT in the rural environment were significantly slower in the 0.05% BAC condition compared to both sober and 0.02% BAC conditions. These effects tended to be most significant at the highest (0.05% BAC) dose. These findings are consistent with previous studies investigating low dose alcohol in motorcyclists (Colburn *et al.* 1993, Creaser *et al.* 2009). Filtness *et al.* (in press) provides a full analysis of all riding performance measures.

Overall NASA-TLX score was observed to increase with alcohol dose in the urban scenario, reflecting the increase in impairment of vehicle handling skills by increased SDLP. Individual subscale scores of success and hard work for the NASA-TLX in the urban scenario were significantly higher for novice participants compared with experienced participants. Although there was no significant difference in SDLP between the two experience groups, the NASA-TLX results suggest that the novice participants experienced greater subjective workload to achieve the same performance outcome in the urban environment, which may indicate that they are better able to compensate for the increased workload than the experienced riders.

Each subscale of the NASA-TLX was analysed to investigate if the main effect of Dose was apparent. This was found to be the case for 'mental demand', 'pace', 'hard work' and 'safety'; however, levels of success and irritation remained constant across Dose conditions. It is possible that Dose did not affect ratings of success because of the nature of the task. The scenarios used were designed to assess subtle impairments in riding performance and not to present a difficult riding condition in which a participant could "fail". As such all participants reached the end of the ride under all Dose conditions which may have lead to consistent ratings of success. As riding performance became impaired it might have been expected that irritation would have increased; however, low dose alcohol has been shown to affect mood, including increasing sleepiness (Ronen *et al.* 2008), which may have counteracted any increasing irritation resulting in a non-significant result. It is possible that success and irritation were not appropriate scales for assessing subjective workload during the current study. In this situation, the multidimensional rating scale is beneficial because the low dose alcohol had varying affect on the different categories of subjective workload. In this case, 'mental demand' followed by 'hard work' showed the greatest increase from sober to 0.05% BAC. This is in line with previous research (Kim *et al.*, 2007), where, although no statistics were provided, 0.05% BAC appeared to have most effect on 'physical demand' (not investigated by the current study) followed by 'effort' (hard work) and 'mental demand'.

The workload sub-scales of the NASA-TLX appear to be measuring distinct aspects of motorcycle riding-related workload as there was a significant main effect of sub-scale in both the urban and rural scenarios. However, post-hoc analysis of the urban scenario revealed that the two subscales not affected by Dose were actually not significantly different from two scales that were significantly affected by Dose. Irritation was not significantly different from safety and success was not significantly different from hard work. The NASA-TLX overall score did not increase with increasing BAC in the rural scenario; this is reflective of riding performance as riding measures were also not affected by Dose in the rural scenario. This is in line with a previous (non-road safety) simulator study, where low dose BAC was only found to increase subjective workload when task performance was impaired (Kim *et al* 2007). However, in the current study reaction time to the PDT did increase. NASA-TLX is sensitive to changes in PDT (Jahn *et al.* 2005) so it is surprising that subjective workload did not increase in the rural road environment in the current study. However, participants in the current study were asked to rate workload in relation to the entire task; it is likely that they were thinking mainly about the riding component and not the PDT. Future studies using similar methodology may benefit from rating subjective workload separately for the main task and for the PDT.

In both urban and rural scenarios there was a significant main effect of scale item in the NASA-TLX MANOVA. This demonstrates that the different scale items are measuring different things. However, in both scenarios post hoc analysis identified that 'mental demand' ratings were not significantly different from 'hard work' and that ratings of 'safety' were not significantly different from those regarding 'irritation'. It has been reported by others that ratings on the 'physical demand' scale item are affected by increased physical demands but not increased mental demands (Mehta & Agnew 2011). It is probable that these current results reflect the nature of the task; because of the simulator protocol there was no physical hard work or compromise to safety. As such, participants may have been relating hard work to mental demand and safety to irritation.

The limitations of the current study should be acknowledged. Riding performance was assessed using a simulator as this is considered to be a safe environment in which to test the effects of alcohol. It is possible that, because participants were in no real danger, they may have ridden in a riskier manner than they would have on real roads and similarly, may have experienced lower subjective workloads. However, use of a repeated measures design should have motivated participants to ride equally safely across the three BAC conditions. The motorcycle was fixed in a static, vertical position, which may also limit the generalizability of the observed results to real world riding. When riding a real motorcycle, steering is achieved through a combination of leaning (tilting) and movement of the handlebars. Due to the impracticalities of enabling tilting of the simulator in a safe manner, it was decided to fix the motorcycle base in place. All participants completed a practice ride prior to the test rides to ensure they were comfortable with the controls of the simulator, however, and none reported any unease. The NASA-TLX was fully explained to participants prior to the simulated ride but participants did not practice using the rating scale. It is possible that results may have been slightly different if participants had prior practice at using this scale.

## 5 Conclusion

Results from the present study have implications for real world motorcycle riding and related road safety policy. Riding performance and hazard perception ability were shown to be impaired by 0.05% BAC, which is the legal limit in many Australasian jurisdictions. The NASA-TLX was sensitive to increasing BAC for the urban but not the rural scenario. Although there was a significant main effect of sub-scale in both scenarios, the individual items were only able to distinguish between alcohol doses in the urban scenario. It is possible that participants may have only considered riding performance (and not PDT performance) when making NASA-TLX ratings. Workload ratings were found to be higher in novice participants, compared to experienced participants, for the same level of performance. Overall, the NASA-TLX appears to be a useful measure of subjective workload for simulated motorcycle riding and is sensitive to impairments in riding performance due to alcohol and differences between experience levels.

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