Student Drivers the Morning After Drinking: A Willingness to Violate Road Rules Despite Typical Visual Attention

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Highlights:

- A naturalistic design to investigate the morning after effects of alcohol on students' driving
- In the morning after condition drivers were more likely to violate speed limits
- Unlike previous research, no differences were found in drivers' visual attention on the road

29 **Abstract**

30

31 Substantial research has investigated the effects of alcohol consumption on cognitive functions.
32 However, little research has been conducted which examines the effects of evening alcohol
33 consumption on next morning driving performance. The current study investigated the effects of a
34 night out involving drinking on students' morning after simulator driving performance, conducted as
35 a within-subject naturalistic study. Thirty student drivers between the ages of 19-23 participated.
36 Driving performance measures and eye movements were recorded while participants performed a
37 short-simulated motorway driving task between 9-10 a.m., both after an evening consuming alcohol
38 and on a control morning (no alcohol consumed). The task required drivers to respond to a speed
39 limit and hazardous vehicle, with driving performance being compared over four road sections (speed
40 reduction section, hazard section and two control sections). Sleep duration the night before the drives
41 and breath alcohol content immediately before each drive were recorded. The main findings indicate
42 that despite the majority of drivers being legal to drive, in the morning after condition drivers tended
43 to travel at higher maximum speeds, travel for a longer period of time over the speed limit and
44 demonstrate a larger variance in speed. However, no differences were found in visual attention
45 measures. These findings suggest that the morning after drinking is associated with dangerous
46 driving behaviour in terms of violating road rules even when no deficits in attention are observed.
47 The implications for road safety are discussed, focusing on informative programmes to educate
48 drivers of the dangers associated with morning after driving.

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50 *Keywords: Alcohol; Driving; Violations; Inattention*

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1. Introduction.

From past research it is evident that driving performance is impaired by alcohol even in low dosage (Ogden & Moskowitz, 2004; Weafer & Fillmore, 2012), with alcohol usage in the general night driving population corresponding to increases in alcohol related crashes (Carlson, 1972). Alcohol consumption results in a particularly high risk of road crashes and fatalities that are reflected in national statistics such as the finding that in 2016, 13% of all fatalities on roads in the UK were associated with alcohol consumption (DfT, 2017a).

The impairments that occur after the consumption of alcohol impact a number of cognitive functions including motor control, planning, tracking, attention, and psychomotor performance (Fogarty & Vogel-Sprott, 2002). Driving, a complex cognitive task, has been shown to be impaired by alcohol across a number of measures including lateral vehicle control such as standard deviation of lateral position (SDLP) (Mets et al., 2011, Verster & Roth, 2014) and longitudinal measures including mean speed (Mets et al., 2011; McCartney, Desbrow, & Irwin, 2017), and standard deviation of speed (SDSP) (Marczinski, Harrison, & Fillmore, 2008). In a meta-analysis and systematic review of seventeen studies investigating the effects of alcohol on simulated driving, Irwin et al. (2017) identified that both SDSP and SDLP are the two most sensitive indicators of driving impairment however, earlier research indicated that SDLP was the most stable and sensitive measure of detecting driving impairment from alcohol intake (Roth & Verster, 2011; Verster & Roth, 2014). The driver's ability to maintain a stable lane position and maintain a safe speed are imperative to driver safety, since greater deviation increases chances of crossing into the paths of other vehicles or drifting off the road (Verster & Roth, 2014), as well as speed variance influencing crash risk and crash severity (Reed & Green, 1999). Additionally, alcohol has also been seen to have sedative properties, where it has been proposed that it may initiate disinhibitory behaviours. This had been thought to explain risky driving impairments caused by alcohol including unnecessary lane changes, speeding, and ignoring traffic signals (Fillmore et al., 2008; Weafer & Fillmore, 2016).

80 While the immediate deleterious effects of alcohol on cognitive performance are reasonably well
81 quantified, relatively few studies have investigated the ‘morning after’ detriment that previous alcohol
82 consumption may have on everyday activities such as driving related skills and abilities (Stephens,
83 2008; Ling et al., 2010). This may be particularly important since reviews concerning traffic accidents
84 at different times of day have found early morning driving to be particularly dangerous even when
85 accidents due to alcohol are removed from the dataset (Akerstedt, Kecklund & Hörte, 2001).

86

87 **1.1. The Morning After Effects of Alcohol on Driving**

88

89 The alcohol hangover is the most commonly reported symptom of heavy drinking the night before.
90 However, there has been dispute as to whether hangovers begin at a low declining blood alcohol
91 concentration (BAC) or when reaching zero (Verster et al., 2010). There is now consensus regarding
92 the definition for alcohol hangover, with an alcohol hangover referring to a combination of mental and
93 physical symptoms experienced the day after an episode of excess drinking, starting when BAC
94 approaches zero (van Schrojenstein Lantman et al., 2016; Verster et al., 2017). Previous research has
95 suggested that there is a biphasic effect in cognitive impairments as a function of the BAC, forming an
96 inverted-U- shaped curve (Starkey & Charlton, 2014; Charlton & Starkey, 2015). Specific BACs on
97 the increasing limb of this curve may have different behavioural effects to equivalent BACs measured
98 a few hours later on the decreasing limb of the same curve. As individuals’ BACs move on the
99 descending limb of the BAC curve, motor coordination is known to recover more quickly than
100 cognitive abilities. Contextually, this may result in drivers perceiving an improvement in visuomotor
101 skills and a feeling of reduced intoxication while being unknowingly still impaired (Cromer, Cromer,
102 Maruff, & Snyder, 2010; Marcziński & Fillmore, 2009). Charlton and Starkey (2013) describe the
103 impairments that continue to be observed on the descending limb as acute protracted errors (APEs),
104 which can be seen in participants in driving at higher maximum speeds and producing a greater
105 number of edge line crossings when participants’ BAC had reached a level on the descending limb

106 compared to the same BAC on the ascending limb. The descending limb of the BAC curve is of
107 particular importance as it is likely that decisions to drive are made when drivers are in this state which
108 can often persist to the beginnings of a hangover (Weafer & Fillmore, 2016). Previous research has
109 found that the effects of an alcohol hangover on general cognitive tasks are larger for participants in
110 hungover conditions compared to individuals who were still intoxicated (McKinney et al., 2012).
111 However, to contextualise this research it is imperative that researchers use actual driving tasks as
112 opposed to tests on general cognitive abilities to understand next day effects of alcohol.

113

114 One of the few studies focusing on the effects of a hangover on driving involved volunteers aged 22-
115 46 and found that acute intoxication severely impaired driving performance but to a much lesser
116 degree the following morning (Törnros & Laurell, 1991). This study was conducted in a driving
117 simulator, however, it is not clear to what extent these tests related to normal driving, as participants
118 were asked to complete the drive in as short time as possible, resembling race track driving more than
119 typical driving. More recent evidence from Verster et al. (2014a) involved a one-hour highway
120 simulated drive comparing the impairments in driving behaviour after drinking the night before and a
121 control day. Results found that although blood alcohol concentrations (BAC) was zero, driving was
122 significantly impaired when participants were hungover relative to the control drive for lateral
123 measures of driving, exhibited through increased SDLP as well as driving being self-reported as
124 significantly poorer by the participants. The researchers found no differences in longitudinal measures
125 such as standard deviation of speed (SDSP), implicating impaired attention as the fundamental
126 mechanism to explain the observed effects. This one-hour simulated drive is representative of highway
127 driving which requires sustained attention and vigilance, however, this task is in contrast to the most
128 common driving routes in the UK in terms of the driving task and task length. The 2016 National
129 Travel Survey reported the average duration per car driver trip as 22 minutes (DFT, 2017a), with the
130 majority of these journeys requiring city driving.

131

132 In addition to these findings, Verster et al. (2014b), gave reason to believe that driving the morning
133 after alcohol consumption is a growing concern. From interviews of 343 professional Dutch truck
134 drivers, it was found that more than half admitted to driving with a hangover (56.4%), and felt their
135 driving was significantly worse compared to no alcohol days. This illustrates that driving with a
136 hangover may be more common than initially expected and therefore, experimental research needs to
137 further investigate the consequences of morning after driving on on-road performance.

138

139 **1.2.The Morning After Effects of Sleep deprivation and Alcohol on Driving**

140 Sleepiness is not only known to independently cause impairments equivalent to that of alcohol
141 (Williamson & Feyer, 2000), but has also been found to exacerbate the negative effects of alcohol
142 (Banks et al., 2004) as well as cause engagement in risky behaviours (Orzel- Gryglewska, 2010). A
143 more recent study has found that reduced sleep is associated with more severe alcohol hangovers (van
144 Schrojenstein Lantman et al., 2017). Sleepiness has been seen to seriously impair driving performance
145 however, unlike the effects of alcohol which can be observed after a small consumption, changes in
146 behaviour as a result of sleepiness have only been reported when high levels of fatigue are reached
147 (Ingre et al., 2006), with much research investigating prolonged wakefulness rather than acute sleep
148 deprivation. From the few studies that have investigated the effect of partial sleep deprivation on
149 participants' driving performance, it has been found that sleep deprivation significantly affects driving
150 measures such as standard deviation of lateral position (SDLP) in both a simulation environment
151 (Otmani et al., 2005) and on-road (Jongen et al., 2015), mean speed (Peters et al., 1999), as well as
152 causing a narrowing of visual search, hindering the processing of peripheral signals (Rogé et al.,
153 2003).

154 The most commonly reported measure impaired from fatigue is the ability to maintain appropriate
155 lateral position (SDLP) (O'Hanlon & Kelly, 1974; Ingre et al., 2006). Theoretically, this appears to
156 associate impairment through fatigue with inattention which has been argued to be the most important
157 type of human error relating to crashes on the road (Gharagozlou et al., 2015). Maintaining appropriate

158 lane position is a particularly sensitive measure of driver fatigue as it requires the highest degree of
159 steadiness, and fatigue is known to slow motor functions and reactions, both of which reduce the
160 ability to maintain lane position (Ingre et al., 2006). This slowing in functions has also been found to
161 lead to diminished processing of information which can impair responses to hazardous situations
162 (Gharagozlou et al., 2015), indicating that sleep deprivation can lead to dangerous impairments in
163 driving by affecting both sustained attention and vigilance.

164 Measures of drivers' eye movements can provide useful insight into the allocation of attention and
165 vigilance (Deubel & Schneider, 1996; Velichkovsky et al., 2002). Eye movements and fatigue have
166 been previously investigated, with fatigued participants having been reported to exhibit narrower gaze
167 as a result of reduced vigilance leading to impaired information processing (Ji & Yang, 2002). Eye
168 movements have also been seen to be affected by alcohol, however, this has not been as extensively
169 researched. Ogden and Moskowitz (2004) state that alcohol causes a slowing in the processing of
170 surrounding information, resulting in longer fixations on objects in order to perceive them.
171 Consequently, effects of alcohol and sleep deprivation on eye movements may elicit similar
172 impairments in attention and together culminate in a potentially dangerous combination on the road.

173
174 Some research has been conducted observing the combined effects of both prolonged wakefulness and
175 alcohol consumption on simulated driving performance. Social drinking is often associated with
176 individuals going to bed later than normal, so in normal contexts sleepiness may routinely exacerbate
177 these physiological effects of recent alcohol consumption (Hershner & Chervin, 2014). Arnedt et al.,
178 (2000) compared measures of subjective sleepiness, simulated driving performance and drivers' ability
179 to judge impairment. Subjective sleepiness was measured using the Stanford Sleepiness Scale, before
180 and after each driving session. Findings suggested that the combination of prolonged wakefulness and
181 alcohol consumption produced greater impairment in simulated driving performance than each factor
182 alone, increasing SDLP and SDSP. Performance was also seen to decrease with time-on-task.

183

184 1.3. Naturalistic Studies

185

186 Many of the previously discussed studies investigating the effects of alcohol consumption and sleep
187 deviation on driving performance have used laboratory based experimental designs, whereby these
188 parameters have been systematically counterbalanced. This drinking experience contrasts with natural
189 drinking environments (Brookhuis, 2004), and previous research has suggested that no constraints on
190 behaviour is best practice for studying next day effects of alcohol (Prat et al., 2008). For this reason,
191 research efforts have been directed towards investigating the effects of alcohol in naturalistic settings,
192 investigating cognitive functioning in a social setting where alcohol consumption is self-regulated.
193 Degia et al., (2006) found that when using portable testing equipment at music festivals, alcohol
194 impaired both divided and sustained attention. Moreover, Tiplady and Degia (2004) found overall
195 impaired performance on a handheld forced choice device, which is thought to measure attention,
196 working memory and size estimation; a tester used for detecting driver impairment on the roadside.
197 This device has been seen to be sensitive to the effects of alcohol both in natural settings and in the lab
198 (Tiplady et al., 2005).

199

200 These naturalistic studies have been furthered by investigating the effects of a naturally occurring
201 hangover, when the consumption of alcohol has been under personal control (McKinney and Coyle,
202 2004). These studies have revealed that under naturalistic conditions, participants' performance is still
203 impaired the morning after alcohol consumption, with this being demonstrated in cognitive functions
204 such as memory, psychomotor performance, and attention when using tasks such as free recall and
205 selective attention tests (McKinney and Coyle, 2004), speed and capacity language processing tests
206 (Finnigan et al., 2005), and mood and anxiety tests on students (McKinney and Coyle, 2005). As
207 aforementioned, one of the only studies to investigate the morning after effect of alcohol consumption
208 on driving directly, also used a naturalistic study design (Verster et al., 2014a).

209

210 **1.4. The Student Population**

211 University students are a population at risk of binge drinking behaviour and exceeding weekly
212 consumption guidelines (e.g. 14 units in the UK; NHS, 2018). Recently, a large-scale Students and
213 Alcohol Survey conducted by National Union of Students (NUS) revealed that 79% of students
214 (n=1240) agreed that drinking and getting drunk is part of university culture (NUS, 2017). This
215 behaviour is of particular concern to the transport industry since intoxicated driving is renowned for
216 having fatal consequences (World Health Organisation, 2016). Encouragingly, the number of fatal or
217 serious crashes involving young drivers caused by drink driving has decreased significantly over the
218 last 14 years in the UK, with 450 young drivers (17-24 years old) involved in a fatal crash while over
219 the alcohol limit in 2001 compared to 170 in 2015 (DfT, 2017b). However, there is concern that a
220 considerable amount of drink driving or driving while still impaired from the effects of alcohol may be
221 occurring unrecorded (MacDonald, 1999). Moreover, for young drivers in particular, sleep deprivation
222 has been found to increase risk of crashing, evident in one prospective study on more than nineteen
223 thousand 17 to 24-year-old drivers in Australia, which found that those who sleep six or fewer hours
224 were more likely to crash, even when driving exposure was controlled (Martiniuk et al., 2013).

225 Previous research has also found that young drivers' willingness to drive under the influence of
226 alcohol is high, particularly with young drivers who often binge drink. It has been found that binge
227 drinkers report less subjective sleepiness and convey a greater perceived ability to drive compared with
228 non-binge drinkers, despite all participants showing greater difficulty maintaining lane position and
229 appropriate speed in addition to making multiple driving errors when intoxicated compared to
230 performance in a placebo condition (Marczinski, Harrison & Fillmore, 2008). The Royal Automobile
231 Club (RAC) motoring report 2017 revealed that, out of a representative sample of 1700 drivers, 16%
232 of motorists admitted to drink-driving, and 10% of motorists believed it occurred as a result of still
233 being over the limit the morning after drinking (RAC, 2017). The RAC estimate that this could equate
234 to five million motorists nationally who think they have driven over the limit, with the majority

235 believing it occurred the morning after. Since undergraduate students are likely to have morning
236 university commitments following a commonly occurring night out, there is potential that they may
237 constitute a significant part of the RAC's 10% of people driving in the morning over the limit.
238

239 **1.5. The Current Study**

240 Driving impairments from alcohol consumption and sleep deprivation are similarly natured,
241 particularly apparent in terms of diminished vigilance and attention, and have been found to persist to
242 the morning after (Verster et al., 2014a). The present study had an ecologically representative testing
243 protocol, with no constraints posed on the participants' drinking and sleeping behaviour. This involved
244 monitoring a sample of students consuming their usual type of alcoholic beverage in their chosen
245 social situation. As many factors can influence morning after impairments such as physical activity
246 during the night out, drinking rate, venue and smoking, it is extremely difficult to control all of these
247 factors and therefore it is questionable to what extent controlled procedures measure realistic effects.
248 In contrast, a naturalistic design allows participants to consume alcohol unsupervised, with no
249 constraints on the amount of alcoholic drinks and type of beverage as well as sleeping in their own
250 environment of choice. This provides the opportunity to assess the likely impacts of typical social
251 drinking with the potentially associated sleep disruption in a student sample on their normal driving
252 behaviour the morning after.

253 The present study focuses on driving performance in a young student population between the ages of
254 19-23, the morning after a university night out. Previous research and crash statistics suggest that this
255 is a high-risk target group and a sample who would be expected to engage in early morning university
256 commitments, which may involve the need to drive. The current study fills a gap in the literature as it
257 is the first to explore the morning after effects of students' unrestricted social drinking on simulated
258 driving performance compared to the morning after a control night with normal sleep and no alcohol
259 consumption.

260

261 1.5.1. Hypotheses

262

263 The current naturalistic study was conducted to investigate whether undergraduate students were
264 impaired at simulator driving the morning after a night out social drinking, compared to a control
265 night. Based on previous research, it is predicted that driving will be significantly impaired the
266 morning after compared to a control day (no alcohol consumed). It is predicted that the morning after
267 condition will adopt significantly higher mean speeds, higher maximum speeds, break the speed limit
268 for a higher percentage of time, and have a larger SDSP and SDLP compared to the control condition.
269 It is also predicted that participants' response time to everyday driving hazards will be significantly
270 slower than in the control condition. Finally, it is predicted that drivers will have narrower visual
271 attention in morning after condition, demonstrated by reduced standard deviation of horizontal fixation
272 locations and vertical fixation locations, as well as longer mean fixation durations.

273

274 2. **Methods.**

275

276 2.1. Design

277 The experiment used a within subjects design with all participants completing a simulated motorway
278 drive the 'morning after' a night of social drinking and a control drive, after a night involving no
279 alcohol consumption. These conditions were counterbalanced to control for carry over effects of a
280 repeated task, with 15 participants having completed the first drive the 'morning after' and 15 of the
281 participants completing the control drive first.

282

283 The experimental motorway drives were split into 8 road sections, shown in Table 1 below. For the
284 analysis, 4 road sections of equal length were used, each approximately 1000m in distance. The 4 road
285 sections not used for analysis served as an initial practice drive and padded out the road sections of

286 interest. The first section was ‘Control Section 1’, where participants were able to drive along the
 287 motorway at an instructed speed of 65 mph. The second ‘Speed Reduction Section’ began when an
 288 overhead gantry sign was in sight, instructing participants to slow down to 40 mph due to roadworks
 289 ahead. This section ended when a delimit gantry was in sight, allowing participants to return to 65
 290 mph. The third road section, ‘Control Section 2’, allowed participants to return to their normal
 291 motorway speed of around 65mph. Finally, the fourth ‘Hazard Section’ began when a vehicle situated
 292 on the hard shoulder was in sight (either a motorbike or car). This vehicle pulled out into the path of
 293 the participant’s vehicle as they approached.

294

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296 **Table 1:** Shows the 8 road sections of the motorway drive and their distances. Road sections in white
 297 were the 4 equal sections used for analysis and the grey sections were distances driven before and
 298 between sections that were not used in the main analysis.

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	Road Section	Distance
	Start of Drive - Control Section 1 Start	5407 m
Control Section 1	1000 m
	Control section 1 End - Speed Reduction Section Start	201 m
Speed Reduction Section	1000 m
	Speed Reduction Section End- Control Section 2 Start	23 m
Control Section 2	1000 m
	Control Section 2 End- Hazard Section Start	191 m
Hazard Section	1000m

313 2.2.Participants

314 Full ethical approval was granted prior to conducting the experiment by the University of Nottingham
315 Psychology Ethics Committee. A power analysis was conducted using the software package, G*Power
316 3.1 (Buchner, Faul & Erdfelder, 1992). The overall sample size of 30 was enough to provide more than
317 adequate power ($>.99$) to detect a large within-subjects effect ($d = .8$) or provide moderate power ($>$
318 $.75$) to detect a medium effect size ($d = .5$). Thirty participants completed both the morning after and
319 control drives: 10 males and 20 females, with ages ranging from 19 to 23 years ($M = 20.9$, $SD = 1.0$).
320 All participants were recruited through advertisement at the University of Nottingham and received a
321 £10 inconvenience allowance. All participants were students who were known to be socialising the
322 night before the experimental condition, enough to assume a next morning alcohol hangover. All
323 participants had a full British driving licence, with years licenced ranging from 1-6 years ($M = 3.33$,
324 $SD = 1.40$), with their annual mileage ranging from 0-10000 miles ($M = 3133.33$, $SD = 2747.83$). An
325 additional two participants completed a screening drive, however, as they reported symptoms of
326 simulator sickness during screening they were not included in the main experiment.

327

328 2.3.Materials/Apparatus

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330 Due to the experiment having multiple stages, participants had to complete a separate information
331 sheet and consent form for the screening phase and the experimental drives. The screening phase
332 information sheet explicitly explained the purpose of this stage and, importantly, if they felt any
333 discomfort in the driving simulator they should end the experiment immediately. The information
334 sheet for the experimental drives explicitly explained what the driving task involved, stating two
335 important specific requirements that participants had to adhere to when taking part in this experiment.
336 Firstly, it highlighted that participants should not drive or cycle to or from the experiment due to
337 potential alcohol impairment. Secondly, it required that participants did not drive for 30 minutes after
338 taking part in any phase of the experiment due to the simulation environment having potential carry-

339 over effects on driving on real roads. Standard simulator sickness questionnaires (Kennedy et al.,
340 1993) were filled out by participants before and after the screening drive and the two experimental
341 drives to check for signs of simulator sickness.

342

343 Participants completed an ‘Alcohol Consumption and Sleep Questionnaire’ prior to both experimental
344 drives which included self-reported sleep duration, units of alcohol consumed the night before and
345 time of their first and last drink. Subjective sleepiness was also scored using the Stanford Sleepiness
346 Scale ‘Alertness Test’ (Shahid, Wilkinson, Marcu & Shapiro, 2012), which was also completed prior
347 to each drive. This was a self-rating scale which was used to quantify sleepiness, comprising of a
348 seven-point Likert-type scale which had descriptors ranging from “feeling active, vital alert, or wide
349 awake” (score = 1) to “no longer fighting sleep, sleep onset soon and having dream-like thoughts”
350 (score = 7).

351 Prior to each drive, a Dräger Alcotest 6810 breathalyser device (Dräger Safety, Germany) was used to
352 measure participants’ breath alcohol concentration (BrAC). The breath alcohol level limit in England
353 is 35 microgrammes of alcohol per 100 millilitres of breath, as this has been seen to increase reaction
354 times and decrease attention (Grant et al., 2000). In addition, the night before each experimental drive,
355 sleep duration was measured objectively using an actigraphy Fitbit flex activity tracker. This device
356 was worn on the wrist of the participant to track movement while sleeping, with software translating
357 these movements into periods of sleep and wake, outputting actual sleep duration in hours and
358 minutes.

359 The driving scenarios were performed using Nottingham Integrated Transport and Environment
360 simulation (NITES) facility’s medium fidelity, fixed based driving simulator (NITES 2). The simulator
361 consisted of a five-metre diameter hemi-cylindrical screen, subtending 180-degrees of the visual field,
362 and included a rear display screen on a 36-inch LCD television. The fixed based driving rig consisted
363 of a force feedback steering system, adjustable seat, and a dashboard that included a steering wheel

364 and speedometer. There was also a gear lever, brake, clutch and accelerator pedal for vehicle control.
365 The rig was faced centrally towards the 180 degrees of visual field. The driving scenarios are formed
366 on the screen using three projectors, allowing the driver to see the road from the driver's perspective.
367 The scenarios are run using XPI simulation software (XPI Simulation, London, UK), generating
368 realistic roadway scenery. The experimental motorway drive aimed to resemble a real-world motorway
369 scenario. Participants' eye movements were also tracked continuously throughout their drives, using
370 two linked FaceLAB 5.0 eye tracking systems (four cameras and two infrared sources), allowing
371 participants' eye movements to be tracked continuously over a range of approximately 90 degrees of
372 forward visual angle.

373

374 **2.4.Procedure**

375

376 Participants were approached to take part in the study around a week before the intended night out. Up
377 to a week before the first experimental drive, participants were asked to partake in a screening drive to
378 check for any signs of simulator sickness. This stage consisted of a short drive that lasted around 5
379 minutes following a route that contained both straight roads and corners. A simulator sickness
380 questionnaire was completed before and after the screening drive to look for any significant changes
381 on any of the items. Participants who did not suffer from simulator sickness were asked to take part in
382 the main experimental study.

383

384 At this point, participants with no signs of simulator sickness were given a second information sheet
385 and consent form explaining what the main study involved and the necessary information regarding the
386 sleep tracker. Participants were then given the Fitbit flex activity tracker and told to wear this device
387 until they returned the next morning. It was also requested that participants keep track of roughly what
388 time they went to bed and awoke the following morning. For careful counterbalancing, fifteen of the

389 participants completed their first motorway drive after a night of socialising, while fifteen of the
390 participants took part in their first drive after a control night without socialising.

391

392 For the main task, participants visited NITES 2 between 9 and 10 a.m. the following morning after
393 either the control or socialising night. Firstly, all participants were breathalysed, recording their BrAC
394 readings. They were then asked to fill out the ‘Stanford Sleepiness Scale’ and ‘Alcohol Consumption
395 and Sleep Questionnaire’ before the drive. In addition, participants were also asked to fill out a
396 simulator sickness questionnaire before and after the drive.

397

398 Participants then made themselves comfortable in the simulator and the eye trackers were calibrated
399 for each individual to record their eye movements. The experimenter read out the following systematic
400 instructions to each participant before each drive; ‘When completing the drive, you should keep in the
401 left-hand lane whenever possible at a speed of 65mph, unless instructed otherwise’. Following these
402 instructions, participants then completed a motorway drive that lasted around 15 minutes. A motorway
403 drive was purposely chosen as this should have been a fairly easy task for all participants.

404

405 Each drive contained two hazards. In both drives, the motorway contained a ‘Speed Reduction
406 Section’ which was indicated by an overhead gantry instructing participants to slow down to 40 mph
407 due to roadworks ahead. Later participants encountered a delimit sign on a gantry indicating that they
408 were able to return to normal speed. A second hazard was designed to surprise participants and cause
409 them to brake or swerve to avoid a collision. Depending on the counterbalanced condition, in the first
410 drive a car parked in the hard shoulder pulled out in front of the participant’s vehicle. In the second
411 drive at the exact same point, a motorbike pulled out of the hard shoulder in front of the vehicle. The
412 opposite order applied for half of the participants. From the point at which the hazard was first visible,
413 the participant’s time to respond to the hazard was measured.

414

415 Participants returned within a week to complete the second drive. The fifteen participants who
416 completed their first drive after a control day then went out socialising, while the other fifteen did not
417 and then participated in their control drive. The same procedure was carried out for the second drive.
418 At the end of all sessions, participants were given their inconvenience allowance and a debrief
419 document to take away with them.

420

421 **3. Results.**

422 In terms of the criterion for reporting findings, all significant results ($p < .05$, two-tailed) will be
423 reported. Where non-significant results represent at least a medium effect size ($d \geq 0.5$, $p_n^2 \geq 0.09$) or
424 are theoretically important they will be included in square brackets []. Where within subjects factors
425 include three levels, Mauchly's test of sphericity has been used and in cases where a significant breach
426 of sphericity was detected significance testing has been conducted using Greenhouse-Geisser adjusted
427 degrees of freedom. Occasions where this has been done are indicated by the use of decimal places in
428 the reported degrees of freedom.

429

430 **3.1. Objective Sleep Actigraphy Measures**

431 All thirty participants' sleep data were analysed. A paired samples t- tests was conducted to test for
432 significant differences in sleep duration between the Control and Morning After condition. Sleep
433 Duration was significantly lower in the Morning After condition ($M = 4.63$ hours, $SD = 1.21$), compared
434 to the Control condition ($M = 7.32$ hours, $SD = 1.00$) ($t(29) = 9.87$; $p < .001$, $d = 1.79$).

435

436 **3.2. Subjective Sleep Measures**

437 The majority of participants disclosed their average hours slept a night to be between 6-8 hours. In
438 terms of their subjective self-report sleep duration on the two experimental nights, this was

439 significantly lower in the Morning After condition ($M=4.81$, $SD=1.21$), compared to the control
440 condition ($M=7.59$, $SD=1.16$) ($t(29) = 9.20$; $p<.001$, $d=1.68$).

441 Subjective sleepiness on the Stanford Sleepiness scale was significantly higher in the Morning After
442 condition ($M=4.33$, $SD=1.15$), compared to the Control condition ($M=2.03$, $SD=.85$) ($t(15) = 8.60$;
443 $p<.001$, $d=1.58$).

444

445 **3.3. BrAC and Subjective Alcohol Consumption**

446 In terms of measurable BrAC at the time of testing, 28 participants were under the legal BrAC limits in
447 both conditions (legal limits=35 microgrammes of alcohol per 100 milliliters of breath), whereas 2
448 participants in the morning after condition were over this limit, with readings of 52 and 54. All
449 participants had a BrAC reading of 0 in the Control condition. In the Morning After condition readings
450 ranged from 0 to 54 ($m= 9.57$).

451

452 In regards to self-reported units of consumed alcohol, these are reported against BrAC readings for
453 each condition in Table 2 below. It is immediately obvious that there is no simple relationship between
454 subjective units of alcohol consumed and BrAC for the self-reports of between 8 and 20 units.

455 Although the five participants with the lowest self-reported alcohol consumptions did indeed have no
456 breath alcohol at the time of testing, after this the relationship breaks down. From the seven
457 participants who reported drinking between 8-12 units the evening before, their breathalyser reading
458 ranged from 0-28, providing an average of 11.9. This was extremely high compared to greater
459 subjective unit categories of 12-16 and 16 to 20, however, again the 8 participants who self-reported
460 drinking the most did have some of the highest breath alcohol readings, including the two participants
461 who were over the legal limit.

462 ***Table 2:*** The number of participants who fall into each of the unit categories in terms of self-reported
463 number of units of alcohol consumed for both conditions, as well as the mean BrAC for those
participants in each of the unit categories.

Self-Reported Units of Alcohol Consumed	Condition			
	Control		Morning After	
	Mean Breath		Mean Breath	
	<i>n</i>	Alcohol	<i>n</i>	Alcohol
0-4	30	0	0	-
4-8	-	-	5	0
8-12	-	-	7	11.9
12-16	-	-	5	3.6
16-20	-	-	5	5.2
20+	-	-	8	20.0

464

465 A multiple logistic regression was conducted with the outcome variable of objective BrAC for the
 466 morning after condition, using the predictor variables of objective sleep duration, subjective sleep
 467 duration, Stanford Sleepiness Scale ratings (SSS), subjective alcohol consumption and reported time of
 468 last drink. For BrAC it was found that by adding five key predictor variables (the four above, plus
 469 objective sleep duration), a significant regression equation was found ($F(5, 29) = 5.074, p < .01$), with
 470 an R^2 of .514. The significant contributions to the model were made by SSS ($p < .01$) and time of last
 471 drink ($p < .05$). It was found that participants who had their last drink later in the evening, and reported
 472 more subjective sleepiness on the Stanford Sleepiness Scale had more residual breath alcohol content
 473 at the time of testing.

474

475 3.4. Driving Performance

476 In terms of analysing driving performance, a 2x3 repeated measures ANOVA was conducted on each
 477 driving measure with factors of Condition (Control vs. Morning After) and Road Sections (Control

478 Section 1, Speed Reduction Section and Control Section 2). For the factor of Road Section two a
479 priori orthogonal contrasts have been specified that first compare behaviour in the Speed Reduction
480 Section with that in the other two control road sections to assess any overall effect of the new speed
481 limit, and secondly compare performance in Control Section 1 with performance in Control Section 2
482 to assess any overall changes in performance over time. The fourth 'Hazard Section' was analysed
483 separately with paired samples t-tests comparing general driving behaviour between the Control and
484 Morning After conditions and including additional measures to assess participants' hazard reaction
485 times. All 30 participants' road data were analysed.

486
487 Six dependent measures were used to characterise driving behaviour - mean speed, maximum speed,
488 percentage of time spent of the speed limit (70mph), standard deviation of speed (SDSP), mean
489 absolute acceleration and standard deviation of lane position (SDLP). Mean speed (mph) was the
490 average speed of drivers over each road section. Maximum speed (mph) was the highest speed each
491 participant reached in each road section. The percentage of time spent over the speed limit was based
492 on the total time in each road section that exceeded the motorway speed limit of 70mph. SDSP (mph)
493 was the chosen measure of speed variance which provides an overall measure of variance within each
494 road section. To provide a measure of the sharpness of this change, change in speed between
495 successive samples in each road section was calculated and the absolute value of this change
496 (acceleration or deceleration) was averaged over the road section, calculated as mean acceleration.
497 Finally, in regards to SDLP this was calculated as the square root of the lateral position variance of the
498 driving simulator vehicle in the four road sections.

499
500 For mean speed, there was a significant main effect of Road Section, $F(1.569, 45.508) = 9.014, p < .001,$
501 $\eta^2 = .237$, see Figure 1a, with contrasts showing speeds being significantly lower in the speed
502 reduction section compared to the control sections, $F(1, 29) = 11.644, p < .01, \eta^2 = .286$.

503

504 For maximum speeds, there was a significant main effect of Condition, $F(1,29) = 4.925, p < .05, \eta^2 =$
 505 $.145$, indicating that drivers travelled at high maximum speeds in the morning after condition
 506 ($m = 68.84$ mph) compared to the control condition ($m = 67.05$ mph), see Figure 1b. For the hazard
 507 section, the paired samples t-test found that there was a marginal tendency have higher maximum
 508 speeds morning after condition ($m = 71.02$ mph), compared to the control condition ($m = 68.58$ mph) [t
 509 $(19) = 1.769; p = .087, d = 0.32$].
 510
 511 For percentage of time spent over the speed limit, there was a main effect of Condition, $F(1,29)$
 512 $= 7.875, p < .01, \eta^2 = .214$, indicating that drivers spend a larger percentage of time over the speed limit
 513 in the morning after condition ($m = 15.70\%$) compared to in the control condition ($m = 5.69\%$). For the
 514 hazard section, the paired samples t-test found that the percentage of time over the speed limit was
 515 significantly higher in the morning after condition ($m = 21.63\%$), compared to the control condition
 516 ($m = 11.09\%$) ($t(29) = 2.270; p < .05, d = 0.41$), see Figure 1c.
 517
 518 In regards to SDSP, there was a significant effect of Condition, $F(1,29) = 5.117, p < .05, \eta^2 = .150$,
 519 indicating that drivers had a larger speed variance in the morning after condition ($m = 3.46$ mph)
 520 compared to the control condition ($m = 2.72$ mph). There was a significant main effect of Road Section,
 521 $F(1.331, 38.606) = 15.695, p < .001, \eta^2 = .351$, with contrasts revealing that speed variance was higher in
 522 the speed reduction section than the other two control sections, $F(1,29) = 17.227, p < .001, \eta^2 = .373$,
 523 and a significant increase in variance from the first control section to the second control section, F
 524 $(1,29) = 7.503, p < .05, \eta^2 = .206$, See Figure 1d.
 525
 526 For absolute mean acceleration (ms^{-2}) there was a marginal main effect of Condition [$F(1,29) = 3.590$,
 527 $p = .068, \eta^2 = .110$] indicating that there was a sharper change in speed in the morning after condition
 528 ($m = .365$) compared to the control condition ($m = .295$). There was also a main effect of Road Section, F
 529 $(1.209, 35.048) = 6.226, p < .05, \eta^2 = .177$, with contrasts revealing an overall increase in absolute

530 acceleration from the first control section to the second, $F(1,29) = 12.685$, $p < .001$, $\eta^2 = .304$, and an
531 increase in the speed reduction section compared to the two control sections, $F(1,29) = 5.483$, $p < .05$,
532 $\eta^2 = .159$, See Figure 1e.

533

534 In regards to SDLP, there was a significant main effect of Road Section, $F(2, 58) = 337.687$, $p < .001$,
535 $\eta^2 = .921$, with contrasts showing an overall increase in SDLP from the first control section to the
536 second, $F(1,29) = 703.902$, $p < .001$, $\eta^2 = .960$, and a reduction in SDLP in the speed reduction section
537 compared to the two control sections, $F(1,29) = 95.688$, $p < .001$, $\eta^2 = .767$, see Figure 1f.

538

539 Participants' response times to the hazard were also analysed. The criterion used to determine response
540 time was the time from the start of the 'Hazard Section' before the participant either swerved at a rate
541 of 1 ms^{-2} or decelerated at a rate of at least 1 ms^{-2} . These criteria were chosen post-hoc to best quantify
542 the behaviour of participants and provided plausible response time measures for all participants. A
543 paired samples t-test found that response time was not significantly different between the two
544 conditions [$t(29) = .62$; $p = .54$, $d = 0.11$].

545

546 Multiple logistic regressions were also conducted with the six driving measures as outcome variables,
547 using the predictor variables of objective sleep duration, subjective sleep duration, Stanford Sleepiness
548 Scale ratings (SSS), BrAC, subjective alcohol content and reported time of last drink. It was found that
549 on all driving measures these predictor variables did not make significant contributions to the models
550 therefore, although there was a genuine impairment in the morning after condition on some driving
551 measures, these impairments were not predicted by these variables or a combination of these variables.

552

553 3.5. Eye Tracking Measures

554 Due to difficulties in calibration with the simulators' eye tracking system not all participants had
555 complete eye tracking data for both drives. Eye movement data were thus analysed from the 22

556 participants who had good eye-tracking data available for both of their two drives. The three eye
557 movement measures of interest were standard deviation of horizontal fixation locations, standard
558 deviation of vertical fixation locations and mean fixation durations. There were no main effects of
559 Condition, Road Section or interactions between Condition and Road Section for any of these eye
560 movement measures.

Figure 1: Shows the six measures of driving performance over the four sections of the drive, plotted separately for the control and morning after condition. Error bars show the one standard error above or below the mean.

562 4. Discussion.

563 The current study investigated whether students were impaired at simulator driving the morning after a
564 night out social drinking, compared to a control night. The main finding of the study was that despite
565 twenty eight of the thirty participants being under the legal driving limit for breath alcohol content,
566 there was evidence of more dangerous driving the morning after compared to the control drive. It was
567 found that when participants completed the morning after drive, they tended to travel at higher
568 maximum speeds, travel for a longer period of time over the speed limit, demonstrate a larger variance
569 in speed, and have a marginal tendency to have a sharper change in speed. However, we did not find
570 differences in drivers' visual attention measures while driving, nor differences in driving measures
571 such as SDLP, suggesting that morning after alcohol consumption impaired our student drivers'
572 judgements on the road, but not their attentiveness. The results of the study have important
573 implications for road safety, as this study investigates a population which have been seen to commonly
574 engage in social excessive drinking, and a sample who would be expected to engage in morning
575 university commitments, which will often require travel to the university.

576

577 Firstly, it was found that there was a particular impairment on longitudinal vehicle control measures.
578 The fact that drivers the morning after displayed significantly greater SDSP compared to control is
579 consistent with a recent meta-analysis conducted on the effects of acute alcohol consumption on
580 simulated driving (Irwin et al., 2017), recent studies investigating the effects of acute alcohol
581 consumption on driving (Mets et al., 2011; McCartney et al., 2017), and research investigating the
582 combined effects of alcohol and sleep deprivation on driving (Arnedt et al., 2001). Previous research
583 from Verster et al., (2014a) did not find a difference in drivers' SDSP the morning after alcohol
584 consumption compared to control however, they did find that SDSP (as well as SDLP and lapses of
585 attention) was more pronounced as the driving task went on, with drivers performing worse on the
586 second half of the driving task compared to the first. This finding was also supported by Verster and
587 Roth (2013) who investigated the progressive nature of driving impairment throughout a driving task

588 in more depth, as well as Arnedt et al., (2001) in regards to sleep deprivation. Similarly, in the current
589 study it was found that although SDSP increased in the speed reduction zone as expected, it also
590 increased in control section two compared to control section one, suggesting that longitudinal
591 measures can get progressively worse, the longer the task.

592

593 In addition, it was found that drivers travelled at significantly higher maximum speeds in the morning
594 after condition compared to the control condition, which is similar to previous findings from Charlton
595 and Starkey (2013). This study found that drivers' higher maximum speeds were observed when
596 participants were on the declining BAC limb compared to the same BAC on the ascending limb. This
597 suggests that driving errors are not abolished on the apparent decreasing BAC stage (Charlton &
598 Starkey, 2015), therefore although many participants in the current study had low BrAC readings (the
599 majority of our participants had a reading of 0 even in the Morning After condition), these driving
600 effects can still persist.

601

602 It was also found that drivers spent more time over the speed limit in the morning after condition
603 compared to the control condition. Previous research has found that speeding is one of the most robust
604 measures of alcohol impairment that affects driver choices directly (Christoforou, Karlaftis & Yannis
605 2012), with the current study's result suggesting that this effect may extend to morning after driving
606 when BrAC is declining, and therefore may be still likely to affect drivers' choices to violate road
607 rules. It should also be highlighted that reduced speeds allow drivers extra time to adapt to changes and
608 respond to risks in the environment, however, as drivers were travelling at higher speeds and breaking
609 the speed limit more often, this allows for decreased time to respond to risks, resulting in an increased
610 risk of accident (Lenné et al., 2010). This accident risk could be made more severe in the Morning
611 After condition, as drivers had a marginal tendency to make sharper changes to their speed compared
612 to control, as previous research has suggested that abrupt braking can increase accident risk,
613 particularly seen with young novice drivers (McKnight & McKnight, 2003).

614

615 Surprisingly however, it was found that there were no differences in drivers' SDLP and drivers' visual
616 attention measures which included horizontal SD, vertical SD and mean fixation durations, despite
617 participants' recordings and reports of sleep being significantly lower and ratings of sleepiness being
618 significantly higher in the morning after condition compared to control. These results were inconsistent
619 with our original hypotheses, which proposed that driving the morning after would elicit behaviours
620 showing evidence of inattentiveness which included SDLP, reduced gaze deviations and longer mean
621 fixation durations. The current results contrast with results obtained by Verster et al., (2014a), and
622 results which suggest that both fatigue (Otmani et al., 2005; Ingre et al., 2006) and alcohol (Helland et
623 al., 2013; Irwin et al., 2017) commonly impair measures of visual attention exhibited by drivers'
624 ability to maintain a steady lane position, as well as reducing gaze deviation and increasing mean
625 fixation durations (Ogden & Moskowitz, 2004; Ji & Yang, 2002). However, inattentive and reckless
626 driving have been argued to be fundamentally different, in which the former is associated with an
627 inability to sustain focussed attention associated with self-regulation (Tay & Knowles, 2004) and the
628 latter a more volitional choice about dangerous driving behaviour (Kostermans et al., 2014).

629 In regards to drivers' mean speed, it was also found that there were no differences in the morning after
630 condition and in the control condition, which is inconsistent with previous research (Mets et al., 2011;
631 McCartney et al., 2017) but consistent with other studies looking specifically at the morning after
632 effects of sleep deprivation (Peters et al., 1999) and alcohol hangover (Verster et al., 2014a). The lack
633 of difference in mean speed (and SDLP) in previous studies has been attributed to the sample, as they
634 used young healthy adults, who had no prolonged sleep deprivation prior to sleep induction paradigms,
635 therefore subtle highway measures may not be affected (Peters et al., 1999). In addition, the significant
636 reduction in mean speed in the speed reduction section suggests that the introduction of a new speed
637 limit influenced participants' behaviour, with some reduction in speed being evident in participants in
638 both conditions. This also supports the idea that drivers were not inattentive in regards to noticing the
639 road signs, but chose to travel at higher speeds than legally permitted.

640

641 Finally, it was found that there was no significant difference in response time between the two
642 conditions towards the planned hazard. This was surprising given that alcohol is known to increase
643 drivers' response times (Summala & Mikkola, 1994). However, from recent validation studies it is not
644 clear how reliable simulator environments are for higher behavioural control tasks such as hazard
645 avoidance (Engström, Johansson & Östlund, 2005), with little previous evidence measuring this. This
646 hazard was also a planned single hazard, whereas multiple hazards may be encountered in real world
647 driving, requiring additional situational awareness.

648

649 So far, the current study's results suggest that students who drive the morning after a night out
650 drinking display impairments in driving judgement in terms of a greater willingness to violate road
651 rules, however, they do not demonstrate impairment in attention. Potential explanations regarding the
652 absence of effects in drivers' attentiveness will be discussed, alongside the potential interventions and
653 further research that could be investigated using the findings of the current study.

654

655 The lack of evidence for sustained attention measures such as SDLP and eye movements could be
656 related to the nature of our driving task. The current study used a 15-minute highway driving task, as
657 opposed to the one-hour drive used by Verster et al. (2014a). The short drive in the current study,
658 chosen as a means to avoid exacerbating the somatic symptoms participants may experience after
659 heavy drinking, may have not been long enough to elicit the effects of fatigue and thus inattention.
660 Previous research has highlighted changes in behaviour caused by fatigue are often only measurable
661 when high levels of fatigue are reached (Ingre et al., 2006), with previous evidence showing
662 detrimental effects to appear around 15 minutes into a driving task (Chapman et al., 1999). This
663 suggests that levels of fatigue in our participants may not have reached a necessary criterion level in
664 order for performance to be increasingly impaired, and may also explain why there were no effects on
665 SDLP and mean speed measures over the course of the drive. The two-fold nature of fatigued driving,

666 including both the fatigue resulting from driving and the effects of fatigue from sleep deprivation the
667 night before (Crawford, 2007) could be argued to be present in the long drive used by Verster et al.
668 (2014a) but absent in the current study as the present 15-minute drive was short, interactive and
669 demanded changes in behaviour as a result of the variable speed limits. It is possible that our
670 participants may have also been partly able to counteract impairment throughout increased effort and
671 motivation to perform a 15-minute task (Verster & Roth, 2013), as motivation has been seen to directly
672 influence drivers' ability to allocate attention to resources (Fuller, 2005).

673

674 Consequently, it could be argued that while Verster et al.'s (2014a) drive was long and monotonous
675 enough to induce fatigue itself, the current drive did not. The duration of the drive in the current study
676 is nonetheless reflective of journeys many students would regularly take in the morning after a night of
677 drinking, for instance from their home to university, and of the average duration of car journeys. Thus,
678 the results from the current study may be more generalisable to everyday driving in the UK than
679 previous research. This dissociation in results indicates perhaps that reckless driving is more of a
680 problem on short drives the morning after alcohol consumption, while inattentive driving may be
681 particularly important for longer drives in the morning after - an area appropriate for further
682 development in future research.

683

684 It is also possible that the naturalistic nature of the current study may explain why some of the results
685 found are inconsistent with previous research which had more controlled manipulations of alcohol
686 consumption and sleep deprivation. The current study was designed to replicate a common real-life
687 scenario, such as driving to work or university after a night out socialising, therefore there was an
688 unavoidable confound that participants would consume variable amounts of alcohol and have variable
689 sleep durations. Equally however, there are substantial advantages of conducting this experiment as a
690 naturalistic study, as this ecologically representative testing protocol can be argued to be more
691 generalisable to real life behaviour, with fewer research studies conducting morning after studies in a

692 naturalistic way. As this study was measuring a situation which occurs regularly in university life, it
693 was important the participants were a sample of young students who had planned to engage in social
694 drinking, from a population known to commonly engage in drinking in excess (NUS, 2017) and who
695 are over-represented in alcohol related crashes (DfT, 2017b).

696

697 The current study highlights the importance of appreciating that impairment in driving the morning
698 after cannot be attributed to one particular cause or mechanism. The naturalistic nature of the
699 investigation means that factors impairing students' morning after driving performance, such as
700 alcohol or sleep deprivation were closely linked and not analytically separable in the current study.
701 Despite this methodological limitation, it is apparent that the typical everyday combination of sleep
702 deprivation and alcohol consumption can to have a selective detrimental effect on morning after
703 driving performance, even on a relatively short drive. It is worth noting that this combination of
704 impairments is likely to be common in real life driving even when drivers are still below the legal
705 BAC. Attempts to fully disentangle the impairments associated with these two factors would require
706 more controlled parameters with a less naturalistic design or a substantially larger naturalistic sample
707 size with lower covariation between sleepiness and alcohol consumption.

708

709 In regards to practical implications, the results of the current study allow for interpretation of morning
710 after driving impairment in terms of an accepted standard for safety. The current study highlights that
711 alcohol induced driving impairments the morning after exist under the national speed limit and
712 irrespective of legality to drive, indicating that drivers may be at risk on the road. It also highlights the
713 difficulty with using absolute BrAC as a standard for safe driving. We found a detriment in
714 performance the morning after drinking despite recorded BrAC being 0 for the majority of
715 participants. It is also important to highlight that there was relatively little association between the self-
716 reported units of alcohol consumed by students and their morning after breathalyser scores, despite
717 around half of the participants reporting to have consumed more units in one night than the UK

718 guidelines for weekly consumption. It is likely that the timing of alcohol consumption was critical in
719 determining whether participants were over the limit the following morning but less important in
720 determining whether driving was actually impaired.

721

722 There is also a concern regarding the dangers associated with sleep deprivation while driving, as there
723 is presently no standard that exists against which sleep-related deficiencies can be judged. Although
724 many countries set allowable BACs at the point that compromises safe performance, it is
725 acknowledged that developing similar standards for fatigue to ensure that people with sleep
726 deprivation are kept from risky behaviours such as driving is more challenging. One possibility is
727 introducing educational programmes that highlight the impairments in driving that persist the morning
728 after alcohol consumption and sleep deprivation, with the aim of preventing engagement in this
729 behaviour. Alvaro et al. (2018) reported encouraging results for programmes raising awareness of the
730 dangers of drowsy driving in young adults, therefore similar programmes could help apply these
731 findings to the wider driving population.

732 The current study's results suggest that in a short highway driving task, students display morning after
733 impairments in driving judgement in terms of a greater willingness to violate road rules however, do
734 not demonstrate impairment in attention. To further investigate if the morning after elicits more
735 impulsive behaviour generally, or if this is only limited to driving behaviours as reported in the current
736 study, a similar naturalistic design but with the incorporation of behavioural task measuring response
737 inhibition, such a go/no-go task (Fillmore, 2003) and sustained attention, such as the vigilance task by
738 Bakan (1959) could be conducted to see if the same dissociative effect exists on simpler cognitive
739 tasks. This might provide greater understanding of the mechanisms underlying the current pattern of
740 impaired driving the morning after drinking. If inattention is measured on simple behavioural tasks, it
741 could be postulated that the drive in the current study was not a sensitive enough measure of attention,
742 or participants may have compensated for their fatigue by ensuring attention was maintained the
743 morning after drinking.

744 **4.1. Conclusions**

745 In conclusion, the current study makes a significant contribution to the current driving safety literature,
746 indicating that students who would typically be travelling to university after a night out demonstrate
747 dangerous judgements in driving behaviour the morning after. The main findings suggest that drivers
748 elicit reckless driving behaviours such as decreased adherence to speed limits, higher maximum
749 speeds, greater deviations in speeds and a marginal tendency to make sharper changes in their speed.
750 Despite this, drivers did not demonstrate any impairments in measures of attention, and more subtle
751 measures of driving behaviour such as SDLP and mean speed. These results suggest that despite
752 average BrAC being three times under the current national legal limit, the morning after effects of
753 alcohol are shown to elicit dangerous driving behaviour, with a greater willingness to violate road
754 rules, with no suggestions of inattentiveness while driving. It is highlighted that the current study's
755 results could be used to implement informative educational programmes about the impairments that
756 persist in morning after driving, making drivers aware that even when under the legal driving limit,
757 short distance drives the morning after drinking can elicit dangerous driving, with the potential of
758 longer drives leading to inattentiveness.

759

760

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764

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766 None.

767

768

769

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