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The Impact of Perceived Stress on the Driving Performance of Car Drivers: a Simulator Study

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Abstract

Stress and driving are closely linked, yet little attention has been given to how stress affects driving behaviour in routine road sections and predictable road conditions (e.g., predictable speed limit changes). This study addresses this gap and explores the impact of prolonged stress on driving behaviour in routine road sections and predictable transitions between speed limits. A total of 27 drivers participated in a car driving simulator experiment, which compared their driving performance in a baseline and stressful scenario. Stressors such as time pressure and hazardous events were added in the stressful scenario. Stress was self-reported using a Stress Visual Analogue Scale. Results showed a minor but significant increase in speed in stressful circumstances, both in low-speed and high-speed segments. Drivers also tended to accelerate sooner or brake later in speed limit transition zones, and their accelerating and braking was harsher. As even minute changes in driving behaviour can impact fatality risks, more attention should be given to mental health in traffic and transportation, both in research and in policy.

Keywords: Stress; Driving behaviour; Driver; Car; Simulator; Traffic safety

1. Introduction

The World Health Organization (2023) reported that traffic safety caused 1.19 million deaths around the globe in 2021. The human factor has an important effect on road safety and driving behaviour: for example, Sabek et al. (2024) found that young drivers with high impulsivity and low mindfulness were more likely to overtake a leading vehicle.

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Stress is one human factor that may impact road safety issues. According to the APA Dictionary of Psychology (2018), stress is “the physiological or psychological response to internal or external stressors”. Gallup (2024) found that 37% of individuals worldwide reported feeling stressed. Gallup (2024) also reported that overall feelings of stress are higher than in previous decades. Given how common stress is, it may exacerbate the road safety issue, Dingus et al. (2016) showed that an observable elevated emotional state increases the crash risk by 9.8 times compared to alert driving. The Transactional Model of Driver Stress explained by Matthews (2002) shows that driving itself can also cause stress. Driver stress arises from personality traits (e.g. fatigue proneness) and environmental stressors (e.g. bad weather). These factors impact the driver’s performance (e.g. loss of attention) and subjective stress symptoms (e.g. apathy).

Previous research using questionnaires indicated that stress has a negative impact on driving behaviour. Lagarde et al. (2004) found that distressing situations (e.g. getting divorced) are related to a higher severe crash risk. Delhomme & Gheorghiu (2021) found that, in truck drivers, higher reported stress was associated with higher perceived crash risk. Perceived stress was also related to an increase in violations, as found by Öztürk et al. (2024). In a study by Rowden et al. (2011), occupational stress was positively correlated with driving errors and violations. Irritation during driving is also related to increased errors, aggressive driving and violations. However, stress may occasionally have positive effects. Hazard monitoring may be a potential stressor, but it makes drivers more cautious, resulting in fewer errors and crashes, as Qu et al. (2016) reported. Earlier driving simulator research showed negative effects of stress on driving performance. Paschalidis et al. (2018) found that time pressure doubles the chance that a driver may accept a gap, which is riskier. Time pressure also tends to increase driver speed, as found by Hussain & Alhajyaseen (2025). Magaña et al. (2020) found that stressed drivers accelerate and brake more often than usual. Paschalidis et al. (2019) reported that drivers accelerate more when stressed in a car-following situation. Notably, the impact of stress can be exacerbated by factors such as listening to fast music. This may lead to more speeding violations, as Magaña et al. (2020) found.

Despite the research on the impact of stress on driving behaviour, most simulator studies on this topic focus on the relationship between (driving behaviour in) specific events (e.g., gap acceptance) and stress (e.g. Paschalidis et al. (2018, 2019)), or include such events (e.g., a slow leading vehicle) as a measure to compare a baseline situation and a stressful situation, such as in Hussain & Alhajyaseen (2025). However, in combination with time pressure, stress gained during such events may have effects on driving behaviour that persist beyond the events: driving behaviour may be impacted even when no other road users directly interact with the driver. To the authors’ knowledge, no recent study has focused on the potential lingering effects of stress induced by driving events and time pressure on driving behaviour on such routine road sections. This study aims to examine whether driving performance deteriorates under stress in (1) routine road sections where no particular driving events occur and (2) commonly encountered, non-hazardous driving situations, namely speed limit transitions. The hypotheses are: (1) speed in routine road sections will increase in a stressful situation; (2) standard deviation of the lateral position in routine road sections will increase in a stressful situation; (3) speed in speed limit transition zones will increase in a stressful situation; and (4) a driver will accelerate and brake more harshly in speed limit transition zones in a stressful situation.

2. Methodology

2.1. Participants

This study is a driving simulator experiment, specifically a within-subjects experiment in which all participants drive through a baseline scenario and a scenario in which stress is induced, which are detailed below. Ethical approval for the study was given by the Social and Societal Ethics Committee (SMEC) of Hasselt University. Twenty-nine drivers, recruited through internal communication at Hasselt University and social media, participated in this study. The inclusion criteria were: residency in the Flemish Region and a valid class B driving license. Exclusion criteria were: pregnancy, excessive alcohol use, drug use, illness of an infectious disease, and inability to speak Dutch. Participants signed an informed consent form. Two participants could not complete the scenarios due to simulator sickness. As such, 27 participants drove through both scenarios. Of these participants, 19 were men and 8 were women. The average age of the participants was 28.4 years (standard deviation of 12.4 years; minimum of 18 years; maximum of 57 years). Seventeen participants had less than 5 years of driving experience.

2.2. Driving simulator

The tests were done in a driving simulator with a dashboard, centre console and driver's seat. Controls included throttle and brake pedals, a steering wheel, an automatic gearbox and a turn indicator. The scenarios were rendered on three screens (total resolution of 5760x1080 pixels with a 60 Hz refresh rate) to provide frontal and side views from the car. A speed indicator was visible at all times. A speaker provided sounds of a car engine. The speed was limited to 130 km/h, and participants could receive warnings for excessive speeding. Figure 1a shows the setup. Hussain et al. (2019a) previously validated a simulator of this type. Their study showed good correspondence between driving behaviour in real life and in this type of simulator, both for actual and perceived speed.

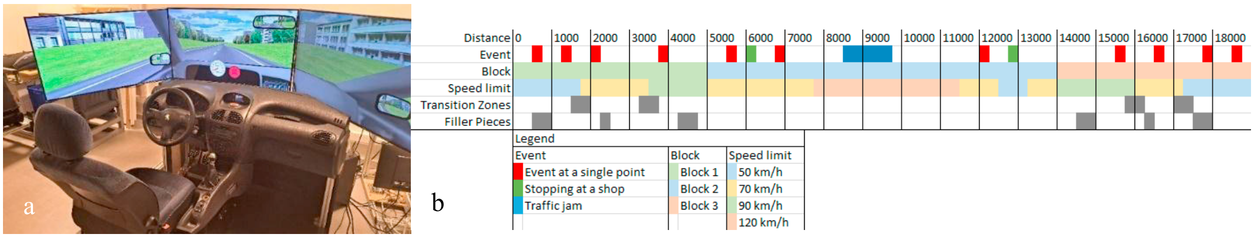

Fig. 1. (a) Photograph of the simulator setup. (b) Scenario design of the stressful scenario, including the sections to be analysed (transition zones and filler pieces). The neutral scenario was identical in layout, though all events at single points and the traffic jam were not included

2.3. Simulator scenarios

Two scenarios and a practice run were programmed in STISIM Drive3. The scenarios resembled roadways that a driver might encounter during a real-life trip. The roadway included local roads (50 km/h), regional roads (70 km/h), expressways (90 km/h) and motorways (120 km/h). Drivers first completed the practice run to get used to the controls. Then, drivers drove through a neutral scenario and a stressful scenario. Both scenarios were 19,000 meters long. Importantly, the choice was made not to counterbalance the experiment. As in Daviaux et al. (2020), drivers always drove through the neutral scenario first, as their reactions to a stressful situation may influence their reactions to a baseline situation. Both scenarios were divided into three blocks. The first and third blocks were similar to each other, but mirrored. In both scenarios, participants were told that they organised a party at home but had to visit a few stores in order to prepare. Both scenarios were identical in layout, but stress-provoking measures were added to the stressful scenario: 12 driving events and artificial time pressure. Stressful events were most often interactions with other road users, as Jones et al. (2021) have shown that such interactions can be stressful for drivers. Events included a car appearing from behind a building on the right, a traffic jam and a traffic light turning orange at a difficult moment.

Time pressure has been used in other studies to induce stress (e.g. Lee and Winston (2016); Paschalidis et al. (2018)). Time pressure was induced as in Paschalidis et al. (2018). Participants were told to complete the scenario within a time limit. The time left was shown with an emoji. A green emoji, yellow emoji and red emoji meant, respectively, that the driver would arrive well on time, just in time and too late. Drivers were told they would receive a small reward if they arrived on time. However, the emoji was programmed to turn colour at specific times. This allowed control over when the driver would feel time pressure (e.g., when the driver encountered a traffic jam). The emoji is visible on the screen in Figure 1a. All participants received a small physical reward at the end of the experiment. A schematic overview of the (stressful) scenario as an illustration is shown in Figure 1b.

For each scenario, stress was rated at four measuring points: three times during the scenario, separated at roughly 5 minutes in between, and once after the scenario. Participants rated their stress level on the Stress Visual Analogue Scale (Stress VAS), reported in Lesage et al. (2012), on a scale from 0 ("no stress at all") to 10 ("the worst stress imaginable"). Participants also filled in the Type D Scale 14 to assess personality differences as described by Denollet (2005). Based on this, seven participants were determined to have a type D personality (TD) (a tendency to negative affectivity and social inhibition).

2.4. Statistical analysis

A Shapiro-Wilk test was used to check for normal distribution. To compare the stress measures, if the difference between the neutral and stressful scenario at each measuring point was normally distributed, a paired samples t-test was performed. If not, a Wilcoxon signed-rank test was used. As for driving behaviour, filler pieces (of 50, 70 and 90 km/h) and transition zones were analysed. Filler pieces were routine road sections without events. Transition zones were road sections where the speed limit and road type changed. In the filler pieces, the analysed parameters included the mean speed, maximum speed and the standard deviation of the lateral position (SDLP). If the data were normally distributed, an R-ANOVA was performed. If not, a Friedman test was used. A Wilcoxon signed-rank test was used to explore the data if necessary. For the transition zones, each zone was split into four segments of 100 meters, with segments 1 and 2 before the transition and segments 3 and 4 after the transition. For each segment, the mean speed and maximum (for speed increase) or minimum (for speed decrease) acceleration were compared between the neutral and the stressful scenario. If the data were normally distributed, a paired samples t-test was used. If not, a Wilcoxon signed-rank test was used. To check for any differences in driving behaviour by gender, driving experience and personality types, the differences in mean speed and max speed in the filler pieces and mean speed in the transition zone segments between these groups were also checked. A Mann-Whitney U test was used to analyse these parameters. This non-parametric test was used as not all data within these subgroups were normally distributed, and the sample sizes of the subgroups are small. The level of significance was set at 0.05 for all tests.

3. Results

3.1. Subjective stress measures

The results of the comparisons between the relevant measurement points for the neutral and stressful scenario are shown in Table 1. Perceived stress was generally low, with mean scores ranking below 5.0 for all measurement points. However, mean scores for perceived stress in the stressful scenario were at least 1 point above the mean stress scores in the neutral scenario.

Table 1. Test Statistics for subjective stress measures.

Scenarios	Test	Sig.	Mean (Neutral scenario)	Mean (Stressful scenario)
Stressful scenario x Neutral scenario (Measurement 1)	T-test (2-sided sig.)	**< 0.001**	2.00	4.43
Stressful scenario x Neutral scenario (Measurement 2)	Wilcoxon SR	**< 0.001**	2.02	3.61
Stressful scenario x Neutral scenario (Measurement 3)	Wilcoxon SR	**< 0.001**	2.07	3.35
Stressful scenario x Neutral scenario (Measurement post scenario)	Wilcoxon SR	**< 0.001**	2.39	3.87

For all measurement moments in the neutral and stressful scenarios, the difference in perceived stress between the scenarios was significantly different. Perceived stress in the stressful scenario was higher than in the neutral scenario.

3.2. Filler pieces

The most significant results were found concerning speed behaviour, specifically the mean speed and the maximum speed reached in each filler piece. These significant results are shown in Table 2. The mean speed was higher in the stressful scenario in several filler pieces. For example, in block 1, mean speeds in the 50 and 90 km/h filler pieces were 48.58 km/h and 89.27 km/h in the neutral scenario and 49.24 km/h and 90.64 km/h in the stressful scenario. The effect is small, generally leading to an increase in mean speed of approximately 1 km/h, but it is significant and consistent. Something similar can be observed for the maximum speed reached within each filler piece. For all significant comparisons, these speeds are consistently higher in the stressful scenario than in the neutral scenario (e.g., 70.94 km/h in the neutral scenario and 72.96 km/h in the stressful scenario in block 3 for the 70 km/h filler piece).

When comparing block 1 and block 3, significant effects are not as common. Where they are present, e.g. when comparing the mean speed between blocks in the 70 km/h filler piece in the neutral scenario, there was consistently a (slightly) lower mean speed in block 3. When comparing different genders and personality types, no significant differences were found concerning mean and maximum speed. For driving experience, only the difference between maximum speed in the 70 km/h filler piece in block 1 in the stressful scenario was significant ($p = 0.040$; mean rank scores of low and high driving experience groups were 16.41 and 9.90).

Table 2. Test statistics for mean speed and maximum speed at different filler pieces.

Variable	Filler Piece	Comparison with sig. result	Test	Sig.	Means (km/h)
Mean Speed	50 km/h		Friedman	**0.034**	
		Neutral Block 1 vs Stressful Block 1	Wilcoxon SR	**0.049**	48.58 vs 49.24
	70 km/h		Friedman	**0.001**	
		Neutral Block 3 vs Stressful Block 3	Wilcoxon SR	**<0.001**	69.14 vs 70.58
		Neutral Block 1 vs Neutral Block 3	Wilcoxon SR	**0.037**	70.28 vs 69.14
	90 km/h		Friedman	**<0.001**	
		Neutral Block 1 vs Stressful Block 1	Wilcoxon SR	**0.001**	89.27 vs 90.64
		Neutral Block 3 vs Stressful Block 3	Wilcoxon SR	**<0.001**	88.63 vs 90.34
		Neutral Block 1 vs Neutral Block 3	Wilcoxon SR	**0.044**	89.27 vs 88.63
Max Speed	50 km/h		Friedman	**0.005**	
		Neutral Block 1 vs Stressful Block 1	Wilcoxon SR	**0.028**	50.50 vs 51.92
		Neutral Block 3 vs Stressful Block 3	Wilcoxon SR	**0.039**	50.11 vs 51.29
	70 km/h		Friedman	**<0.001**	
		Neutral Block 3 vs Stressful Block 3	Wilcoxon SR	**<0.001**	70.94 vs 72.96
	90 km/h		Friedman	**<0.001**	
		Neutral Block 1 vs Stressful Block 1	Wilcoxon SR	**0.013**	91.64 vs 93.08
		Neutral Block 3 vs Stressful Block 3	Wilcoxon SR	**0.008**	90.85 vs 92.33

For SDLP, no results indicated a significant difference between the neutral and the stressful scenario. An R-ANOVA test showed a significant effect of the block on this variable, but only in the filler piece of 50 km/h ($p = 0.013$). In both the neutral and the stressful scenario, the SDLP was slightly higher in the third block than in the first block (respectively 0.11 vs 0.10 in the neutral scenario and 0.11 vs 0.09 in the stressful scenario).

3.3. Transition zones

Results for the transition zones are shown in Table 3, showing the mean speed reached within each segment around a speed limit transition. Significant results were found for each transition zone. In all cases of these results, the mean speed was higher in the stressful scenario than in the neutral scenario. Notably, the mean speed was sometimes over the posted speed limit. For example, in segment 3 of the transition from 70 km/h to 50 km/h, the speed limit was 50 km/h. However, the mean speed in the stressful scenario was 56.57 km/h and 52.12 km/h in the neutral scenario. When comparing the different genders and personality types, no significant differences in mean speed were found. For different driving experience groups, there was only a significant difference in mean speed in segment 2 of the transition from 70 to 50 km/h in the stressful scenario ($p = 0.040$, mean rank scores of low and high driving experience groups are respectively 16.41 and 9.90).

Table 3. Test statistics for mean speed at different segments in different transition zones.

Transition Zone	Segment	Test	Sig.	Mean (Neutral) (km/h)	Mean (Stressful) (km/h)
50 to 70 km/h	1	T-test (2-sided sig.)	**0.036**	49.98	50.93

	2	T-test (2-sided sig.)	0.275	52.23	53.06
	3	T-test (2-sided sig.)	**0.036**	60.55	62.55
	4	T-test (2-sided sig.)	**<0.001**	67.14	69.64
70 to 90 km/h	1	T-test (2-sided sig.)	**<0.001**	68.73	71.91
	2	T-test (2-sided sig.)	**<0.001**	73.19	77.98
	3	Wilcoxon SR	**<0.001**	83.05	87.40
	4	Wilcoxon SR	**<0.001**	87.74	91.89
90 to 70 km/h	1	T-test (2-sided sig.)	0.664	87.46	86.96
	2	T-test (2-sided sig.)	0.697	80.49	81.01
	3	T-test (2-sided sig.)	0.087	70.63	72.32
	4	T-test (2-sided sig.)	**<0.001**	67.80	69.94
70 to 50 km/h	1	T-test (2-sided sig.)	**0.003**	65.23	68.72
	2	T-test (2-sided sig.)	**<0.001**	59.42	65.55
	3	Wilcoxon SR	**<0.001**	52.12	56.57
	4	Wilcoxon SR	0.136	48.87	50.11

Results for the maximum and minimum acceleration were mostly non-significant. Only the difference in maximum acceleration in segment 3 of the transition from 50 to 70 km/h was significant ($p = 0.009$): the mean maximum acceleration was 1.15 m/s² in the neutral scenario and 1.47 m/s² in the stressful scenario. As for minimum acceleration, the only significant effects were in the transition from 70 km/h to 50 km/h, in segments 3 ($p < 0.001$) and 4 ($p = 0.006$). The mean minimum acceleration in segment 3 was -0.56 m/s² in the neutral scenario and -1.15 m/s² in the stressful scenario. In segment 4, these values were -0.26 m/s² in the neutral scenario and -0.48 m/s² in the stressful scenario. As such, acceleration and deceleration in the stressful scenario were harsher in some situations.

4. Discussion

This study aimed to determine the impact of stress on driving behaviour on (1) routine road sections and (2) speed limit transitions. Hussain & Alhajyaseen (2025) showed that time pressure greatly impacted speed, with drivers in a time pressure condition driving, e.g., around 20 km/h faster. However, in our study, results for the speed variables showed that speed increased by approximately 1 km/h in the stressful scenario when compared to the baseline scenario. The difference was small but consistent across all filler pieces, confirming the first hypothesis. Participants could be more inclined to keep to the speed limit, even in the stressful scenario. However, as reported by Hussain et al. (2019b), an increase in impact speed of 1 km/h raises the odds of a pedestrian fatality in a crash by 11%. No significant differences in SDLP between the neutral and the stressful scenario were found. The stressful scenario was expected to be cognitively challenging. Cognitive load can stabilise the SDLP, as reported in Li et al. (2018) and Öztürk et al. (2023), though this could not be replicated in the current study. As such, the second hypothesis could not be confirmed. As for the transition zones, the mean speed in each segment was higher in the stressful scenario than in the neutral scenario, which confirms the third hypothesis. When confronted with a higher speed limit, drivers increased their driving speed sooner. When confronted with a lower speed limit, drivers decreased their driving speed later. In some cases, the mean speed of the drivers violated the speed limit in the stressful scenario. In other cases, a violation occurred in both scenarios, but it was more severe in the stressful scenario. This is in line with the survey findings of Qu et al. (2016), who found that stress is correlated with dangerous driving behaviour. In the stressful scenario, drivers may have wanted to save time by driving slightly faster than allowed. They may also have "overshot" the speed limit when accelerating. For the 50-70 km/h and 70-50 km/h transition zones, stress was associated with a larger maximum or smaller minimum acceleration, which confirms the fourth hypothesis, but only in specific situations. This appears consistent with the findings of Paschalidis et al. (2019), who state that stress increases acceleration in a car-following situation. As Chung et al. (2019) note, driver stress can be detected through driving behaviour monitoring. Harsh acceleration and braking could thus function as markers for stress to this end.

This study has shown that stress impacts driving behaviour on routine road sections and predictable speed limit transitions. Given how even minute speed increases impact fatality risk, as Hussain et al. (2019b) note, this study has important traffic safety implications. Sources of time pressure need to be mitigated to prevent time pressure's impact on driving behaviour as much as possible. However, sources of time pressure must therefore be investigated per target group (e.g., for truck drivers, tight schedules may be a source of time pressure as studied by Jazairy et al. (2023)). In addition, Chung et al. (2019) discuss countermeasures to driver stress, which are useful in the context of this study: for example, driver assistance systems reduce stress and improve driving performance. They also mention environmental soothing, which alleviates stress through, e.g., music or a relaxation massage from the car seat. Of course, as Chung et al. (2019) mention, care should be taken when implementing countermeasures, as inappropriate countermeasures could cause stress (e.g., incorrect notifications for stress). The subtle differences in driving behaviour found in this study could also feed into "mindless" stress detection as discussed by Béquet et al. (2020). The stressful situation could be resolved by modifying the driving context: Béquet et al. (2020) mention integrating stress detection within ADAS. They note, however, that this could also induce stress because of the perceived lack of control.

5. Conclusion

This study explored the impact of stress on driving behaviour in routine road sections and speed transitions. Twenty-seven participants drove through a neutral and a stressful situation in a driving simulator. Speed increased by approximately 1 km/h in road sections in a stressful situation compared to a baseline. In speed transitions, mean speeds before and after a transition were higher in a stressful situation than in a baseline situation, sometimes leading to (more severe) speed violations.

Limitations of this study were the following: firstly, participants wore an eye tracker and a Zephyr chest strap if possible. The analysis of this data was outside the scope of this paper, which focuses on the driving behaviour itself. These devices were designed to be undisruptive, but they may have slightly influenced the driving behaviour. Secondly, the subjective stress was self-reported, and stressors in daily life (e.g. occupational stressors) could not be mimicked. Thirdly, while simulator research is a safe way to study driving behaviour, the ecological validity of the results depends on how realistic the simulation was. Lastly, with only 4 participants older than 50, the sample may be biased towards young people. There was also a gender imbalance, as 19 of the 27 participants were male. Despite these limitations, this study showed that the impacts of stress on driving behaviour persist even in routine road sections. Time pressure should be mitigated where possible, which requires further study of the sources of time pressure. Additionally, stress detection should be integrated into ADAS systems. Avenues for future research include studying real-life driving behaviour under stress and the effectiveness of countermeasures. In naturalistic studies, measurement devices able to measure such events open up venues for research further exploring the link between stress and driving behaviour, as long as participants are not put in hazardous situations. Future research could also focus on underrepresented groups in this study, such as seniors or professional drivers. Road freight drivers or public transport drivers frequently drive for their job. They could be more vulnerable to the effects of stress on driving behaviour, though their training may allow them to cope better with stress, with fewer effects on their driving behaviour. Studies focusing on these groups may provide further insights.

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