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Mild hypohydration increases the frequency of driver errors during a prolonged, monotonous driving task

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HIGHLIGHTS

- Mild hypohydration has been shown to cause impaired cognitive function and altered mood.
- This study reports an increase in driver errors with mild dehydration.
- Error incidence increased over time, but occurred at a greater rate following fluid restriction
- Higher subjective feelings of thirst, as well as impaired concentration and alertness were also apparent
- Driver education programmes should also encourage appropriate hydration practices.

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ABSTRACT

The aim of the present study was to examine the effect of mild hypohydration on performance during a prolonged, monotonous driving task.

Methods: Eleven healthy males (age 22 ± 4 y) were instructed to consume a volume of fluid in line with published guidelines (HYD trial) or 25% of this intake (FR trial) in a crossover manner. Participants came to the laboratory the following morning after an overnight fast. One hour following a standard breakfast, a 120 min driving simulation task began. Driver errors, including instances of lane drifting or late breaking, EEG and heart rate were recorded throughout the driving task.

Results: Pre-trial body mass ($P = 0.692$), urine osmolality ($P = 0.838$) and serum osmolality ($P = 0.574$) were the same on both trials. FR resulted in a 1.1 ± 0.7% reduction in body mass, compared to −0.1 ± 0.6% in the HYD trial ($P = 0.002$). Urine and serum osmolality were both increased following FR ($P < 0.05$). There was a progressive increase in the total number of driver errors observed during both the HYD and FR trials, but significantly more incidents were recorded throughout the FR trial (HYD 47 ± 44, FR 101 ± 84; ES = 0.81; $P = 0.006$).

Conclusions: The results of the present study suggest that mild hypohydration, produced a significant increase in minor driving errors during a prolonged, monotonous drive, compared to that observed while performing the same task in a hydrated condition. The magnitude of decrement reported, was similar to that observed following the ingestion of an alcoholic beverage resulting in a blood alcohol content of approximately 0.08% (the current UK legal driving limit), or while sleep deprived.

1. Introduction

Under 'normal' conditions, an individual's total body water (TBW) fluctuates throughout the day, but overall daily water balance is generally maintained through a series of interrelated factors which control intake and output of water. The homeostatic regulation of salt and water balance normally acts to limit excursions in TBW to no more than about 1% per day [24]. Nevertheless, there are several routinely encountered situations that act to either increase fluid losses (e.g. illness, exposure to heat/humidity, diuretics), or serve to restrict fluid intake (e.g. access to beverages and/or latrines). Over time, one, or a combination, of these factors results in the progressive reduction in TBW. The ensuing hypohydration causes a reduction in the circulating blood volume and an increase in plasma osmolality, which are typically proportional to the magnitude of decrease in TBW [32]. Populations at particular risk of hypohydration are the very young, those engaged in professions where fluid homeostasis is regularly

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challenged and the elderly. Limited data are available on the prevalence of hypohydration, but there is evidence to suggest that this may be relatively common among sections of the elderly population [24].

Mild hypohydration can cause symptoms such as headache, weakness, dizziness and fatigue, and generally makes people feel tired and lethargic, with lower self-reported ratings of alertness and ability to concentrate [36]. Body water losses have been shown to impair performance in a variety of tests of both physical and mental performance. Evidence suggests that either starting exercise in a hypohydrated state, or allowing hypohydration to accrue during exercise, will result in an increase in subjective feelings of exertion, or this likely contributed to the reduction in exercise performance [24]. As little as a 2% reduction in body mass due to insufficient hydration can also result in impaired cognitive function, with changes in mood state and modest reductions in concentration, alertness and short-term memory reported [1,24]. In addition to the established physiological consequences of hypohydration, the generally unpleasant symptoms of hypohydration (e.g. dry mouth, thirst, headache) may directly produce a negative effect on mood state [2,12]. In fact, some authors maintain that dehydration-associated impairment of tasks with a large cognitive component is driven primarily by the discomfort and distraction associated with these symptoms [6].

Data quantifying the hydration practices of regular drivers is scarce, but assessments of hydration status and reported beverage intakes among employees in a variety of workplace settings highlighted that a significant proportion of employees report to work exhibiting signs of dehydration [25]. A large proportion of those individuals also remained in a state of hypohydration at the end of their shift, citing restrictions on when and where they could consume fluid and access to toilet facilities as the primary barriers to increasing water intake. It is likely that driving in a hot car will lead to significant losses of water over the course of a long journey, but these data are not readily available in the scientific literature. Even in an air-conditioned car, evaporative water losses from the skin and lungs are likely to accumulate during a long drive due to exposure to dry air because of the increased vapour pressure gradient. Taking these points into consideration, the European Hydration Institute recommends the regular ingestion of non-alcoholic beverages during long automobile journeys to help to reduce road fatigue [10]. These guidelines are likely to be sound, but anecdotal reports suggest that many drivers avoid drinking adequately, with a view to limiting the need for bathroom stops during long journeys.

While it is widely acknowledged that the use of alcohol or drugs among drivers increases the risk [29] and the severity [3] of road traffic accidents, there are currently no scientific evidence linking dehydration to an increased incidence of traffic accidents. At present only one recent study has investigated the possible effects of dehydration on simulated driving performance [20]. Again the primary focus was to examine the effects of moderate quantities of alcohol on aspects of driving performance, but this group also suggested a possible interaction between alcohol consumption and dehydration. The authors suggested that alcohol-induced impairments in cognition, and consequently on simulated driving performance, would be greater when individuals were also in a state of dehydration. Although the results of this study failed to identify any significant impact of hydration status on driving performance, it is worth noting that the simulated driving task employed was short (15 min) and was set in a suburban environment.

An estimated 1.2 million people worldwide are killed as a result of road traffic accidents each year, with around 50 million people also injured annually [40]. Driver error is by far the largest cause of these accidents, accounting for approximately 68% of all vehicle crashes in the UK [7,8]. Factors including failing to look properly, misjudging another driver's path or speed and driver distraction are cited in the top ten most common causes of traffic accidents [7,8]. During long and monotonous driving, most drivers progressively show signs of visual fatigue and loss of vigilance [4]. Hypohydration has been shown to result in altered mood and deficits in aspects of cognition, it is reasonable to assume that dehydrated drivers may be more susceptible to errors in judgement and/or the successful execution of motor skill. With this in mind, the aim of the present study was an initial exploration of the effects of mild hypohydration, on performance during a prolonged, monotonous driving task where aspects of cognition relevant to driving (e.g. response times and loss of vigilance) are likely to be challenged.

2. Methods

2.1. Participants

Twelve healthy males were recruited to participate in this randomised crossover design study. All participants were experienced drivers; having driven for over 2 years on a full licence and for more than 2 h/week. Prior to volunteering, participants received written information regarding the nature and purpose of the study and a written statement of consent was signed. One participant completed all trials but was excluded from the final results after displaying a high propensity to fall asleep during the driving task (perhaps caused by sleep deprivation). Physical characteristics (Mean ± SD) of the remaining 11 participants were: age 22 ± 4 y; height 1.75 ± 0.06 m; and body mass 77.4 ± 10.0 kg. This study was approved by the local Ethical Advisory Committee (REF: R14-P12).

2.2. Experimental design

Each volunteer visited our laboratories on three separate occasions. The first visit was a familiarisation trial that involved the completion of the same driving task undertaken in the experimental trials. This was intended to enable the participants to become accustomed with the study protocol and limit any possible learning effect apparent with the use of the driving simulator. This was followed by two experimental trials. All trials were separated by at least 7 days and experimental trials were completed in a randomised order. Participants were provided with a customised diary to record dietary intake and physical activity during the 24 h before the first experimental trial and were asked to replicate this on the day prior to the subsequent experimental trials. During each trial period (as illustrated in Fig. 1), participants were asked to record dietary intake in a food and beverage record diary, using the portion size method. No restrictions on routine or food/beverage intake, other than those mentioned below, were enforced during this period, as the aim was to mimic free-living conditions. To help ensure the volunteers were adequately hydrated, they were instructed to consume at least 2.5 L of fluid, spread evenly across the day [9]. No strenuous exercise or alcohol consumption was permitted in the 24 h before, as well as during, each trial.

2.3. Experimental protocol

Each experimental trial took place over two days, as illustrated in Fig. 1. On day 1, volunteers visited the laboratory in the morning after an overnight fast (10 h, with no food or fluid permitted). A urine sample was obtained and body mass measured to the nearest 10 g in minimal clothing (underwear). Volunteers then sat for 15 min, before a 5 mL blood sample was collected from a superficial antecubital vein. During the 15 min of seated rest, subjective feelings related to thirst, hunger, concentration and alertness were assessed using a series of 100 mm visual analogue scales [36]. Volunteers were then free to leave the laboratory with the instruction to replicate their food intake of the pre-trial standardisation day. During the hydrated (HYD) trial volunteers continued to consume at least 2.5 L of fluid, spread evenly across the day. During the fluid restriction (FR) trial, only 25% of the HYD fluid intake was permitted; this was expected to result in a ~1% reduction in body mass over a 24 h period [36].

Participants then returned to the laboratory the following morning after an overnight fast (10 h, with no food or fluid permitted). A urine sample was obtained and body mass measured in minimal clothing.

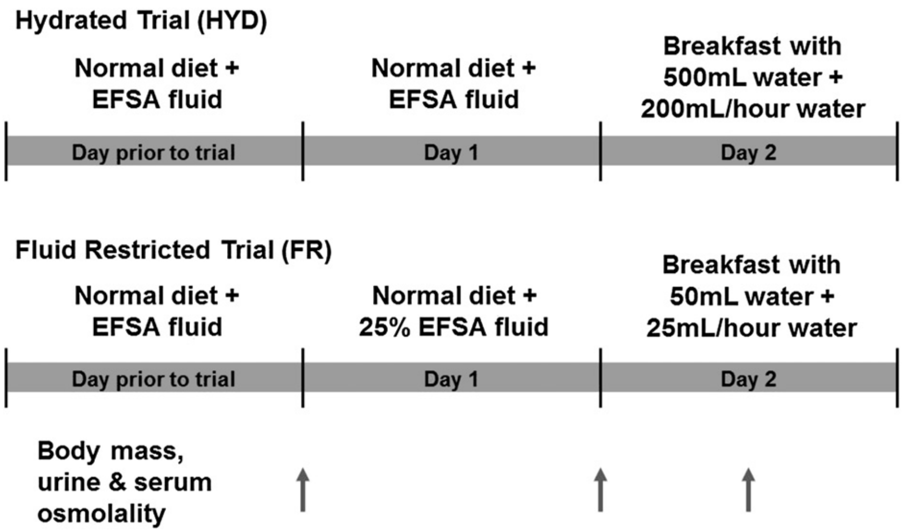

Fig. 1. A schematic representation of the experimental protocol describing the methods employed to manipulate of hydration status on days 1 and 2 of the trials. Arrows indicate the measurement of body mass, urine and serum osmolality undertaken upon arrival laboratory at the start of days 1 & 2 of the experimental protocol, as well as the end of the driving protocol.

After sitting for 15 min, a 5 mL blood sample was then collected from a superficial antecubital vein. The same visual analogue scales were also completed at this time and a heart rate telemetry band was positioned (Polar RS400, Kempele, Finland). Participants were then provided with a standardised dry breakfast (2 cereal bars; Alpen, Weetabix Ltd., Kettering, UK), providing 1052 kJ, 42 g of carbohydrates, 7.6 g of fat and 3.8 g of protein. During the HYD trial they were given a volume of plain water to drink with breakfast (500 mL), but on the FR trial only a very small volume was provided (50 mL). They were then fitted with electroencephalogram (EEG) and electrooculogram (EOG) electrodes. Electrodes were attached for two channels of EEG, with inter-electrode distances carefully maintained by using the '10–20 EEG montage' (main channel C3–A1, backup channel C4–A2), and there were two EOG channels (electrodes 1 cm lateral to and below left outer canthus and 1 cm lateral to and above right outer canthus; both referred to the centre of the forehead).

One hour following breakfast, volunteers began a driving simulation task, similar to that described in several publications [11,30,31]. The task comprised of a 2 h continuous drive in an immobile car with a full-size, interactive, computer-generated road projection of a dull monotonous dual carriageway, each carriageway having two lanes. The road also had a hard shoulder and simulated auditory 'rumble strips' (incorporated into white lane markings) either side of the carriageway and a barrier separating the carriageways, with long straight sections followed by gradual bends. Slow moving vehicles were met occasionally, and these had to be overtaken. Drivers were instructed to remain within their lane unless overtaking. During the HYD trial volunteers were be provided with 200 mL of fluid every hour, and on the FR trial only 25 mL was made available each hour. Immediately following the drive, volunteers then sat for 15 min, before a 5 mL blood sample was collected from a superficial antecubital vein. A final assessment of subjective feelings related to thirst, throat dryness, hunger, concentration and alertness was undertaken, before a urine sample was obtained and body mass was again measured in minimal clothing.

2.4. Analysis

2.4.1. Dietary intake

Nutritional analysis of food intake records was undertaken using commercially-available nutritional analysis software (NetWISP v4.0, Tinuviel Software, UK). Total water intake from all food and drink, as determined from food composition tables within the database, was the primary focus. The contribution of metabolic water to total body water was not accounted for, as this was assumed to be consistent across both trials. Energy, macronutrient and caffeine intakes were also examined to ensure consistency across trials.

2.4.2. Driving related measures

Instances of lane drifting or late breaking are the most common manifestation of driver error, and a car wheel touching (or crossing) the rumble strip or lane line was identified as a driving 'incident'. These were classified as 'minor incidents', whereas 'major incidents' included cases where the car completely leaves the lane, hits the barrier or another car. Split-screen video footage of the roadway and driver's face (filmed by an unobtrusive infrared camera) enables the cause of the incident to be determined. Those due to sleepiness (e.g. excessive blinking, eye closure, eyes rolling upwards or vacant staring ahead) were logged as 'sleep-related incidents'. Non-sleep related incidents (driver distraction, fidgeting or looking around) are also recorded.

2.4.3. EEG and EOG

EEGs and EOGs were recorded using "Embla" (Flaga Medica Devices, Iceland) and spectrally analysed using "Somnologica" (Flaga) in 4 s epochs. EEG low and high band-pass filtering at >20 Hz removed slow eye movements and muscle artefacts. Increases in EEG power in the alpha (8–11 Hz) and theta (4–7 Hz) ranges indicate increasing sleepiness [22] and reduced vigilance [4]. EEG power in this (4–11 Hz) frequency range was then averaged in one-minute epochs. To remove individual differences in these EEG power levels and to permit better comparison between conditions, these data were standardised for each participant by taking the difference between each epoch and mean value for that person's EEG power during the first 30 min of the HYD trial, divided by the standard deviation around that mean [11,31].

2.4.4. Blood and urine samples

Blood samples collected throughout the experimental protocol were drawn into dry syringes before being dispensed into plain tubes and left to clot at room temperature for 1 h. These samples were then centrifuged at 3000 g for 10 min to yield serum. When urine samples were obtained, participants were instructed to empty their bladder as completely as possible into a collection container. The volume of each void was determined, and a 5 mL aliquot was retained in a sterile collection tube. All urine and serum samples were stored at 4 °C for a maximum of 7 days before being analysed for osmolality using freezing point depression (Gonotoc Auto; Berlin, Germany).

2.5. Statistical analysis

On the basis of the results of previous investigations undertaken using the same experimental model [11,18,30,31], we estimated a 90% probability of detecting a difference in total errors of at least 32 with a sample size of 11 subjects (G-Power 3.1, Dusseldorf, Germany). Data are presented as mean ± standard deviation (SD) unless otherwise stated. Driving incidents and the EEG data were averaged into 30 min epochs, as described by Reyner et al. [31]. The distribution of the data was first assessed using the Shapiro–Wilk test. Differences in the total number of driver errors recorded during each trial, as well as the baseline measures used to check pre-trial standardisation, were assessed using paired sample t-tests. Cohen's *d* effect sizes (ES) for the differences in driver error rate were also determined. To identify differences in normally-distributed data collected throughout each trial, two-way (time-by-trial) ANOVA were employed. Where a significant interaction was apparent, pair-wise differences were evaluated using the Bonferroni correction. For the purpose of hypothesis testing, the 95% level of confidence was predetermined as the minimum criterion to denote a statistical difference ($P < 0.05$).

3. Results

Pre-trial body mass ($t = 0.391$, $P = 0.692$), urine osmolality ($t = -0.216$, $P = 0.838$), serum osmolality ($t = 0.338$, $P = 0.574$) were the same on both trials, suggesting that the participants were in a similar state of hydration before the start of each trial. Pre-trial dietary energy (HYD 12.6 ± 1.2 MJ; FR 12.3 ± 1.8 MJ; $t = 0.297$, $P = 0.742$) and caffeine (HYD 157 ± 51 mg; FR 131 ± 46 mg; $t = 0.412$, $P = 0.742$) intakes were also not different. Participants also started both trials reporting the same subjective feelings of thirst, throat dryness, hunger, alertness and ability to concentrate; further supporting this view. Total water intake from all sources during day 1 of the HYD trial was 3.0 ± 0.2 L, compared to 0.9 ± 0.1 L ingested during the FR trial ($t = 10.647$, $P < 0.001$). This comprised 2.6 ± 0.2 L from beverages and 0.4 ± 0.2 L from foods in the HYD trial, whereas 0.5 ± 0.2 L and 0.4 ± 0.1 L was ingested through beverages and foods respectively during the FR trial. Caffeine intake was lower during the FR trial (55 ± 12 mg) compared to the HYD trial (208 ± 49 mg; $P = 0.017$). FR during day 1 resulted in a 1.1 ± 0.7% (range −0.7 to −2.3%) reduction in body mass, compared to −0.1 ± 0.6% (range +1.1 to −0.7%) in the HYD trial ($F = 38.482$, $P = 0.002$). The 24 h restriction of fluid intake resulted in an increase in both serum ($F = 92.042$, $P = 0.007$) and urine osmolality ($F = 207.904$, $P < 0.001$; Fig. 2).

The number of driver errors made during the trials, both minor and major incidents, grouped into 30 min blocks, is illustrated in Fig. 3. There was a progressive increase in the total number of driver errors observed during the HYD trial, with significantly more incidents recorded during the last 30 min period (17 ± 16), than in the first 30 min (7 ± 8; $F = 3.587$, $P = 0.043$). However, the frequency of driver error increased to a greater extent throughout the FR trial ($F = 8.043$, $P = 0.008$). FR resulted in a marked increase in the total number of driving errors, with 47 ± 44 and 101 ± 84 recorded during the HYD and FR trials respectively ($t = -4.549$, $P = 0.006$; ES = 0.81). Four major incidents were recorded over the course of the study, but these were evenly distributed between the HYD and FR trials. There was no clear relationship between the number of errors made during the FR trial and the degree of dehydration accrued ($r^2 = 0.18$; $P = 0.544$); it is likely that there is insufficient statistical power to detect such an effect with the number of participants recruited, nor was the experiment designed to examine this question.

The analysis of the EEG data is presented in Fig. 4. There was a progressive increase in alpha (8–11 Hz) and theta (4–7 Hz) activity throughout both the HYD and FR trials ($F = 4.528$, $P = 0.038$), indicative of greater sleepiness and perhaps reduced vigilance. The magnitude of change tended to be greater in the FR trial, but this response just failed to reach significance ($F = 2.998$, $P = 0.062$).

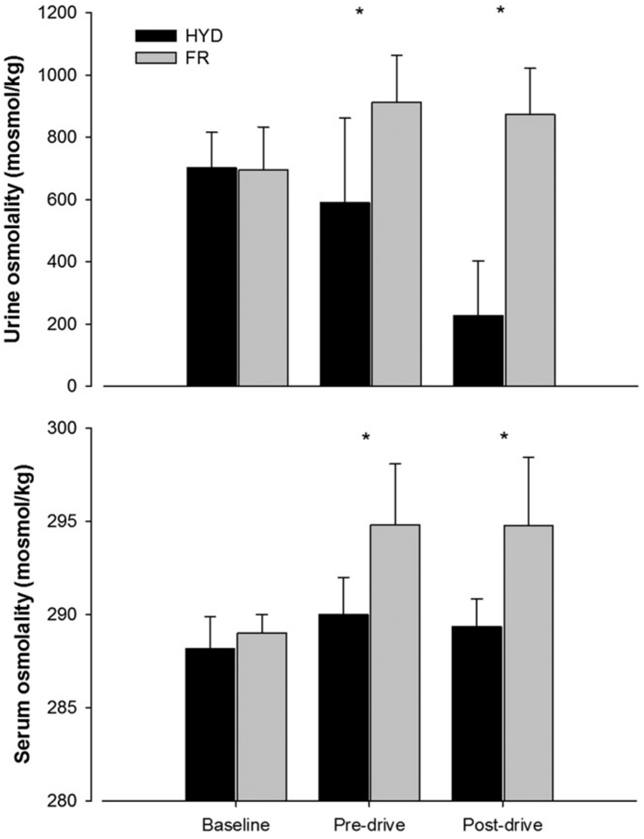

Fig. 2. Urine (top) and serum (bottom) osmolality throughout the HYD and FR trials. * denotes a significant difference between trials at the corresponding time point ($P < 0.05$). Data are presented as mean ± standard deviation.

There was no change in thirst perception over the course of the HYD trial, but self-reported ratings of thirst increased by 107 ± 17% throughout the FR trial ($F = 80.920$, $P < 0.001$). The same response was apparent when examining the perceived feelings of throat dryness. Perceived ability to concentrate (−39 ± 17%; $F = 22.475$, $P < 0.001$) and alertness (−48 ± 26%; $F = 6.845$, $P = 0.016$) had also reduced over the course of the FR trial, but these were both significantly lower at the end of the

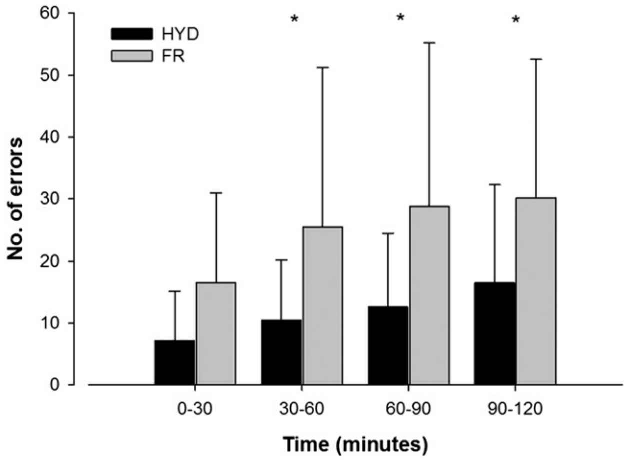

Fig. 3. The total number of driver errors made during each 30 min period of the HYD and FR trials. * denotes a significant difference between trials at the corresponding time point ($P < 0.05$). Data are presented as mean ± standard deviation.

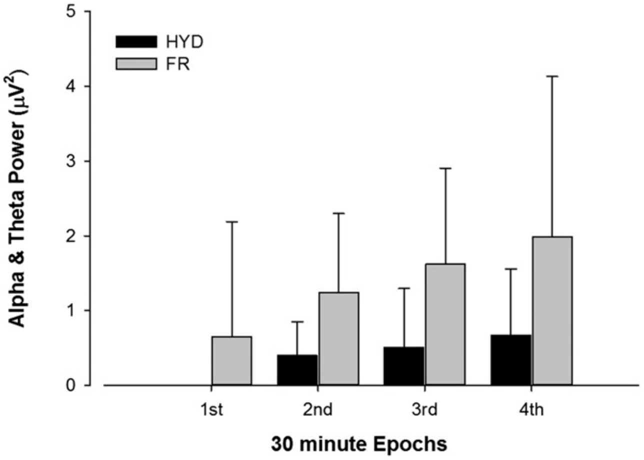

Fig. 4. EEG alpha + theta power (4–11 Hz) averaged every 30 min and normalised against each individual's power in these ranges, by taking the difference between each minute's epoch and the individual's mean value over the first 30 min of the HYD data, and dividing this by the standard deviation around the mean of that 30 min of data. Data are presented as mean ± standard deviation.

drive during the FR trial than compared with the HYD trial (both $P < 0.001$).

4. Discussion

4.1. General discussion

Driver error is by far the largest cause of road traffic accidents, accounting for approximately 68% of all vehicle crashes in the UK [7,8]. During motorway/highway driving, drivers tend to progressively show signs of visual fatigue and loss of vigilance [4]. Since deficits in TBW are associated with altered mood and decrements in aspects of cognitive function, it is possible that dehydrated drivers may be prone to making more errors in judgement and car handling. The results of this exploratory study suggest that mild hypohydration, induced through a short-term period of fluid restriction, produced in a significant increase in minor driving errors during a prolonged, monotonous drive, compared to that observed while performing the same task in a hydrated condition. Mild dehydration can produce negative changes in mood state and modest reductions in concentration, alertness and short-term memory [1,2,12,14]. While there remains some uncertainty whether these responses result from a physiological impairment caused by the reduction in total body water and electrolyte imbalance, or are simply due to the discomfort and distraction associated with dehydration, these subtle changes in mood and cognition mostly likely explain the decrement in driving performance observed.

Water accounts for 50–60% of body mass in most healthy individuals, and maintaining water balance is essential for health. Body water turnover rate, a function of fluid losses (respiratory water, sweat, urine, faeces) and fluid gain from food, beverages and metabolic water, is highly variable between individuals with typical values of between three to six litres/day reported in the literature. The homeostatic regulation of salt and water balance normally acts to limit excursions in total body water to no more than about 1% per day [5]. Exposure to environmental extremes (particularly heat and humidity) and prolonged physical activity, as well as some nutritional (fluid restriction, alcohol) and pharmacological (diuretics) interventions can significantly accelerate fluid losses over time. Hypohydration causes a reduction in the circulating blood volume, a reduction in stroke volume and an elevated heart rate at a given exercise intensity [13,26]. There is also evidence of direct effects of hypohydration on the central nervous system [28,39], which may contribute to these observed changes in both mood and cognitive function.

The American College of Sports Medicine qualifies mild hypohydration as body mass losses exceeding 1%, and as such are deviations in total body water that may be encountered routinely by adults during daily activities [33]. While data quantifying the hydration practices of regular drivers is scarce, when hydration status has been assessed in a variety of workplace settings, a significant proportion of employees report to work exhibiting signs of dehydration [25]. In addition, it is likely that driving in a hot car may lead to significant losses of water over the course of a long journey, but again these data are not readily available in the scientific literature. While it has been suggested that drivers should aim to regularly ingest non-alcoholic beverages during long automobile journeys to help to reduce road fatigue [10], and caffeine containing beverages, including coffee and energy drinks, are regularly promoted to counteract driver fatigue [30], factors such as limited free access to fluids and desire to avoid stops for bathroom breaks mean that drivers may place themselves at greater risk of dehydration.

At present only one study has examined the effects of dehydration on simulated driving performance [20]. This particular study was primarily designed to investigate a possible interaction between exercise-induced dehydration and alcohol consumption, as the authors suggest that many people tend to consume alcoholic beverages following participation in sports. No effect of dehydration was observed, but it is worth noting that the driving task employed was particularly short (15 min). While several studies have reported decrements in aspects of cognitive function with dehydration [1,2,12,14], there are a number of conflicting reports suggesting little or no change in cognition following a variety of dehydration protocols [21,37,38]. Innate intelligence and life experience of familiar day-to-day tasks, such as driving, result in functionally more efficient cognitive networks and therefore provide a cognitive reserve [34]. This acts as a buffer providing resilience to cope with increasingly complex tasks while still functioning adequately, and also delays the onset of clinical manifestations of neurodegenerative disorders such as Alzheimer's disease. There is evidence that individuals are able to tolerate a degree of dehydration without any measureable impairment in cognition by increasing the degree of brain activation required for a given task [21]. It appears likely that in the present study the task was sufficiently complex and long lasting to overcome this reserve capacity and result in a measurable decrement in cognitive performance. It is worth noting that while some studies do not report significant differences in task performance with varying levels of dehydration, these data suggest that losses of body water and/or electrolyte imbalances do appear to produce decrements in aspects of brain function underlying important cognitive processes.

4.2. Implications and limitations of the study

Driving performance in the present study was assessed through a simulated driving task, rather than ‘real world’ on-road driving. The use of a driving simulator allowed us to study long, monotonous, and uninterrupted driving task, but it is difficult to know how to translate the driving errors measured during a simulated drive to the likelihood of accidents occurring on the road. The simulator employed in the present study has been internally validated against an instrumented real car circulating a race track, and it has been employed in several published studies investigating the link between tiredness and driving performance publications [11,18,30,31]. The car cabin environment, including commands and instruments were identical to an operative car, but it should be recognised that a driving simulation is not real driving. While participants were instructed to drive as diligently as they would on the road, the consequences of a minor error made during a simulation are clearly not the same as would be experienced while driving at speed on a motorway [4]. However, the present data do suggest that decrements in vigilance, decision making and mood, as apparent from the EEG data and the reported subjective feelings, are likely to have a significant influence on driving behaviour. This is likely to translate into a greater potential for errors in both simulated and real world settings, and consequently influencing the possibility of road traffic accidents.

Driver fatigue and sleep-related vehicle accidents account for a considerable proportion of all vehicle accidents, especially those on motorways and other monotonous roads [17]. These types of accidents are of particular concern since the possibility of a fatality is approximately three times greater than encountered in general road accidents [7,8]. Many road traffic accidents are preventable, and a variety of national initiatives and targets to reduce road deaths and serious injuries have been implemented in recent years [7,8]. Interventions that have been implemented both within the UK and elsewhere to prevent or reduce the occurrence of accidents on the road and the severity of injuries sustained, include changes to the road environment, media safe driving campaigns, drink driving campaigns, stricter enforcement of legislation relating to roads, and finally targeted driver education programmes. The later approach aims to enhance safe driving skills through increased awareness of the dangers involved and improved recognition of driving hazards. While the effects of alcohol consumption and driving while tired is mentioned in these courses, there is no mention of other factors that drivers should be aware of to maintain attention and vigilance.

In conclusion, the results of this initial exploratory study suggest that mild dehydration, induced through a short-term period of fluid restriction, produced in a significant increase in minor driving errors during a prolonged, monotonous drive, compared to that observed while performing the same task in a hydrated condition. Due to the nature of the experimental protocol, it is unclear whether this response was caused by prior the fluid restriction, difference in fluid intake during the drive or combination of both these factors. Further work is warranted to examine contribution of these factors to the response observed. The level of dehydration induced in the present study was mild and could easily be reproduced by individuals with limited access to fluid over the course of a busy working day. To provide some context to the magnitude of decrement in stimulator performance reported, a similar increase in driver error rate has been observed when driving following the ingestion of an alcoholic beverage resulting in a blood alcohol content of approximately 0.08% (the current UK legal driving limit), or while sleep deprived [19]. There is no question that both drink-driving and driving while tired increases the risk of road traffic accidents [40], and many countries have instigated national campaigns to educate drivers of the associated risks. Given the present findings, perhaps some attention should also be directed to encouraging appropriate hydration practices among drivers.

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