#### Clinical Pain Research

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# When driving hurts: characterizing the experience and impact of driving with back pain

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#### **Abstract**

**Objectives:** Driving is one of the most widespread aspects of daily living to people in the United States and is an active process that requires various cognitive functions, such as attention. Chronic low back pain (CLBP) is one of the more prevalent and costly health conditions in the world, with individuals who report CLBP also reporting significant impairment across different domains of daily life both physically and cognitively. However, despite the prevalence of these two constructs, research detailing the experience of driving in pain remains largely underrepresented. This cross-sectional study sought to characterize the driving experience of people who experience CLBP, focusing on the psychological constructs related to chronic pain like pain catastrophizing, affective responses (irritability, anxiety, fear), and self-reported driving behaviors and outcomes.

**Methods:** This study distributed an online questionnaire measuring pain, disability, and other psychological constructs commonly associated with CLBP like pain catastrophizing through M-turk to 307 U.S. participants with recurring CLBP and regular driving activity. Participants also answered questions regarding driving in pain, affective responses to driving in pain (i.e., irritability, anxiety, and fear), driving behaviors and violations, driving

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avoidance habits as a result of pain, opioid use, using pain medication while driving, and recent vehicle collisions within the past three years. Bivariate correlations were used to compare study variables, and one-way ANOVA's were used to compare means between participants with and without a collision history within the past three years. Results: Findings demonstrated significant positive associations not only between the psychological factors commonly associated with chronic pain, such as pain intensity, pain disability, pain catastrophizing, and the cognitive intrusion by pain, but also statistically significant relationships between these measures and pain intensity while driving, affective responses to driving in pain, driving violations, and driving avoidance habits. Additionally, in comparison to participants with no collision history within the past three years, participants who had been driving during a vehicle collision reported greater pain catastrophizing and cognitive intrusion by pain scores.

Conclusions: To our knowledge, the current study is the first to characterize driving experience specifically among individuals with CLBP, with attention to the relationship among key sensory, affective, and cognitive psychological metrics as well as self-reported driving history and behavior. The current findings reinforce multiple associations between pain and cognitive-affective variables that have been observed in literature outside the driving context, including pain intensity, anger, inattention, and behavioral disruption. Given that driving is a pervasive, potentially risky behavior that requires some form of cognitive focus and control, the current findings point to a continued need to examine these associations within this specific life context.

We believe we have laid a groundwork for research considering the role of psychological pain variables in a driving performance. However, the nature of our analyses prevents any sort of causality from being inferred, and that future experimental research is warranted to better understand and explain these mechanisms underlying driving in pain while accounting for participant bias and subject interpretation.

**Keywords:** attention; chronic low back pain; distraction; driving; pain; pain catastrophizing.

# Introduction

Driving is considered an instrumental activity of daily living [1]. Driving is likewise an active process requiring cognitive functions such as perception, decision-making, and attention [2–4]. Studies across multiple domains have reliably demonstrated that pain "demands attention" [5–8] and can negatively impact performance on tasks that require attentional control [9]. Accordingly, a growing body of research has examined the interface between driving and pain experience [3, 4, 10-13]. In general, both lab [4, 14] and field studies [13] have found deficits in driving performance across such conditions as fibromyalgia [11, 15], whiplash [3, 4, 16], and other chronic nonmalignant pain conditions [13, 14]. Collectively, these findings suggest that the experience of driving in pain is a relatively common phenomenon that deserves further empirical scrutiny.

Low back pain is a leading cause of pain and disability in the United States [17, 18], as well as one of the most common reasons for work days lost [19, 20]. Individuals with chronic low back pain (CLBP) report significant impairment across domains of daily living, including family, social, and workplace function [21–23], as well as significant psychological distress [24–28]. Studies find that over 60% of long haul delivery drivers [29], taxi drivers [30], and bus drivers [12] experience CLBP. While these studies focus on the physical/ musculoskeletal repercussions of long driving hours [12, 29-32], to date, very few studies have examined the potential impact of CLBP on driving experience, including that of non-professional drivers. For example, Hu et al. [33], used epidemiological data from Department of Motor Vehicles (DMV) records to identify back pain as a potential crash risk factor in older women (but not men). Another study reported that back pain was significantly associated with a collision history in truck drivers, which the authors attributed to potential distraction stemming from pain as well as a limited range of movement [34].

In summary, despite the ubiquity of both driving and CLBP, almost no studies to date have characterized the experience of driving with CLBP. Further, no studies have examined the association between driving with pain and key cognitive-psychosocial predictors of pain experience. In particular, pain catastrophizing, defined as an exaggerated negative orientation toward pain [35], has been associated with worse physical and psychological outcomes in CLBP [36], as well as with greater difficulties in performing cognitive tasks while in pain [37]. Of particular interest to the current study, catastrophizing has been associated with attentional capture

by pain [7, 38] and most recently with cognitive intrusion by pain [5, 7, 38]; the latter was assessed by the Cognitive Intrusion of Pain Scale (ECIP) [5], developed to measure cognitive/attentional interruption by an endogenous or exogenous pain stimulus.

The current study represents a preliminary crosssectional investigation of self-reported driving experience in a sample of individuals with CLBP, focusing on the experience of pain, affective response (specifically fear, anxiety, and irritation), and self-reported driving behavior and outcomes. The current descriptive findings are intended to serve as a foundation for more future, causally oriented research. We predicted that pain experience, affective responses, pain catastrophizing and the cognitive intrusion by pain would have positive associations not only amongst each other, but also with risky driving behaviors and poor driving outcomes.

# Materials and methods

#### **Participants**

Participants were recruited from the United States using Mechanical Turk (MTurk), which is an online marketplace that allows people to post their study to a job board that is accessible by people with an MTurk worker account. MTurk is commonly utilized in epidemiological and psychological research to collect data from the general population [39]. Studies of MTurk responses have been found to retain a satisfactory level of internal and test-retest reliability, and have prevalence rates of clinical symptoms matching the general population [40, 41]. The MTurk job listing invited participants to complete a paid 60-min Qualtrics questionnaire pertaining to chronic back pain and driving. Interested participants were screened for if they had recurring back pain (minimum three months, with more than half the days in the past six months) and have driven a vehicle in the past week. If participants did not pass the screening process, they were excluded from the survey and had their IP addresses blocked from being able to retake the survey. Qualitative questions were provided throughout the survey to both provide better insight into participant pain and driving experience and serve as an additional check for inattentive responses (i.e., impossible to achieve weekly driving hours, greater duration of pain than age, etc.). Participants gave informed consent before being screened for eligibility and were compensated \$2.00 upon completion of the survey. This study was reviewed and approved by the University Institutional Review Board (IRB) at the University of Alabama in Birmingham (UAB).

#### Measures

Demographic characteristics and driving history: Demographic information was collected in accordance with the minimum dataset for CLBP [18], including participants' gender, age, income, education, and race. Participants reported the average number of hours spent driving a vehicle each week. Additionally, participants reported the total number of vehicle collisions (where they were the driver) within the last three years.

Pain characteristics: Average low back pain intensity over the past seven days was assessed using a single item on a ten-point scale ranging from 1 (no pain) to 10 (worst imaginable pain) [18]. Participants were also asked to indicate the duration of their back pain.

The Pain Disability Index (PDI) [42] was used to measure the degree to which participants perceived that chronic pain typically disrupted aspects of their daily life across seven different domains: home, social, recreational, occupational, sexual, self-care, and life support activities (e.g., sleeping and eating). Each domain was scored on an 11-point scale ranging from 0 (no disability) to 10 (worst disability). Scores could range from 0 to 70, with higher scores signifying greater perceived disability as a result of chronic pain. A Cronbach's alpha score of 0.89 indicated high internal consistency.

Participants were also asked to indicate how often they utilized opiate pain medications (e.g., Vicodin, Lortab, Norco, hydrocodone, codeine, Tylenol #3 or #4, Fentanyl, Duragesic, MS Contin, Percocet, Tylox, OxyContin, oxycodone, methadone, tramadol, Ultram, Dilaudid) using a 7-point scale including the items 1 (Never), 2 (Once every few months), 3 (About once a month), 4 (A few times a month), 5 (About once per week), 6 (A few times per week), and 7 (Every day).

Cognitive-characteristics: The Pain Catastrophizing Scale (PCS) [35] was used to measure a heightened negative orientation towards pain which included the tendency to magnify, ruminate on, and feel helpless in the presence of pain. Participants were presented with 13 items that characterized various thoughts or feelings about the pain experience and were asked to indicate the degree to which they experienced these feelings using a 5-point scale ranging from 0 (not at all) to 4 (all the time). PCS scores range from 0 to 52, with higher scores indicating a higher degree of pain catastrophizing. A Cronbach's alpha score of 0.95 indicated high internal consistency.

The Experience of Cognitive Intrusion of Pain Scale (ECIP) [5] was modified for a driving context and used to measure the degree to which pain interrupts or dominates participants' cognition and attention whenever they drive in pain. Participants were presented with 10 items that described various cognitive interruptions as a result of pain while driving and were asked to indicate how much each statement applied to them using a 7-point scale ranging from 0 (does not apply to me at all) to 6 (applies to me a lot). ECIP scores could range from 0 to 60 with higher scores indicating a greater instance of cognitive intrusion by pain while driving. A Cronbach's alpha score of 0.97 indicated high internal consistency.

Pain while driving: A single item indicating the degree to which participants experience pain while they drive was assessed using a 7-point scale ranging from 0 (does not apply to me at all) to 6 (applies to me a lot). Similarly, a single item assessed the degree to which participants' pain was made worse by driving was scored using a 7-point scale ranging from 0 (does not apply to me at all) to 6 (applies to me a lot).

Participants were also asked to indicate how often they take pain medications, opiates not specified, while driving. This was a single question on a 4-point scale ranging from 1 (never) to 4 (always).

**Affective responses to driving in pain:** Participant affective responses to driving in pain were assessed using three items on a 0 (not at all) to 10 (extremely) scale; items included irritable, anxious, and afraid. Participants were also asked to indicate both the degree to which they experienced irritability at other drivers and other passengers in the car as a result of their pain using two items on a 7-point scale ranging from 0 (does not apply to me at all) to 6 (applies to me a lot).

Driving behavior: The Driving Behavior Questionnaire (DBQ) [43] is well-validated and widely used measure within transportation research; the DBQ was used to measure the frequency with which participants commit violations or make driving errors using 19 items on a 6-point scale ranging from 0 (never) to 5 (nearly all the time). DBQ items provided specific instances of driving violations and bad driving behavior. such as using the right lane to pass drivers due to impatience and tailgating slower vehicles to make them go faster. DBQ scores range from 0 to 95 with higher scores indicating worse driving behavior. A Cronbach's alpha score of 0.96 indicated high internal consistency.

The 9-item avoidance subscale of the Driving Habits Questionnaire (DHQ) [44] was used to measure the frequency with which participants avoid various driving situations in the past three months on a 5-point scale ranging from 0 (never) to 4 (always). DHQ scores range from 0 to 36 with higher scores indicating more avoidance habits while driving. A Cronbach alpha score of 0.84 indicated high internal consistency.

A single item measured the frequency with which participants let others drive when they are in pain on a 4-point scale ranging from 1 (never) to 4 (always).

#### Analytic plan

All analyses were conducted using SPSS Version 25. Means and standard deviations were reported for all study variables after checking for potential outliers. Univariate Analyses of Variance (ANOVAs) examined potential differences between male and female participants. Correlational analyses examined bivariate relationships between study measures assessing relevant demographic, pain, cognitive, affective, and driving behavior variables. Partial correlations were run between study measures after controlling for opioid use and pain duration. One-way ANOVAs examined differences across demographic, pain, cognitive, affective, and driving behavior variables for individuals who reported 0 or 1 or more collisions in the past three years. Additional one-way ANOVAs were performed after specifically controlling for participants who had reported CLBP for at least three years. To reduce the likelihood of type I error we adjusted the alpha level in this research to 0.01.

### Results

#### Participant demographic characteristics

Participant demographic information and key count variables are summarized in Table 1. Of the 435 participants who accessed the survey, a total of 315 participants qualified via the screener questions and completed the study. After examining the qualitative questions provided throughout the survey, an additional eight participants were omitted for providing inattentive responses, leaving 307 total participants (157 female). Of the participant sample, 237 (77.2%) identified as White, and the duration of back pain ranged from 4 months to 45 years (M=6.29, SD=6.63). Participants reported driving an average of 8.06 h per week (SD=6.41), similar to recent national estimates among average U.S. drivers [45]. Of 307 participants, 53 (17.5%) reported having been involved in at least one collision over the past three years. Male participants reported significantly more hours spent driving per week than did female participants (F[1, 302]=7.73, p<0.01). These gender differences

as well as the number of collisions observed in the sample are similar to other driving studies with samples similar in age and gender distributions [46-48].

# Pain and psychological characteristics

Means and standard deviations for participants' pain intensity (M=5.63, SD=1.51) and pain-related disability

Table 1: Sample characteristics (n=307).

Variable	n (%) or mean (SD)	Variable	n (%) or mean (SD)
Demographic variables		Opioid use	
Age	35.23 (10.57)	Frequency of opiate use	
Duration of pain	6.29 (6.63)	Never	129 (42.2%)
		Once every few months	48 (15.7%)
Gender		About once a month	23 (7.5%)
Female	157 (51.1%)	A few times a month	39 (12.7%)
Male	150 (48.9%)	About once per week	28 (9.2%)
		A few times per week	22 (7.2%)
Ethnicity		Every day	17 (5.6%)
Non-hispanic white	237 (77.2%)		
Non-hispanic black	24 (7.8%)	Driving Variables	
Hispanic (white and black)	19 (6.2%)		
Other	27 (8.8%)	Time spent driving (hrs/wk)	8.06 (6.41%)
Marital status		Collisions (past 3 yrs)	
Single	157 (51.1%)	No collisions	251 (82.6%)
Married	124 (40.4%)	1 collision	40 (13.2%)
Divorced	19 (6.2%)	2 collisions	9 (3.0%)
Separated	4 (1.3%)	3 collisions	4 (1.3%)
Widowed	3 (1.0%)	How often do you take pain medication while driving?	
Education level		, ,	
Less than HS	1 (0.3%)	Never	153 (50.3%)
HS Diploma	41 (13.4%)	Sometimes	125 (41.1%)
Some college	80 (26.1%)	Often	20 (6.6%)
Occupational	12 (3.9%)	Always	6 (2.0%)
Associate's	45 (14.7%)	I let other people drive while I'm in pain	
Bachelor's	104 (33.9%)		
Master's	15 (4.9%)	Never	57 (18.8%)
Professional	4 (1.3%)	Sometimes	130 (42.8%)
Doctoral	5 (1.6%)	Often	96 (31.6%)
Income	, ,	Always	21 (6.9%)
<20K	44 (14.4%)	,	, ,
20-49K	139 (45.3%)		
50-80K	68 (22.1%)		
80+K	56 (18.2%)		
Employment status	, ,		
Working	241 (78.5%)		
Unemployed	12 (3.9%)		
Sick or maternity leave	4 (1.3%)		
Disabled due to back	7 (2.3%)		
Disabled for reasons other	5 (1.6%)		
than back	•		
Student	9 (2.9%)		
Retired	2 (0.7%)		
Keeping house	22 (7.2%)		
Other	1 (0.3%)		

(M=27.89, SD=13.63) appear in Table 2 along with other study variables detailed below. Score means fell within the expected range of values found in prior publications on CLBP [49–52]. Of the sample, 42.2% (n=129) reported never consuming opiate medications. Relative to male participants, female participants reported greater disability associated with pain (F[1, 304]=4.01, p<0.05). Male participants reported a somewhat higher frequency of opioid use relative to female participants (F[1, 304]=3.93, p<0.05).

Participants' mean pain catastrophizing scores (M=20.76, SD=11.39) and ECIP-Driving scores (M=23.81, SD=15.07) are listed in Table 2. As noted, for the purposes of the current study, the instructions of the ECIP were modified to reflect cognitive intrusion of pain in the driving context; scores ranged widely from 0 to 60 and were of magnitude and distribution commensurate with previous studies [5, 53].

# Pain and affective responses while driving

Participants' ratings of pain while driving and affective responses when driving in pain are summarized in Table 2. Almost all participants indicated some agreement with the

statement "I have pain when I drive", with a little more than half the sample (i.e., 53.7%, n=164) endorsing substantial agreement (i.e., >3 on a 0 to 6 scale). Similarly, the majority of participants endorsed that driving makes their back pain worse, with 61.3% (n=187) indicating substantial agreement.

In terms of irritability when driving in pain, participant endorsement was distributed across the response options, with 6-13% of participants indicating agreement with each response item; 6.6% (n=20) of participants did not endorse irritability and 43.2% endorsed substantial agreement (≥6 on a 0 to 10 scale). A similar distributed pattern was observed for items addressing irritability at other passengers and drivers, respectively, with more participants endorsing some irritability at other drivers (n=274) vs. other passengers in the car (n=261).

While most participants reported some anxiety and fear when driving in pain, 20.3% (n=62) endorsed no anxiety experience and 55.3% (n=169) endorsed scores below 5 (on a 0 to 10 scale). Likewise, 43.3% of the sample (n=132) denied feeling afraid when driving in pain and 77.7% scored below 5.

Table 2: Means and standard deviations for study variables for the entire sample and for participants with various collision histories.

		Total sample (n=307)	Range of scores	Positive collision history (n=53)	Negative collision history (n=251)
Pain and psychological	Age	35.23 (10.57)	19-68	31.58 (8.66) <sup>a</sup>	36.00 (10.79)
characteristics	Pain duration	6.29 (6.63)	0.33-45	5.94 (6.66)	6.36 (6.63)
	Driving hours	8.06 (6.41)	0-50	9.45 (8.95)	7.76 (5.72)
	Pain intensity	5.63 (1.51)	2-10	5.72 (1.57)	5.62 (1.50)
	PDI	27.89 (13.63)	0-70	30.17 (14.85)	27.41 (13.34)
	Opioid use	2.75 (1.96)	1-7	2.98 (1.87)	2.70 (1.97)
	PCS	20.76 (11.39)	0-52	24.85 (12.65) <sup>a</sup>	19.90 (10.94)
	ECIP-driving	23.81 (15.07)	0-60	28.98 (16.44) <sup>a</sup>	22.71 (14.57)
Pain while driving	Pain while driving	3.58 (1.49)	0-6	3.85 (1.75)	3.53 (1.42)
	Pain exacerbation	3.75 (1.63)	0-6	3.85 (1.73)	3.73 (1.61)
Affective response	Irritable	4.86 (2.90)	0-10	5.47 (3.07)	4.73 (2.85)
	Anxious	3.92 (3.03)	0-10	4.51 (2.90)	3.79 (3.04)
When driving in pain	Afraid	2.12 (2.61)	0-10	2.49 (2.79)	2.05 (2.57)
	Irritable at drivers	2.99 (1.73)	0-6	3.47 (1.69) <sup>b</sup>	2.88 (1.72)
	Irritable at	2.73 (1.83)	0-6	3.43 (1.88) <sup>a</sup>	2.58 (1.78)
	passengers				
Driving behavior	DBQ	16.07 (15.86)	0-74	22.94 (18.47) <sup>a</sup>	14.62 (14.89)
	DHQ	14.77 (6.96)	0-33	16.62 (7.48) <sup>b</sup>	14.38 (6.79)
	Pain meds while driving	1.60 (0.70)	1-4	1.74 (0.76)	1.57 (0.69)
	Let others drive	2.27 (0.84)	1-4	2.47 (0.93)	2.22 (0.82)

<sup>&</sup>lt;sup>a</sup>Score is significantly different than Negative Collision History Group at p<0.01; <sup>b</sup>score is significantly different than Negative Collision History Group at p<0.05; Driving Hours = Number of hours participants drive on average per week; PDI, Pain Disability Index; Opioid Use = The frequency that participants use opioids to deal with their pain; PCS, Pain Catastrophizing Scale; ECIP-Driving, Experience of Cognitive Intrusion of Pain Scale modified for driving in pain; Pain exacerbation = 'Driving makes my pain worse'; DBQ, Driving Behavior Questionnaire; DHQ, Driving Habits Questionnaire avoidance subscale; Let others drive = 'I let others drive when I'm in pain'; Given the concern over pain duration in regards to collision history, we have provided an updated table controlling for participants who have experienced CLBP for at least three years in the supplementary materials.

# **Driving behavior**

Contrary to prior research [54], male participants reported higher DBQ scores relative to female participants, indicating more errors and violations when driving (F[1, 301]=14.74,p=0.00). Women reported greater driving avoidance vs. men (F[1, 301] = 20.24, p = 0.00), and reported being more likely to let others drive when they are in pain (F[1, 302]=10.73,p<0.001).

# Bivariate correlations among study variables

Table 3 shows bivariate correlations between study variables, which are color-blocked in order of magnitude to facilitate ease of interpretation only if their statistical significance reached the 0.01 alpha level criterion. Self-reported pain intensity showed a strong positive correlation with pain while driving (r=0.41, p<0.01). A moderate positive association was observed between pain intensity and pain exacerbation while driving (r=0.29, p<0.01), and irritability when driving in pain (r=0.21, p<0.01). Additionally, pain intensity was moderately positively associated with participants' PCS (r=0.26, p<0.01) and ECIP scores (r=0.29, p<0.01). Self-reported disability likewise showed moderate to strong positive associations with all study variables, including DBQ scores and DHQ-avoidance scores. Self-reported disability was also positively associated with frequency of utilizing pain medication when driving.

Pain catastrophizing and attentional capture by pain when driving (PCS and ECIP scores) were highly positively correlated; while both showed positive correlations with pain (r=0.35 and r=0.39, p<0.01) and pain exacerbation (r=0.37 and r=0.41, p<0.01) when driving. In terms of driving behavior, higher PCS and ECIP scores were associated with greater DBO scores (r=0.34 and r=0.34, p<0.01). PCS showed a higher correlation than ECIP scores with DHQ avoidance behavior and letting others drive when in pain. Both PCS and ECIP scores showed a small-moderate correlation with frequency of opioid utilization and smallmoderate associations with utilization of pain medication while driving.

Higher pain intensity while driving was strongly associated with exacerbation of pain when driving; both showed moderate to strong positive associations to affective responses, in particular irritability at other drivers and passengers when in pain, respectively. Both likewise showed a small-moderate correlation with DHQ avoidant driving responses and taking medication while driving.

Affective responses (i.e., irritability, anxiety, and fear) while driving were all strongly associated with each other and showed small-moderate positive associations with

DBQ (excluding irritability, r=0.26, and r=0.39, p<0.01) and DHQ avoidance scores (r=0.22, r=0.36, and r=0.26, p<0.01), respectively. Likewise, small to moderate associations were observed between anxiety and fear responses while driving in pain and letting others drive while in pain and taking pain medication while driving. Finally, a moderatestrong positive association was observed between DBQ scores and the use of pain medication while driving (r=0.42, p<0.01). Notably, DBQ scores likewise showed a small positive association with frequency of opioid use (r=0.21, p<0.01).

#### Partial correlations among study variables

Partial correlations were performed to control for opioid use and pain duration. Following these analyses, the following associations were no longer statistically significant: pain intensity and letting others drive when experiencing pain (r=0.08, p=0.19) and irritability while driving in pain and DBQ scores (r=0.09, p=0.12). Associations between taking pain medications while driving and a number of different variables were also no longer statistically significant even at the 0.05 alpha level, including: irritability (r=0.06, p=0.34), anxiety (r=0.05, p=0.36), irritability at other drivers while driving in pain (r=0.07, p=0.23), and letting other people drive while in pain (r=0.05, p=0.41). These changes are noted in Table 3; however, the majority of the observed correlations before controlling for these variables remained relatively unchanged in statistical significance afterward.

#### Collision history

Table 2 shows means and standard deviations across study measures for individuals with and without recent collision history in the past three years. Analyses revealed several significant differences. In comparison to participants with no collision history, those who reported a history of collisions reported higher PCS scores (F[1, 303]=8.46, p<0.01) and higher attentional capture by pain when driving (i.e., ECIP-Driving scores); (*F*[1, 303]=7.73, p<0.01). Additionally, participants who endorsed a collision history reported greater irritability at other passengers and other drivers when driving in pain – (F[1, 303]=9.77, p<0.01) and (F[1, 303]=5.12, p<0.05), respectively. Participants with a collision history also reported higher DBQ scores (F[1, 301]=12.52, p<0.001) and higher DHQ-Avoidance scores (F[1, 301]=4.60, p<0.05) than participants who did not endorse a collision history. Finally, participants with a

Table 3: Associations between study variables.

Age Pain duration O.40** Driving hours O.01 -0.08 Pain intensity O.02 -0.06 PDI Opioid use O.06 -0.13* PCS C.08 -0.05 ECIP Pain exacerbation O.18** O.02 -0.08 Anxious O.03 -0.02 Irritable at drivers O.00 -0.03 OIITitable at passengers OOO OOO OOO OOO OOO OOO OOO OOO OOO O	Vari;	Variable	1	2	3	4	5	9	7	8	6	10	11	12	13	14	15	16	17	18
Pain duration       0.40**       -         Driving hours       -0.01       -0.08       -         Pain intensity       0.02       -0.06       0.08       -         PDI       0.11*       0.00       0.06       0.50**       -         PDI       0.11*       0.00       0.06       0.50**       -         PDI       0.01*       0.00       0.06       0.56**       0.29**       0.20**         PCS       -0.08       -0.05       0.07       0.05**       0.26**       0.20**         ECIP       -0.07       -0.06       0.05       0.29**       0.45**       0.20**         Pain while driving       0.08       0.11*       0.18**       0.41**       0.14*         Pain exacerbation       0.18**       0.12*       0.12*       0.29**       0.36**       0.14*         Irritable       -0.02       -0.08       0.07       0.21**       0.14*         Anxious       -0.07       -0.02       0.09       0.17**       0.37**       0.16**         Afraid       -0.05       -0.09       0.09       0.17**       0.37**       0.14*         DBQ       -0.09       -0.12*       0.02       0.08	1.	Age	1															Key:	0.20-0.29	
Driving hours         -0.01         -0.08         -           Pain intensity         0.02         -0.06         0.08         -           PDI         0.11*         0.00         0.06         0.50**         -           PDI         0.01*         0.00         0.06         0.50**         -           PCS         -0.08         -0.05         0.07         0.26**         0.29**         0.20**           PCS         -0.08         -0.05         0.07         0.06         0.05         0.29**         0.45**         0.20**           Pain while driving         0.08         0.11*         0.18**         0.11*         0.14**         0.14*           Pain while driving         0.08         0.11*         0.18**         0.21**         0.23**           Pain exacerbation         0.18**         0.12*         0.12*         0.29**         0.36**         0.14*           Irritable         -0.02         -0.08         0.07         0.21**         0.22**         0.16**           Anxious         -0.07         -0.02         0.09         0.17**         0.37**         0.22**           Afraid         -0.05         -0.09         0.09         0.17**         0.39**	2.	Pain duration	0.40	ı															0.30-0.39	
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210 210 210 200 200	18.	I let others drive	0.00	-0.08	90.0	$0.13^{*a}$	$0.19^{**}$	0.20**	0.25**	0.21**	0.20**	$0.13^*$	0.08	0.23**		0.19**	$0.15^{**}$	0.16**	0.30**	ı
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\*p<0.05 (not colored for magnitude); \*\*p<0.01; <sup>a</sup>No longer significant when controlling for opioid use and pain duration; Driving Hours = Number of hours participants drive on average per week; PDI, Pain Disability Index; Opioid Use = The frequency that participants use opioids to deal with their pain; PCS, Pain Catastrophizing Scale; ECIP-Driving = Experience of Cognitive Intrusion of Pain Scale modified for driving in pain; Pain exacerbation = Driving makes my pain worse; DBQ, Driving Behavior Questionnaire; DHQ, Driving Habits Questionnaire avoidance subscale; Let others drive = I let others drive when I'm in pain. positive collision history were younger than those with a negative collision history; (F[1, 305]=7.80, p<0.01).

The Supplementary Table 2 shows that when correcting for participants who have experienced CLBP for a minimum of three years, changes to significance were observed in all previous relationships except for collision history on DBQ scores (F[1, 203]=5.18, p<0.05). However, despite the lack of statistical significance, means for PCS and ECIP scores were noticeably higher in the collision group (M=23.30, SD=13.35; M=26.59, SD=17.30) than in the non-collision group (M=20.36, SD=11.35; M=23.00, SD=15.00), respectively.

# **Discussion**

To our knowledge, the current study is the first to characterize driving experience specifically among individuals with CLBP, with attention to the relationship among key sensory, affective, and cognitive psychological metrics as well as self-reported driving history and behavior. Broadly, findings suggest that drivers with CLBP experience a wide range of somatic and affective responses. Indeed, over half of our participants reported experiencing pain when they drive, and the majority reported driving to be a source of increased pain intensity. Further, participants reported that pain while driving resulted in substantial irritation at both passengers and other drivers on the road. In line with studies of other pain conditions (e.g., whiplash, fibromyalgia [3, 11, 15, 16]), these data suggest that driving may be a significant source of pain and distress among many individuals with CLBP.

Surprisingly, the current study is the first to assess participants' affective response to driving in pain, and the first to address anger/irritation in the context of pain and driving. The relationship between anger and pain has been well-documented in the literature [55-60], as has the relationship between anger and driving [61-65]. In the context of pain and disability, studies link anger with negative physical, social, and functional outcomes [58, 60, 66]. Studies also reliably implicate anger and irritation in negative driving outcomes, including more fines, traffic violations, accidents, and aggressive driving behaviors [63, 65]. In partial support of the above associations, CLBP participants who reported a recent history of collisions while driving likewise reported higher irritation with other passengers and other drivers when driving in pain (note: before controlling for CLBP duration). It is important here to note that pain severity did not relate to the number of collisions; rather, the data points to the importance of psychological factors while driving with pain. While

participants did not generally report substantial levels of fear/anxiety when driving in pain, suggesting overall confidence on the road, a substantial portion of the sample reported avoiding driving or letting others drive when in pain.

Of particular interest in the current study were associations observed between participants' ECIP-Driving and PCS scores with pain, affective, and driving variables. In the current study, the ECIP was used to assess the extent to which pain interrupts or dominates participants' attention when they drive [5]. Echoing previous findings [6, 38] higher scores of attentional capture by pain and pain catastrophizing were consistently associated with elevated pain and negative affective responses in the driving context, Further, elevated ECIP-Driving and PCS scores were associated with more self-reported unsafe driving behaviors (driving errors and violations) and greater likelihood of a having had a collision; this effect remained even after adjusting for CLBP duration. These findings should be considered in the context of an established body of evidence that pain (including back pain) contributes to impaired performance on a variety of attentional tasks [67–72], and that self-reported cognitive intrusion by pain predicts worse performance on tasks designed to mimic real world challenges [6, 7]. Further, pain catastrophizing is generally associated with greater pain hypervigilance and difficulty disengaging from pain-related stimuli [37].

To date, very few studies have examined attentional function in the context of driving with pain. Studies of drivers with whiplash disorders found self-report of reduced concentration/ attention when driving [3, 16]. Three studies failed to find laboratory-assessed differences in attention-related functions between healthy controls and participants with pain, including mixed pain [13], fibromyalgia [15], and whiplash [4] samples. At the same time, all studies identified performative driving deficits (e.g., greater weaving, worse coordination) among participants with pain [4, 13, 15]. While the current study did not compare participants to healthy controls, our results suggest that, in addition to standard tests of attention, it would be useful to assess the relative attentional toll of pain among drivers with painful conditions, and that this may provide a more nuanced understanding of driving-related findings. Further, although chronic pain patients have been shown to perform poorly on a range of neurocognitive tasks, these have generally been tasks performed for brief periods of time and which are novel to participants. Driving by comparison is a highly automated process which may therefore show differing relationships between pain and cognitive processing.

It is important to note that participants with CLBP in our sample did not report higher frequency of crashes compared to prior work with comparable samples. Although prior studies have identified driving performance deficits in specific pain populations [4, 13], and have even drawn association between back pain and vehicle collisions [34], the current findings do not suggest that CLBP is a risk factor for poor driving outcomes. Rather, our study is the first to link common psychological phenotypes among individuals with CLBP [34] with a number of problematic driving-related outcomes. Given the prevalence of CLBP in the general population [17, 18] and in professional drivers [12, 29, 30], the current study provides a foundation for efforts to better understand the mechanisms involved in driving behaviors of those with CLBP as well as the relationship between key cognitive-affective, attentional, and behavioral factors identified in the current study.

While research examining the direct effects of pain on driving performance is currently quite limited, considerable research has examined the effects of analgesic medication, in particular opioids, on driving outcomes [2, 73–79]. In addition to cognitive and attentional impairments [79], opioids are also related to various driving outcomes, such as collisions [80-82], longer reaction times [83], and trouble maintaining attention behind the wheel [79]. Although medication use was not the focus of the current study, sample responses to items related to medication use while driving are worthy of note. Approximately half the sample reported some opioid use and about half reported taking pain medication while driving. More frequent use of medication while driving showed some association with pain intensity, negative affective responses, and attentional capture by pain, as well as more driving errors and violations. Additionally, when controlling for opioid use and pain duration, taking medication while driving was no longer significantly associated with irritability and anxiety while driving in pain as well as letting others drive when in pain. Given extensive inquiry regarding risky/illegal driving behavior, the current study chose not to ask specifically regarding opiate use while driving, choosing to remain more general with respect to medication use. However, given that associations between medication use while driving and some affective responses were no longer statistically significant, it is possible that this change was observed because opiates were the medication of choice taken while driving. This question remains pertinent for further study. Further, no causal claims or direction can be asserted regarding medication use and the above outcomes. Rather, combined with self-imposed driving restrictions when in pain (above), our findings point to potentially varied attitudes toward driving and medication use among individuals with CLBP and should be explored in future research.

A clear strength of the current study is that we were able to recruit a representative group of individuals with CLBP which allowed us to examine broad and basic questions with respect to pain during driving. However, the online nature of the data collection also represents a potential limitation, particularly as responses were selfreport, with no objective assessment. As a result, responses are subject to potential negative biases [84] and socially desirable responding patterns [85], especially when discussing the possibility of poor driving performance. For example, while DBQ items provided instances of inappropriate driving actions, it is unclear whether participants recognized these as inappropriate or risky (e.g., texting and driving), or whether they even engaged in them. Another possible limitation is the overlapping time windows for study measures, which variably assessed pain-related responses during driving, in general, and in the span of the past week, thus potentially affecting observed correlations. Further, we cannot verify whether all participants reported back pain prior to collision, which was assessed over the past three years, and thus report supplementary results which limit the sample to individuals with at minimum three years of back pain. While overall relationships between variables do not change, observed loss of statistical significance (i.e., PCS and ECIP scores between individuals with and without collision history) suggest either a lack of power or key role of early injury in the relationship between collision and back pain. Further analysis revealed that PCS and ECIP scores in the collision group were substantially higher for those who had CLBP for less than three years than those who had experienced CLBP for more than three years, possibly suggesting particular relevance of these constructs for those with more recent onset of pain.

Although this study laid groundwork for research considering the role of psychological pain variables in driving performance, many of the results and questions posed in this study, including those suggested above, can more rigorously be addressed within an experimental context. For example, studies that actively compare the driving behavior between pain and non-pain groups, controlling strictly for duration of pain, are imperative to gaining a better grasp of the relationships suggested in this study. Possible avenues for objectively measuring participant driving behaviors have been discussed in the literature, with the main two methods being the use of an advanced driving simulator to monitor attentional control and responses to stressful events [2, 4, 14] or use of real world driving tests to measure the amount of vehicle swerving while on the road [2, 13, 78]. Such studies can objectively capture participant attentional and behavioral performance without the potential bias of subject

interpretation or reporting bias to self-report questionnaires. Potentially, such experimental work can serve to validate or challenge paper-based responses.

Although causal interpretations cannot be drawn. there are clear clinical implications of the current descriptive findings. As noted above, driving is a critical activity for daily living, be it for attending work, maintaining social relationships, or attending medical appointments. As individuals in pain may have mobility issues which can impair walking or other modes of transport, driving may be even more crucial. The current findings reinforce multiple associations between pain and cognitive-affective variables that have been observed in literature outside the driving context, including pain intensity, anger, inattention, and behavioral disruption. Given that driving is a pervasive, potentially risky behavior that requires some form of cognitive focus and control, the current findings point to a continued need to examine these associations within this specific life context. As part of pain management approaches that facilitate high quality of life and participation, it may be important to consider strategies that address/mitigate pain and pain-related psychological responses behind the wheel, with potentially powerful implications for driving safety.

## Conclusion

In conclusion, individuals with CLBP reported significant pain and distress during driving activity, suggesting that the experience of driving with back pain deserves more study and perhaps clinical consideration. Further, our findings suggest that key pain psychological variables, including pain catastrophizing and cognitive/attentional intrusion by pain while driving may be associated with negative emotional responses and problematic driving behavior. The current study is intended to provide a foundation for further scrutiny of this important subject.

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**Competing interests:** Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study.

**Ethical approval:** The research conducted within this study was reviewed and approved by the UAB institutional review board.

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