Accident Analysis and Prevention 178 (2022) 106856

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

How distracting is chronic pain? The impact of chronic pain on driving behaviour and hazard perception

Atiyeh Vaezipour[a,*], Mark S. Horswill[b], Nicole E. Andrews[a,c,d], Venerina Johnston[a], Patricia Delhomme[e], Oscar Oviedo-Trespalacios[f]

[a] RECOVER Injury Research Centre, The University of Queensland, Australia
[b] School of Psychology, The University of Queensland, Australia
[c] Tess Cramond Pain and Research Centre, The Royal Brisbane and Women's Hospital, Herston, Queensland, Australia
[d] Occupational Therapy Department, The Royal Brisbane and Women's Hospital, Herston, Queensland, Australia
[e] Univ Gustave Eiffel, Université Paris Cité, LaPEA, Versailles, France
[f] Queensland University of Technology (QUT), Australia

ARTICLE INFO

Keywords:
Driver behaviour
Distracted driving
Chronic pain
Hazard perception
Human factors
Driving assessment

ABSTRACT

In road safety research, few studies have examined driving behaviour in chronic pain cohorts. The aim of this study was to investigate driving behaviour among drivers experiencing chronic pain. We compared individuals with chronic pain with age-gender matched healthy controls. Participants completed: (i) an anonymous online survey that included participant demographics, transport characteristics, self-reported driving behaviour, and pain characteristics (ii) a response-time hazard perception test and a verbal-response hazard prediction test for drivers, and (iii) a driving diary in which participants recorded their driving over two weeks. The results showed that participants with chronic pain were not significantly worse than controls for hazard perception and prediction test scores, self-reported attention-related errors, driving errors, driving violations, and involuntary distraction. Drivers with chronic pain did report significantly more driving lapses but this effect became non-significant when variables confounded with chronic pain, such as fatigue, were adjusted for. We also found that participants who reported particularly high levels of chronic pain performed worse in the hazard prediction test compared to the control group (and this effect could not be accounted for by other variables associated with chronic pain). In addition, participants with chronic pain reported significantly higher driving workload (mental demand, physical demand, effort, and frustration) compared with controls. The findings of this study provide new insights into driving behaviour in individuals with chronic pain and recommendations for future research in terms of driving assessment and self-regulation strategies are provided.

1. Introduction

Driving plays a significant role in daily mobility and quality of life (Carr et al., 2019), particularly in rural and remote areas where it is often the only mode of transport. However, driving is a behaviour that carries inherent risks, with road traffic crashes contributing to over one million deaths and 50 million injuries each year worldwide (World Health Organization, 2021). Driver inattention and distraction, which involves a motorist directing their focus away from the driving task intentionally or unintentionally, is a risk factor commonly linked with crash causality (Oviedo-Trespalacios et al., 2021; Regan et al., 2011). Specifically, driver inattention and distraction may involve using a mobile phone while driving, looking at roadside advertising, arousal and mental states, or even internal thoughts unrelated to the driving task (Burdett et al., 2019; Hinton et al., 2022; Nguyen-Phuoc et al., 2020; Oviedo-Trespalacios et al., 2022; Oviedo-Trespalacios et al., 2019).

Chronic pain represents a possible form of distraction, as pain occurring during driving may divert the motorist's attention from the driving task. A recent systematic review conducted by Vaezipour et al. (2022) reported that individuals experiencing chronic pain reported

* Corresponding author at: RECOVER Injury Research Centre, The University of Queensland, Level 7, Surgical Treatment and Rehabilitation Service (STARS), 296 Herston Road, Herston, QLD 4029, Australia.
E-mail address: a.vaezipour@uq.edu.au (A. Vaezipour).
URL: https://recover.centre.uq.edu.au (A. Vaezipour).

https://doi.org/10.1016/j.aap.2022.106856
Received 31 March 2022; Received in revised form 22 September 2022; Accepted 26 September 2022
Available online 10 October 2022

difficulties with various driving tasks affecting driving performance. This included difficulties with driving tasks at the strategic level (e.g., driving in heavy traffic, prolonged driving), the tactical level (e.g., reversing, changing lanes) and the operational level (e.g., braking or accelerating, steering). This is in line with Michon's model of driving, (Michon et al., 1986) which conceptualises driving performance at three different levels of the driving task: strategic, tactical, and operational. The strategic level involves high-level planning regarding a driving journey, such as route selection. The tactical level involves behaviour related to the immediate traffic conditions, for example, monitoring potential hazards. The operational level involves vehicle control operations, such as steering, accelerating, and braking. In addition, previous studies have reported that chronic pain is positively associated with deficits in executive functioning (Berryman et al., 2014), which may increase crash risk (Vaezipour et al., 2022; Walshe et al., 2017).

Vaezipour and colleagues' systematic review also highlighted a number of gaps in the existing literature regarding the experiences of those driving with chronic pain (Vaezipour et al., 2022). Firstly, assessments of driver behaviour among people with chronic pain have typically not been conducted in a systematic or comprehensive manner. Evaluations have also seldomly employed validated measurements of driving behaviour (Veldhuijzen et al., 2006), driver distraction and attention (Feng et al., 2014) and attention-related driving errors (Ledesma et al., 2010). Therefore, it is unclear if clinically meaningful differences between drivers experiencing chronic pain and matched healthy controls exist. Secondly, driving behaviour among people with chronic pain has typically been studied with a focus on driving performance at the operational level (e.g., vehicle control, head movement, reaction time), with minimal consideration of other aspects of driver behaviour, such as self-reported errors, lapses and driving violations (Stephens and Fitzharris, 2016). Finally, there is also a paucity of research examining the impact of chronic pain in high-level cognitive driving skills, such as hazard perception, which is the ability to anticipate potentially dangerous road situations (Horswill, 2016). Hazard perception is critical to road safety, as it is positively associated with crash involvement, both prospectively (Horswill et al., 2015; Wells et al., 2008) and retrospectively (Boufous et al., 2011; Horswill et al., 2010; Horswill et al., 2020; McKenna and Horswill, 1999; Tūskė et al., 2019). Therefore, if chronic pain impacts hazard perception ability, this could have implications for road safety.

Whilst some research has been carried out on the impact of chronic pain on driving behaviour, many unknowns remain concerning how individuals manage driving safety when experiencing chronic pain. The relationships between chronic pain and risky behaviours, inattention, hazard perception, and driving workload have not been systematically investigated. The aims of the current study are to (i) examine the driving behaviour of individuals experiencing chronic pain compared with a healthy control group and (ii) explore the day-to-day driving difficulties and self-regulatory behaviours reported by chronic pain drivers.

2. Method

2.1. Participants

Eighty-nine drivers (45 chronic pain group, 44 healthy control group) were recruited from Australia. General eligibility criteria required participants to (i) be over 18 years old; (ii) hold a valid Australian driver license; (iii) drive at least three times a week in Australia; (iv) not have been diagnosed with conditions affecting the vestibular, central nervous system, or visual acuity; and (v) be able to read and write English. Specific eligibility criteria for the chronic pain group included having experienced persistent non-cancer pain for at least three months. After the recruitment of the chronic pain cohorts, age-gender matched healthy participants were recruited. The specific eligibility criterion for the healthy controls was that they had not experienced chronic pain in the last three months.

Participants were recruited using social media advertisements (i.e., Twitter and Facebook), and posts on the University of Queensland and Queensland University of Technology websites, which included a description of the study to improve the management of driving behaviour in individuals with chronic pain and the eligibility criteria (chronic pain and healthy control groups). Those interested were instructed to contact the research team and were assessed by a research officer over the phone to ensure their eligibility for participation, before being asked to provide informed consent for participation. The study was conducted in accordance with the Australian Code for Responsible Conduct of Research (University of Queensland Human Research Ethics Committee, Ethics approval number 2019002720).

2.2. Procedure

This study involved three phases of data collection: (1) an online questionnaire, (2) two validated computer-based tests of hazard perception skill, and (3) a two-week driving logbook. After the assessment of eligibility for participation in the study by a member of the research team (see Section 2.1), in *Phase 1*, a link to an online survey (SurveyMonkey platform) was emailed to eligible participants. This 30-minute survey collected data on participant demographics, driving experience (i.e., the number of years with a valid driver's license, kilometres driven per year, number of traffic crashes), and self-reported driving behaviour (see Section 2.3.1 for details). Additionally, pain measures in the chronic pain group (i.e., intensity, duration, and localisation of the pain) were collected. In *Phase 2*, participants completed two computer-based hazard perception tests (a response-time hazard perception test and a verbal-response hazard prediction test; see Section 2.3.2 for details) by attending an in-person session at the RECOVER Injury Research Centre (The University of Queensland, Australia) or online from their home computer (monitored by a research officer), depending on their preference. Both tests were completed on a standard Windows PC (Dell 15.6-inch monitor) at the University of Queensland or on participants' own standard Windows PC at home. Each participant took approximately 30 min to complete the tests. In ***Phase 3***, participants completed a two-week driving logbook, which was administered via a free mobile app on their smartphone (Expiwell, compatible with iOS and Android). The app contained a logbook questionnaire, which sent daily notifications to the participants. Each logbook entry took approximately 10 min to complete. At the completion of all three phases of the study, participants received an AUD100 gift card for contributions to the study.

2.3. Measures

2.3.1. Questionnaires (Phase 1)

A self-report questionnaire was used to capture: (1) demographic details (age, gender, education, employment), (2) driving characteristics (driver license type, vehicle type, frequency of driving, type of roads most commonly driven on, typical purpose of the driving, self-reported motor vehicle crashes), (3) general health characteristics. In addition, the following scales were included:

2.3.1.1. Fatigue Assessment Scale (Michielsen et al., 2003). This instrument was included to assess participant fatigue levels because high fatigue is common among chronic pain cohorts and may affect driving outcomes. This measure involved 10-items with response options ranging from 1 (never) to 5 (always).

2.3.1.2. Brief Pain Inventory (Cleeland and Ryan, 1991). This questionnaire was used to assess the impact of pain on one's life (i.e., interference) and pain severity experienced by the chronic pain group. The four pain severity items were rated on a scale of 0 (No pain) to 10 (Pain as bad as you can imagine). The seven pain interference items were also rated on a scale of 0 (Does not interfere) to 10 (Completely interferes).

2.3.1.3. Driver Behaviour Questionnaire (Stephens and Fitzharris, 2016). This measure was included to assess self-reported unsafe driving behaviour. It involved participants reporting how often, in the past six months, they were engaged in 4 types of driving behaviour: (1) aggressive violations (3 items), (2) ordinary violations (8 items), (3) errors (11 items), and (4) lapses (6 items). Response options ranged from 1 (never) to 6 (all the time). An average score was calculated for each sub-scale with higher values representing a higher degree of unsafe driving behaviour.

2.3.1.4. Susceptibility to Driver Distraction and Attention (Feng et al., 2014). This measure assessed two types of self-reported distraction propensity while driving: engagement distraction (7 items; 1 (never) to 5 (very often) and involuntary distraction (8 items; 1 (strongly disagree) to 6 (never happens)). An average score was calculated for each subscale.

2.3.1.5. Attention Related Driving Errors (Ledesma et al., 2010). This measure consisted of 19 items asking about self-reported attention-related driving errors (e.g., errors monitoring traffic environment and unintentional driving mistakes). Response options ranged from 1 (never) to 5 (almost always). An average score was calculated for the scale.

2.3.1.6. Self-reported driving difficulties (Takasaki, 2013). Participants were asked to report difficulties behind the wheel corresponding to three levels of the driving task: (i) strategic (6 items), (ii) tactical (4 items), and (iii) operational levels (2 items) where response options ranged from 1 (no difficulty) to 4 (great difficulty).

2.3.2. Hazard perception tests (Phase 2)

Participants completed two computer-based validated hazard perception tests: a response-time based hazard perception test (Hill et al., 2019) and a verbal-response hazard prediction test (Horswill et al., 2020). These tests were chosen based on previous validity evidence indicating that test scores were associated with indicators of driving safety. Scores on the response-time hazard perception test have previously been found to (1) differentiate high risk (young novice drivers) and lower risk (experienced drivers) groups and (2) be associated with on-road driving performance (heavy braking rates, as measured by g-force triggered dashcams) (Henderson et al., 2013). Previous versions of the test have also been found to be associated with crash involvement both retrospectively and prospectively (Horswill et al., 2015). Verbal-response hazard prediction test scores have been found to (1) differentiate high risk (young novice drivers) and lower risk (experienced drivers) groups and (2) be associated with crash risk in two independent samples (Horswill et al., 2010).

For the response-time test, participants viewed thirty video clips of traffic scenarios recorded from the driver's perspective. The videos depicted traffic conflicts (events in which the car with the camera had to take evasive action to avoid a collision with another road user) (Fig. 1). The clips were presented in the same fixed order for every participant (order randomization was not necessary as conflicts were not analysed individually in this study). Using a computer mouse, participants were asked to click, as early as possible, on any road users likely to be involved in a traffic conflict with the camera car. Response times to each of the 30 clips were converted into z scores based on sample means and standard deviations for each clip. The overall test score was an average of these standardized response times. Note that, as this test was designed as a response time measure, traffic conflicts were chosen to have close-to-ceiling hit rates (that is, virtually all drivers would respond to every conflict eventually), and hence hit rates were not appropriate to be used as test scores (percent of traffic conflicts responded to was 97 % for the chronic pain group and 96 % for the healthy controls, with no statistically significant group difference, *Mann-Whitney* $U = 864.50$, $p = .356$).

To control for individual differences in simple reaction time and computer mouse skill in the response-time hazard perception test, participants also completed a Simple Spatial Reaction Time (SSRT) test (Horswill et al., 2020), designed to mimic the response mode of the hazard perception test independent of the traffic context. This test involved 15 high contrast rectangles appearing at random locations and time intervals on the computer monitor. Participants were told to use the computer mouse to click on these rectangles as soon as they appeared. The test score was participants' average reaction time to the appearance of the rectangles.

The verbal-response hazard prediction test involved participants watching six video clips of traffic, which cut to black just before a potential traffic conflict. Participants were asked to talk out loud, making as many predictions as possible as to what might happen after the cut point. Participants' predictions were recorded and scored by an experienced research officer not involved in the testing, who was blind to each participant's group. Participants received a point for every prediction they made that matched a list of predictions previously made by an expert panel (three driving examiners). The overall test score was the average number of matched predictions per clip.

Fig. 1. A screenshot from the hazard perception test, depicting a traffic conflict.

2.3.3. Longitudinal design: Driving diary study (Phase 3)

A self-reported driving diary approach (Palat et al., 2019) was used, in which participants were asked to keep a log of their pain intensity and driving patterns over the course of two weeks. Self-reported data were collected on the duration of each drive, driving difficulties and experiences, including near-crash events where the driver was required to manoeuvre the vehicle suddenly to avoid a crash. Additionally, participants were asked to complete the NASA Task Load Index (TLX) scale (Hart and Staveland, 1988), which measured six components of workload in relation to their driving behaviour on a scale of 1 (low) to 100 (high). The workload components were: (1) mental demand (how mentally demanding the driving was), (2) physical demand (how physically demanding the driving was), (3) temporal demand (how hurried or rushed the pace of the driving was), (4) performance (how successful the driver was in accomplishing the driving trip/aim), (5) effort (how hard the driver had to work to accomplish their level of performance in driving), (6) frustration level (how insecure, discouraged, irritated, distressed and/or annoyed the driver was while driving).

2.4. Data analysis

All statistical analysis was conducted using Jamovi (www.jamovi.org, Version 1.8) and SPSS (Statistical Package for Social Sciences, Version 28). Descriptive statistics of the demographic and driving characteristics of the sample were obtained. To analyse differences in self-reported behaviour variables between the two groups, 2-tailed independent-sample Student's t-tests were conducted. Welch's *t*-test was reported if group variances were not homogeneous. In instances where the variables were not normally distributed (Shapiro-Wilks test of normality, $p < .05$), they were transformed to normality if possible. Otherwise, non-parametric tests were reported.

Scores from the response-time hazard perception test and the verbal-response hazard prediction test were used to examine the hypothesis that drivers experiencing chronic pain were worse at hazard perception than a healthy control group. For the hazard perception test and the hazard prediction test, independent-sample t-tests were conducted, with the group as the independent variable and the outcome measure (response time or mean predictions) as the dependent variable.

To examine whether any statistically significant group differences could be accounted for by confounding variables, any variable that correlated with both group and outcome measure was included in a regression to see if adjusting for that variable rendered the group difference statistically non-significant.

3. Results

3.1. General characteristics of the sample

The demographic characteristics of the participants are presented in Table 1. The sample comprised a total of 61 females (68.5 %) and 28 (31.5 %) males, aged 22 to 70 years ($M = 44.43$, $SD = 13.86$).

There were statistically significant differences (independent-sample *t*-test) in fatigue levels measured by FAS among the chronic pain group ($M = 28.38$, $SD = 7.50$) and healthy control group ($M = 19.27$, $SD = 4.57$; *Welch's t* $(80.84) = 7.21$, $p < .001$, square root transform to achieve normality). The magnitude of the differences in the means was a large effect (*Cohen's d* = 1.53). Additionally, as can be seen in Table 2, there were statistically significant differences in self-reported overall health between the two groups.

3.2. Pain characteristics of the chronic pain sample

Chronic pain participants reported the origin of their pain as an injury ($N = 16$, 35 %), motor vehicle crash ($N = 14$, 31 %), medical condition ($N = 8$, 18 %), no obvious reason ($N = 5$, 11 %), and other ($N = 2$, 4 %). Over 31 (69 %) of the chronic pain participants reported their pain was always present with varying pain levels. Additionally, 80 % of participants reported taking medication for pain management (see details in Supplemental Digital Content I). Table 3 outlines the pain characteristics and Fig. 2 illustrates the most common pain locations across the sample.

Table 1
Demographic and driving characteristics.

Variable	Chronic Pain	Healthy Control
Mean age (SD), years	44.96 (13.46)	43.89 (14.38)
Gender		
Female	31 (68.9 %)	30 (68.2 %)
Male	14 (31.1 %)	14 (31.8 %)
Education		
No formal education	1 (2.2 %)	–
High school	10 (22.2 %)	3 (6.8 %)
Trade qualification	10 (22.2 %)	4 (9.1 %)
Undergraduate degree	17 (37.8 %)	13 (29.5 %)
Postgraduate degree	7 (15.6 %)	24 (54.5 %)
Employment		
Full-time	10 (22.2 %)	25 (56.8 %)
Part-time/casual	11 (24.4 %)	11 (25 %)
Currently not in paid employment/study	24 (53.3 %)	8 (18.2 %)
License type		
Provisional (P)	1 (2.8 %)	–
Open	35 (97.2 %)	43 (97.7 %)
International	–	1 (2.3 %)
Vehicle transmission type		
Manual	8 (22.2 %)	7 (15.9 %)
Automatic	28 (77.8 %)	37 (84.1 %)
Driving purpose		
Driving to/from work/study	11 (30.6 %)	27 (61.4 %)
Driving as a part of work	3 (8.3 %)	6 (13.6 %)
Mostly personal	22 (61.1 %)	11 (25 %)
Mean Km driving per week (SD)	214.7 (281.5)	240.27 (177.9)
Mean hours driving per week (SD)	9.72 (18.2)	7.59 (5.6)
Most common road drives		
Urban	62.5 %	64.05 %
Rural	15.2 %	8.39 %
Motorway	22.2 %	27.57 %
Crash involvement as a driver		
Yes	25 (69.4 %)	35 (79.5 %)
No	11 (30.6 %)	9 (20.5 %)

Table 2
The general health of the sample.

Variables	Chronic PainN (%)	Healthy ControlN (%)
Difficulty sitting for a long time	36 (80 %)	4 (9 %)
Restricted movement	35 (77.8 %)	2 (4.5 %)
Fatigue	34 (75.6 %)	4 (9 %)
Anxiety	32 (71.1 %)	8 (18.2 %)
Depression	27 (60 %)	5 (11.4 %)
Sleep deprivation	26 (57.8 %)	3 (6.8 %)
Difficulty concentrating	23 (51.1 %)	5 (11.4 %)

All comparisons significant at $p < .001$.

Table 3
Pain characteristics of the chronic pain sample (n = 45).

Variables	Mean	SD	Range
Pain duration, months	148.7	131.2	6–504
Average BPI pain severity[a] (current + worst + least + average pain over past 24 h)	4.9	1.46	2–8
BPI Pain interference[b]			
General activity	5	2.1	0–10
Mood	5.2	2.7	0–10
Walking ability	4.2	3.1	0–10
Normal work (housework/outside home)	5.1	2.6	0–10
Relationship with others	4	2.8	0–10
Sleep	4.7	2.8	0–10
Enjoyment of life	5	2.5	0–10
Pain relief from medication[c]	54.9	22	0–89

BPI = Brief Pain Inventory.
[a] Rated on a scale of 0 (No pain) to 10 (Pain as bad as you can imagine).
[b] Rated on a scale of 0 (Does not interfere) to 10 (Completely interferes).
[c] Rated on a scale of 0 (No Relief) to 100 (Complete relief).

3.3. Self-reported behavioural performance in the driving task

Table 4 shows the means for self-reported behavioural driving performance. As can be seen, there were no statistically significant differences in errors, ordinary violations and aggressive violations between participants in the chronic-pain group and healthy control group measured by DBQ. However, the chronic pain group reported significantly more lapses, *Welch's t* (69.47) = 2.90, *p* =.005, *Cohen's d* = 0.61, with the magnitude of the effect being between medium and large.

To investigate the possibility that the group difference in lapses could be due to other variables, we first inspected relevant variables to determine if any correlated significantly with both group (chronic pain vs controls) and lapses. Fatigue, anxiety, difficulty concentrating, and difficulty sitting all correlated statistically significantly with both group and lapses (other candidate variables that did not meet this criterion included kilometres driven per week, hours driven per week, medication use, depression, and sleep deprivation). Then, multiple regressions were conducted, in which the relationship between group and lapses was adjusted for each of the four potential confounds identified (one model per potential confound to avoid overfitting and minimize multicollinearity; model *r*'s = 0.09–0.11, adjusted *r*'s = 0.07–0.09, *VIF*'s = 1.22–2.03). Adjusting for each of these four variables rendered the relationship between group and lapses statistically non-significant (*p*'s = 0.054–0.162), and hence we cannot rule out the possibility that the group difference for lapses was a function of one or more of these confounds.

While there was no statistically significant difference in involuntary distraction, as measured by the SDDA, the chronic pain group reported significantly *less* distraction engagement compared to the healthy controls, *t* (87) = −2.02, *p* =.046, *Cohen's d* = −0.43 (square root transform to reduce skewness), and the magnitude of this difference was between small and medium. Distraction engagement did not correlate significantly with any potential confounding variables (fatigue, driving exposure, health issues, medication use), indicating that these were unlikely to account for this group difference. Finally, there were no statistically significant differences in attention-related errors when driving, as measured by the ARDES.

As can be seen in Table 5, self-reported driving difficulties were assessed at three levels of driving performance: (i) strategic (ii) tactical and (iii) operational. Results show that the chronic pain group were more likely to report moderate to great difficulty when compared to the healthy group, associated with driving for more than one hour (57.8 % and 2.3 %, respectively) and driving on bumpy roads (30 % and 0 %, respectively). In addition, the chronic pain group was more likely to report slight difficulty in relation to all other examined behaviours. It is worth noting that no individuals in the healthy group reported great difficulty with any of the driving behaviours, while for the chronic pain group, six individuals reported great difficulty with driving on a bumpy road, five with driving for more than one hour, and one individual reported difficulty with driving in the rain, driving in rush-hour traffic, reversing, and braking suddenly.

3.4. Response-time hazard perception test and verbal-response hazard prediction test

There was no statistically significant difference between the chronic pain and healthy control groups for the response-time hazard perception test, *t* (85) = 1.42, *p* =.158, *Cohen's d* = 0.31 (square root transform to minimize skewness), the verbal-response hazard prediction test, *t* (84) = -0.63, *p* =.529, *Cohen's d* = −0.14, or the simple spatial reaction time task, *t* (85) = 0.76, *p* =.447, *Cohen's d* = 0.16 (log10 transform to

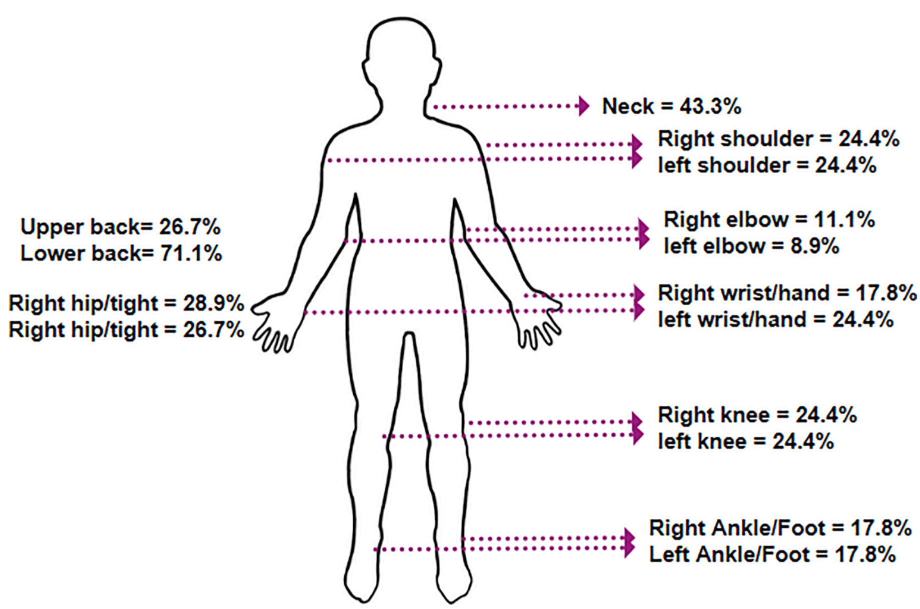

Fig. 2. Area of most pain of the chronic pain group (n = 45).

Table 4
Self-reported behavioural performance in the driving task.

Measure	Variables	No. of items	Chronic PainM (SD)	Healthy ControlM (SD)	Significance (*p value*), Effect size
DBQ[a]	Errors	11	1.36 (0.4)	1.32 (0.3)	–
	Lapses	6	2.06 (0.6)	1.76 (0.3)	*p* =.005, *d* = *0.61*
	Ordinary violations	8	1.78 (0.6)	1.78 (0.5)	–
	Aggressive violations	3	1.75 (0.7)	1.66 (0.6)	–
SDDQ[b]	Distraction engagement	7	2.46 (0.7)	2.73 (0.8)	*p* =.046, *d* = *-0.43*
	Involuntary distraction	8	2.78 (0.8)	2.76 (0.7)	–
ARDES[c]		19	1.51 (0.4)	1.43 (0.3)	–

N = 89 valid responses.
a = Driver Behaviour Questionnaire; range 1 (never) – 6 (all the time).
b = Susceptibility to Driver Distraction Questionnaire; range 1 (never) – 5 (very often).
c = Attention Related Driving Errors; range 1 (never) – 5 (almost always).

minimize skewness). There was also no group difference in response-time hazard perception test, after simple spatial reaction time was adjusted for, F (1,84) = 1.64, p =.204, $\eta^2 = 0.02$. That is, we found no evidence that those reporting chronic pain had worse hazard perception skill or slower reaction times than controls.

However, additional exploratory analyses revealed that individuals who reported a pain score of greater than 6 (based on the average of current pain and worst/least/average pain over the previous 24 h, as per Table 3) generated significantly fewer predictions in the hazard prediction test than controls, t (51) = −2.13, p =.038, *Cohen's d* = −0.78 (large effect). There was also a statistically significant correlation between pain score and hazard prediction test score, r (43) = −0.31, p =.038, within the chronic pain group, with greater pain levels associated with making fewer predictions. This raises the possibility that chronic pain may impair hazard perception performance, but only if the pain is of a sufficient magnitude. However, these two relationships were not statistically significant in response time hazard perception test scores (pain > 6 vs control: t (51) = 0.44, p =.67, *Cohen's d* = 0.16; pain and hazard perception response time correlation: r (40) = −0.04, p =.825), indicating the need for caution when interpreting these results.

One possibility was that the correlation found between hazard prediction score and pain score in the chronic pain group could have been created by a third confounded variable. However, none of the measures of potential variables (fatigue score, kilometres driven per week, hours driven per week, health issues, or medication use) correlated with both hazard prediction test score and pain score (with or without the healthy control group included as zero pain). This indicates that it is unlikely the relationship between pain level and hazard prediction test score was an artefact of any of these other variables.

3.5. Driving frequency and workload measured using a diary

Driving frequency and workload were measured over a two-week period using a driving diary. As can be seen in Fig. 3, participants in the chronic pain group drove on proportionally fewer days (M = 64.45 % of all days surveyed) compared to the healthy control group (M = 71.26 %), however, the differences were not statistically significant (*Mann-Whitney U* = 741.50, p =.081, *Rank Biserial Correlation* = 0.22). The chronic pain group reported a significantly greater average proportion of days of experiencing driving difficulties (M = 73.29 % of days driven) compared to the healthy control group (M = 5.51 %), *Mann-Whitney U* = 54.50, p <.001, *Rank Biserial Correlation* = 0.94.

Table 5
Frequency of the self-reported driving difficulties of the sample.

	No difficultyN (%)		Slight difficulty N (%)		Moderate-great difficulty N (%)	
	Chronic pain	Healthy control	Chronic pain	Healthy control	Chronic pain	Healthy control
Strategic level						
Driving at dusk	18 (40 %)	29 (65.9 %)	18 (40 %)	10 (22.7 %)	2 (4.4 %)	1 (2.2 %)
Driving in rain	18 (40 %)	23 (52.3 %)	18 (40 %)	11 (25 %)	5 (11.1 %)	7 (15.9 %)
Driving for more than 1 h	3 (6.7 %)	28 (63.6 %)	12 (26.7 %)	10 (22.7 %)	26 (57.8 %)	1 (2.3 %)
Driving on a bumpy road	3 (6.7 %)	25 (56.8 %)	18 (40 %)	8 (18.2 %)	18 (30 %)	–
Driving on high-traffic roads	16 (35.6 %)	31 (70.5 %)	19 (42.2 %)	9 (20.5 %)	5 (11.1 %)	1 (2.3 %)
Driving in rush-hour traffic	14 (31.1 %)	16 (36.4 %)	20 (44.4 %)	1 (2.3 %)	8 (17.8 %)	–
Tactical level						
Changing lanes	22 (48.9 %)	37 (84.1 %)	16 (35.6 %)	5 (11.4 %)	1 (2.2 %)	–
Checking blind spots	16 (35.6 %)	35 (79.5 %)	19 (42.2 %)	7 (15.9 %)	5 (11.1 %)	–
Merging on motorway	22 (48.9 %)	35 (79.5 %)	16 (35.6 %)	5 (11.4 %)	2 (4.4 %)	2 (4.5 %)
Reversing	16 (35.6 %)	34 (77.3 %)	22 (48.9 %)	5 (11.4 %)	4 (8.9 %)	1 (2.3 %)
Operational level						
Braking suddenly	24 (53.3 %)	26 (59.1 %)	8 (17.8 %)	4 (9.1 %)	7 (15.5 %)	1 (2.3 %)
Turning steering wheel quickly	19 (42.2 %)	25 (56.8 %)	14 (31.1 %)	2 (4.5 %)	2 (4.4 %)	–

In relation to driving workload, analyses showed statistically significant differences between the chronic pain and healthy groups over the two-week period (see Fig. 4). Specifically, the chronic pain group reported greater mental demand (*Mann-Whitney U* = 473.50, p <.001, *Rank Biserial Correlation* = 0.50), physical demand (*Mann-Whitney U* = 402.00, p <.001, *Rank Biserial Correlation* = 0.58), effort level (*Mann-Whitney U* = 505.50, p <.001, *Rank Biserial Correlation* = 0.47), and frustration level (*Mann-Whitney U* = 532.00, p <.001, *Rank Biserial Correlation* = 0.44) than the healthy group. The effect size for each of these findings was large. The effect of group on temporal workload approached significance, *Mann-Whitney U* = 741.00, p =.083, *Rank Biserial Correlation* = 0.22. There were no statistically significant differences observed in overall performance, *Mann-Whitney U* = 798.50, p =.211, *Rank Biserial Correlation* = 0.16. There was also a statistically significant positive correlation between average reported pain and self-reported overall driving workload amongst the chronic pain group, such that higher average pain scores were associated with greater self-reported workload, *Spearman's* ρ (42) = 0.42, p =.005.

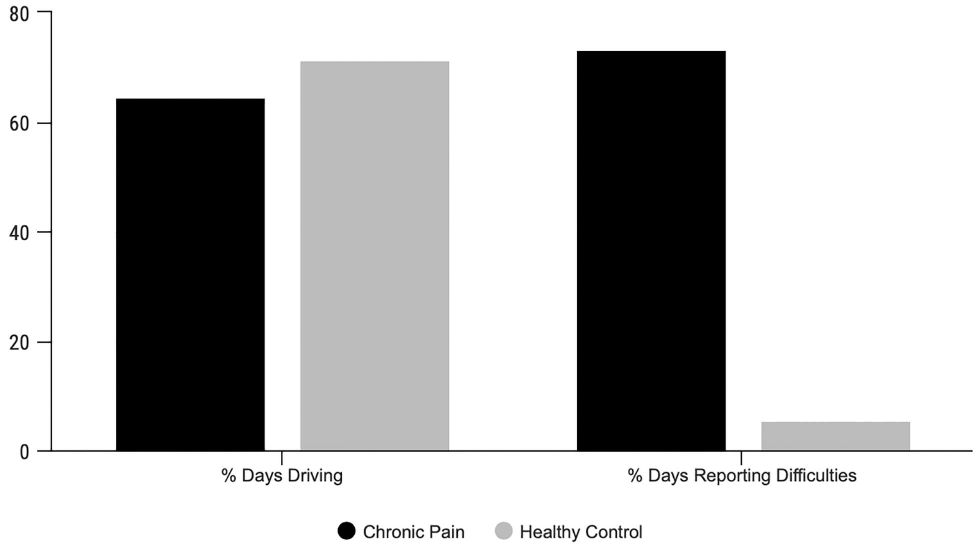

Fig. 3. Frequency of driving and days reporting difficulties over two weeks.

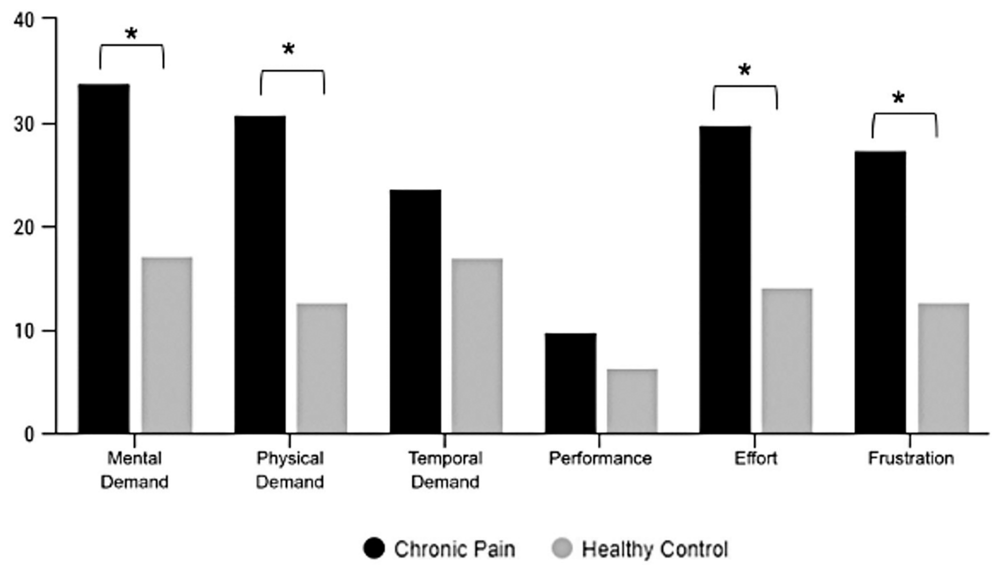

Fig. 4. Mean workload scores of NASA-TLX by both participant groups (* denotes statistically significant difference between groups).

3.6. *Driving difficulties, self-regulation and near-misses measured using a driving diary*

Drivers were asked to keep a log of their driving difficulties and self-regulation strategies used to compensate for their pain over the two-week period. Overall, drivers experiencing chronic pain reported twelve main categories in relation to their driving difficulties compared to seven categories in the healthy control group (Table 6). Additionally, seventeen self-regulation strategies are reported by the chronic pain group related to driving tasks which are listed in Table 7.

Finally, participants reported 42 near misses (24 chronic pain groups compared to 18 healthy control groups) over two weeks of driving. There were no statistically significant differences in the self-reported number of near misses over a two-week period of data collection between participants in the chronic-pain group and healthy control group. When reviewing the information provided by the participants concerning the context and response to the near misses, no clear patterns concerning the moment in their drive that the near miss occurred were identified. For both groups, the near-misses generally occurred near the city with a 60–70 kph speed limit (58 % in chronic pain compared to 61 % in healthy control group). However, the chronic pain group reported that 42 % of their near misses occurred when driving in a straight section of the road compared to 28 % in the healthy control group. Another of the differences between groups was that the chronic pain group mainly managed the situation by braking abruptly (40 %) whilst the control group managed the situation by braking gently (26 %). Indeed, only in 21 % of the near misses reported by the healthy control group were abrupt braking. The details of the driving diary data are included in Supplemental Digital Content II.

4. Discussion

This study provides insight to the driving behaviour of drivers experiencing chronic pain compared with a healthy control group. Additionally, day-to-day driving difficulties and self-regulation behaviours were investigated among drivers experiencing chronic pain. Analyses confirmed that the two cohorts (chronic pain and healthy control) significantly differed in their incidence of general health conditions,

Table 6
Self-reported driving difficulties reported during driving diary.

Driving Difficulties	Healthy Control	Chronic Pain
Lack of concentration, attention	7	–
Misjudged the behaviour of road users (i.e., vehicles, pedestrians)	4	–
Difficulty driving on highway/during heavy rain	3	–
Uncomfortable sitting in the car during long drive	2	–
Missed a turn during the driving journey (distracted)	2	–
Fatigue and sleepiness	2	–
Difficulty parking a vehicle	1	–
Experiencing Pain	–	
Neck	–	46
Back	–	31
Hand, Wrist, Arm	–	27
Headache	–	27
Shoulder	–	17
Ankle, Foot	–	7
Knee, leg	–	8
Hip, Tight	–	6
Difficulty monitoring road environment i.e., twisting neck to check blind spot, merging, and reversing	–	39
Uncomfortable sitting in the car	–	35
Pain negatively impacts on mood, cause frustration and difficulty concentrating on driving	–	34
Driving flares up pain and lead to fatigue	–	23
Prolonged sitting in the car flares up pain	–	20
Difficulties with acceleration, brake, clutch, and steering flare up pain	–	20
Difficulties with getting in and out of the car	–	13
Difficulties putting on the seat belt in the car	–	6
Sleep deprivation due to pain	–	6
Driving on highway and unknown places flares up pain	–	3
Medication negatively affects driving	–	3

Table 7
Self-reported self-regulation strategies that were reported by chronic pain participants in the driving diary.

Self-regulation strategies	Frequency
Use pacing strategies by taking break during the trip and stretch	55
Drive shorter distances, limit, and avoid driving	29
Postural adaptations to prevent pain flares up during the drive	27
Trying to drive more attentive and vigilant	21
Listening to Radio, Music to distract oneself from the pain	19
Use mindfulness and breathing techniques	18
Use heat pack before and after the drive	16
Use support cushion and tense machine	15
Use pain medications	15
Ask someone else to drive	15
Use knee and back brace	12
Adjust the way holding the steering wheel to compensate for pain	10
Visiting physiotherapy, massage, Thai Chi and applying ointment before and after driving	7
Drink Caffeine to stay alert	7
Use Advanced Driver Assistance System	5
Uses the whole body to perform shoulder checks	4
Talking on the phone to distract myself from pain	2

including fatigue level. Among drivers experiencing chronic pain, the most common pain sites were the lower back (71.1%) and neck (43.3%). This finding is consistent with a previous study suggesting that back problems are one of the most common causes of chronic pain (Henderson et al., 2013). An implication of this for driving is the possibility that pain in these areas can be exacerbated by particular driving tasks, such as prolonged sitting and monitoring the road environment (e.g., shoulder checks, turning the head to the right or left to change lanes, turning back) (Takasaki et al., 2011; Vaezipour et al., 2022).

Self-reported driver behaviour, driver distraction and attention-related errors were not different between the chronic pain and healthy control groups for most of the variables. One exception was that drivers with chronic pain reported more driving lapses, which is consistent with the impaired cognitive performance that drivers with chronic pain may experience (Crombez et al., 1997; Lorenz and Bromm, 1997). However, this group difference became statistically non-significant when factors correlated with both group and lapses, such as fatigue, were adjusted for. That is, we cannot rule out the possibility that the difference may be due to factors associated with chronic pain, such as fatigue, rather than the chronic pain itself. The other exception was the chronic pain drivers reported significantly less distraction engagement than controls and this could not be accounted for by confounding variables. While it should be noted that this effect only just reached statistical significance, it could be reflective of some sort of compensatory behaviour among the chronic pain group. That is, they are less willing to deliberately engage in distractions.

During the two-week observation period for the diary data, drivers experiencing chronic pain reported higher perceived mental demand, physical demand, temporal demand, and frustration levels from the driving task than healthy controls. The lack of statistically significant differences observed in overall performance of driving tasks between groups may be due to the fact that participants who experience chronic pain are aware of their condition and, therefore, may be investing more resources during the driving task to maintain their safety (Takasaki et al., 2011; Vaezipour et al., 2022). This phenomenon is often referred as self-regulation or risk compensation (Nguyen-Phuoc et al., 2020). The lack of a group difference for temporal workload could be because driving is a self-paced task: for instance, drivers can choose to drive slower to compensate for perceived workload burdens. A statistically significant positive correlation between average reported pain and self-reported overall driving workload amongst the chronic pain group was found such that higher average pain scores were associated with the greater self-reported workload. This is not surprising as the experience of chronic pain has been demonstrated to influence cognitive deficits (Berryman et al., 2013; Kuhajda et al., 2002) and mental effort (Takasaki et al., 2014).

No statistically significant differences were observed among participants in the chronic pain group and the healthy control group for either the response-time hazard perception test, the verbal-response hazard prediction test, or the simple spatial reaction time task. The latter finding is consistent with previous work, which found chronic pain did not significantly influence reaction time (Veldhuijzen et al., 2006). However, participants with self-reported pain scores greater than six out of 10 generated significantly fewer matched predictions in the hazard prediction test than controls. Within the chronic pain group, those with greater pain scores also performed worse in the hazard prediction test. This raises the possibility that chronic pain may impair hazard perception performance, but only if the pain is of a sufficient magnitude. However, these findings were not replicated for the response time hazard perception test, indicating that we need to treat this conclusion as tentative. Further work would be useful to clarify the relationship between pain magnitude and driving performance, perhaps involving larger samples of people with more severe chronic pain.

During the study, participants experiencing chronic pain reported considerably more difficulties engaging in their daily driving compared to participants without chronic pain. Participants experiencing chronic pain reported a number of difficulties while driving, such as problems monitoring the road environment due to pain as a result of uncomfortable sitting positions in a car. Chronic pain appears to interfere with vehicle control in some individuals, such as acceleration and braking. This is consistent with previous research where participants with chronic pain reported difficulties performing operational driving activities (Fan et al., 2012; Takasaki et al., 2011; Takasaki et al., 2012; Takasaki et al., 2014). As expected, participants in the chronic pain group in the present study appeared to be experiencing difficulties typically associated with their condition.

Another issue that participants with chronic pain experienced is that driving caused pain flare-up due to prolonged sitting while driving.

Previous research has shown participants with chronic pain reported moderate to great difficulties with driving for more than one hour (Takasaki et al., 2012), and indicated that prolonged sitting could flare pain (Costa et al., 2020). This finding raises the question of how long a person with chronic pain should drive, which might be a useful subject for further research. Indeed, some participants in this study appeared to strategically avoid driving to manage their pain, which is consistent with previous studies (Fan et al., 2012; Okunribido et al., 2007). Chronic pain not only impairs attention but may result in states associated with risky driving such as negative mood, which has been previously linked with behaviours such as speeding (Oviedo-Trespalacios and Scott-Parker, 2019).

Drivers used self-regulation strategies to overcome driving difficulties linked with their chronic pain. Participants used pacing strategies such as (1) taking breaks during the trip and stretching, (2) driving shorter distances, and (3) limiting and avoiding driving. They also used postural adaptations to prevent pain flare ups during the drive and tried to drive more attentively and with greater vigilance. There were some instances where individuals with chronic pain highlighted the use of Advanced Driver Assistance Systems as a self-regulation strategy. The wide range of strategies employed by study participants could explain the lack of impact that chronic pain experience has on driver behaviour and objective measurements of hazard perception. Consistent with previous research reporting that self-regulation among distracted drivers increased safety (Oviedo-Trespalacios et al., 2020; Li et al., 2020), this study further confirms the common adoption of self-regulation strategies among chronic pain cohorts (Vaezipour et al., 2022). Nonetheless, there was great variability among participants in terms of the strategies used, and further work to optimise these strategies might be of value.

One limitation of this study is that the driving diary component was conducted during COVID-19 travel restrictions, which may have influenced the driving pattern of some participants. Furthermore, the convenient sampling approach was adopted for recruitment. Future research should address this limitation by recruiting a larger and more representative sample of participants though this could be challenging among this clinical population due to the burden of their chronic condition. Also, it could be that the effects of chronic pain on hazard perception ability might be greater than found in our study because the hazard perception tests were relatively short in duration and hence participants may not have reached the time at which their pain became more distracting due to prolonged sitting. Similarly, the hazard perception tests did not involve participants having to engage in all aspects of driving (e.g., they did not have to control a vehicle during the tests). It could be that chronic pain has a greater effect on hazard perception during real driving when individuals would be engaging in more movement and performing additional tasks. Another limitation is that the sample size was not sufficient to allow us to conduct a multiple regression on group differences in driving behaviours (i.e., driving lapses) with all potential confounding variables adjusted for at once. Finally, with respect to the driving behaviour survey data and driving diary, self-reported data has been used. Future research measuring driving behaviour during real on-road driving might address some of these issues.

5. Conclusion

Although the current study is based on a small sample of participants, the findings suggest participants with chronic pain did not differ significantly from healthy controls both for self-reported driving behaviour and for two validated measures of hazard perception skill. However, participants with chronic pain nonetheless reported considerably greater difficulty in engaging in their daily driving than controls. This suggests that drivers with chronic pain may, on average, be able to safely manage their driving, despite the challenges created by this condition. However, this management may not be sufficient in individuals with more severe levels of pain. These results highlight the need for more work to understand the relationship between chronic pain and driving, in order to inform evidence-based fitness-to-drive guidelines for individuals with chronic pain. In particular, research focused on pain medication intake and other comorbidities within chronic pain populations is needed to provide evidence-based advice on self-regulation strategies to minimise driving risk. Finally, future work is needed to understand the balance between the potential impairments and benefits of pain medication with regard to safe driving.

6. Disclosure

We certify that this work is original, has not been previously published, and is not under consideration elsewhere. All authors have made substantial contributions to this paper. No other contributors participated in this manuscript.

7. A Funding Source Declaration

We would like to acknowledge the funding support provided by the Motor Accident Insurance Commission, Australia.

The funding for data collection was partially supported as a part of the Road Safety Research Fund of the Royal Automobile Club of Victoria in Australia.

Dr Oscar Oviedo-Trespalacios contribution to the manuscript was funded by an Australian Research Council Discovery Early Career Researcher Award [DE200101079].

CRediT authorship contribution statement

Atiyeh Vaezipour: Project administration, Conceptualization, Methodology, Formal analysis, Writing – original draft. **Mark S. Horswill:** Conceptualization, Methodology, Formal analysis, Writing – review & editing. **Nicole E. Andrews:** Conceptualization, Methodology, Writing – review & editing. **Venerina Johnston:** Conceptualization, Methodology, Writing – review & editing. **Patricia Delhomme:** Conceptualization, Methodology, Writing – review & editing. **Oscar Oviedo-Trespalacios:** Conceptualization, Methodology, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgement

We would like to acknowledge the contribution of research assistance Ms Fatima Amershi in recruitment and data collection and Dr Genevieve Kieseker for coding the hazard prediction test data. Funding support for this research was provided by the Motor Accident Insurance Commission, Australia. Oscar Oviedo-Trespalacios' contribution was funded by an Australian Research Council Discovery Early Career Researcher Award [DE200101079]. The funders did not have any role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aap.2022.106856.

References

Berryman, C., Stanton, T.R., Bowering, K.J., Tabor, A., McFarlane, A., Moseley, G.L., 2013. Evidence for working memory deficits in chronic pain: a systematic review and meta-analysis. Pain® 154 (8), 1181–1196.

Berryman, C., Stanton, T.R., Bowering, K.J., Tabor, A., McFarlane, A., Moseley, G.L., 2014. Do people with chronic pain have impaired executive function? A meta-analytical review. Clin. Psychol. Rev. 34 (7), 563–579.

Boufous, S., Ivers, R., Senserrick, T., Stevenson, M., 2011. Attempts at the practical on-road driving test and the hazard perception test and the risk of traffic crashes in young drivers. Traffic Inj. Prev. 12 (5), 475–482.

Burdett, B.R., Charlton, S.G., Starkey, N.J., 2019. Mind wandering during everyday driving: An on-road study. Accid. Anal. Prev. 122, 76–84.

Carr, D.B., Stowe, J.D., Morris, J.C., 2019. Driving in the elderly in health and disease. Handb. Clin. Neurol. 167, 563–573.

Cleeland, C.S., Ryan, K., 1991. The brief pain inventory. Pain Res. Group 20, 143–147.

Costa, N., Hodges, P.W., Ferreira, M.L., Makovey, J., Setchell, J., 2020. What triggers an LBP flare? A content analysis of individuals' perspectives. Pain Med. 21 (1), 13–20.

Crombez, G., Eccleston, C., Baeyens, F., Eelen, P., 1997. Habituation and the interference of pain with task performance. Pain 70 (2–3), 149–154.

Fan, A., Wilson, K.G., Acharya, M., Cranney, A., Buenger, U., Marshall, S., 2012. Self-reported issues with driving in patients with chronic pain. PM&R 4 (2), 87–95.

Feng, J., Marulanda, S., Donmez, B., 2014. Susceptibility to driver distraction questionnaire: development and relation to relevant self-reported measures. Transp. Res. Rec. 2434 (1), 26–34.

Hart, S.G., Staveland, L.E., 1988. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Adv. Psychol. 52, 139–183.

Henderson, J.V., Harrison, C.M., Britt, H.C., Bayram, C.F., Miller, G.C., 2013. Prevalence, causes, severity, impact, and management of chronic pain in Australian general practice patients. Pain Med. 14 (9), 1346–1361.

Hill, A., Horswill, M.S., Whiting, J., Watson, M.O., 2019. Computer-based hazard perception test scores are associated with the frequency of heavy braking in everyday driving. Accid. Anal. Prev. 122, 207–214.

Hinton, J., Watson, B., Oviedo-Trespalacios, O., 2022. A novel conceptual framework investigating the relationship between roadside advertising and road safety: The driver behaviour and roadside advertising conceptual framework. Transp. Res. Part F: Traffic Psychol. Behav. 85, 221–235.

Horswill, M.S., 2016. Hazard perception in driving. Curr. Direct. Psychol. Sci. 25 (6), 425–430.

Horswill, M.S., Anstey, K.J., Hatherly, C.G., Wood, J.M., 2010. The crash involvement of older drivers is associated with their hazard perception latencies. J. Int. Neuropsychol. Soc. 16 (5), 939–944.

Horswill, M.S., Hill, A., Wetton, M., 2015. Can a video-based hazard perception test used for driver licensing predict crash involvement? Accid. Anal. Prev. 82, 213–219.

Horswill, M.S., Hill, A., Jackson, T., 2020. Scores on a new hazard prediction test are associated with both driver experience and crash involvement. Transp. Res. Part F: Traffic Psychol. Behav. 71, 98–109.

Kuhajda, M.C., Thorn, B.E., Klinger, M.R., Rubin, N.J., 2002. The effect of headache pain on attention (encoding) and memory (recognition). Pain 97 (3), 213–221.

Ledesma, R.D., Montes, S.A., Poó, F.M., López-Ramón, M.F., 2010. Individual differences in driver inattention: the attention-related driving errors scale. Traffic Inj. Prev. 11 (2), 142–150.

Li, X., Oviedo-Trespalacios, O., Rakotonirainy, A., 2020. Drivers' gap acceptance behaviours at intersections: A driving simulator study to understand the impact of mobile phone visual-manual interactions. Accid. Anal. Prev. 138, 105486.

Lorenz, J., Bromm, B., 1997. Event-related potential correlates of interference between cognitive performance and tonic experimental pain. Psychophysiology 34 (4), 436–445.

McKenna F.P., Horswill M.S. Hazard perception and its relevance for driver licensing. IATSS Res. 1999;23(HS-042 879).

Michielsen, H.J., De Vries, J., Van Heck, G.L., 2003. Psychometric qualities of a brief self-rated fatigue measure: The Fatigue Assessment Scale. J. Psychosom. Res. 54 (4), 345–352.

Michon, J.A., 1986. A critical view of driver behavior models: what do we know, what should we do? In: Evans, L., Schwing, R.C. (Eds.), Human Behavior and Traffic Safety. Springer US, Boston, MA, pp. 485–524.

Nguyen-Phuoc, D.Q., Oviedo-Trespalacios, O., Su, D.N., De Gruyter, C., Nguyen, T., 2020. Mobile phone use among car drivers and motorcycle riders: The effect of problematic mobile phone use, attitudes, beliefs and perceived risk. Accid. Anal. Prev. 143, 105592.

Okunribido, O.O., Shimbles, S.J., Magnusson, M., Pope, M., 2007. City bus driving and low back pain: a study of the exposures to posture demands, manual materials handling and whole-body vibration. Appl. Ergon. 38 (1), 29–38.

Oviedo-Trespalacios, O., Nandavar, S., Haworth, N., 2019. How do perceptions of risk and other psychological factors influence the use of in-vehicle information systems (IVIS)? Transp. Res. Part F: Traffic Psychol. Behav. 67, 113–122.

Oviedo-Trespalacios, O., Afghari, A.P., Haque, M.M., 2020. A hierarchical Bayesian multivariate ordered model of distracted drivers' decision to initiate risk-compensating behaviour. Anal. Methods Accid. Res. 26, 100121.

Oviedo-Trespalacios, O., Newton, J.D.A., Demant, D., Phillips, J.G., Struckman-Johnson, C., 2022. Understanding sexual activity while driving as a form of distracted driving. Accid. Anal. Prev. 169, 106621.

Oviedo-Trespalacios, O., Scott-Parker, B., 2019. Fast and furious: A neglected issue in health promotion among young drivers. Health Promot. J. Austr. 30 (3), 311–316.

Oviedo-Trespalacios, O., Regan, M.A., 2021. Driver distraction. International encyclopedia of transportation. Transp. Psychol. Transp. Sustain. Health 7, 113–120.

Palat, B., Saint Pierre, G., Delhomme, P., 2019. Evaluating individual risk proneness with vehicle dynamics and self-report data– toward the efficient detection of At-risk drivers. Accid. Anal. Prev. 123, 140–149.

Regan, M.A., Hallett, C., Gordon, C.P., 2011. Driver distraction and driver inattention: Definition, relationship and taxonomy. Accid. Anal. Prev. 43 (5), 1771–1781.

Stephens, A., Fitzharris, M., 2016. Validation of the driver behaviour questionnaire in a representative sample of drivers in Australia. Accid. Anal. Prev. 86, 186–198.

Takasaki, H., 2013. Driving Difficulty and Performance in People with Chronic Whiplash. The University of Queensland.

Takasaki H., Johnston V., Treleaven J.M., Jull G.A. 2012. The Neck Pain Driving Index (NPDI) for chronic whiplash-associated disorders: development, reliability, and validity assessment. Spine J. 12(10):912-920. e911.

Takasaki, H., Johnston, V., Treleaven, J., Pereira, M., Jull, G., 2011. Driving with a chronic whiplash-associated disorder: a review of patients' perspectives. Arch. Phys. Med. Rehabil. 92 (1), 106–110.

Takasaki, H., Treleaven, J., Johnston, V., Van den Hoorn, W., Rakotonirainy, A., Jull, G., 2014. A description of neck motor performance, neck pain, fatigue, and mental effort while driving in a sample with chronic whiplash-associated disorders. Am. J. Phys. Med. Rehabil. 93 (8), 665–674.

Tūskė, V., Šeibokaitė, L., Endriulaitienė, A., Lehtonen, E., 2019. Hazard perception test development for Lithuanian drivers. IATSS Res. 43 (2), 108–113.

Vaezipour, A., Oviedo-Trespalacios, O., Horswill, M., Rod, J., Andrews, N., Johnston, V., Delhomme, P., 2022. impact of chronic pain on driving behaviour: a systematic review. Pain 163 (3), e401–e416.

Vaezipour, A., Andrews, N., Oviedo-Trespalacios, O., Amershi, F., Horswill, M., Johnston, V., Delhomme, P., 2022. Exploring driving behaviour from the perspectives of individuals with chronic pain and health professionals. Appl. Ergon. 102, 103755.

Veldhuijzen, D.S., Van Wijck, A., Wille, F., Verster, J.C., Kenemans, J., Kalkman, C., Olivier, B., Volkerts, E.R., 2006. Effect of chronic nonmalignant pain on highway driving performance. Pain 122 (1–2), 28–35.

Walshe, E.A., Ward McIntosh, C., Romer, D., Winston, F.K., 2017. Executive function capacities, negative driving behavior and crashes in young drivers. Int. J. Environ. Res. Public Health 14 (11), 1314.

Wells P., Tong S., Sexton B., Grayson G., Jones E. Cohort II: a study of learner and new drivers. Volume 1—Main Report: Road Safety Research Report, 2008.

World Health Organization. Road Traffic Injuries. Available at www.who.int/news-room/fact-sheets/detail/road-traffic-injuries, 2021.