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The effects of time pressure on driver performance and physiological activity: A driving simulator study

E. Rendon-Velez [a,1], P. M . van Leeuwen [b,*,1], R. Happee [b], I. Horváth [a], W.F. van der Vegte [a], J.C.F. de Winter [b]

[a] Delft University of Technology, Faculty of Industrial Design Engineering, The Netherlands
[b] Delft University of Technology, Biomechanical Engineering, Faculty of Mechanical, Maritime and Materials Engineering, The Netherlands

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ABSTRACT

Speeding because of time pressure is a leading contributor to traffic accidents. Previous research indicates that people respond to time pressure through increased physiological activity and by adapting their task strategy in order to mitigate task demands. In the present driving simulator study, we investigated effects of time pressure on measures of eye movement, pupil diameter, cardiovascular and respiratory activity, driving performance, vehicle control, limb movement, head position, and self-reported state. Based on existing theories of human behavior under time pressure, we distinguished three categories of results: (1) driving speed, (2) physiological measures, and (3) driving strategies. Fifty-four participants drove a 6.9-km urban track with overtaking, car following, and intersection scenarios, first with no time pressure (NTP) and subsequently with time pressure (TP) induced by a time constraint and a virtual passenger urging to hurry up. The results showed that under TP in comparison to NTP, participants (1) drove significantly faster, an effect that was also reflected in auxiliary measures such as maximum brake position, throttle activity, and lane keeping precision, (2) exhibited increased physiological activity, such as increased heart rate, increased respiration rate, increased pupil diameter, and reduced blink rate, and (3) adopted scenario-specific strategies for effective task completion, such as driving to the left of the lane during car following, and early visual lookout when approaching intersections. The effects of TP relative to NTP were generally large and statistically significant. However, individual differences in absolute values were large. Hence, we recommend that real-time driver feedback technologies use relative instead of absolute criteria for assessing the driver's state.

1. Introduction

1.1. The dangers of 'time pressure'

A large portion of road traffic crashes occurs because drivers have been speeding or committing other types of traffic violations, such as tailgating and dangerous overtaking (Elander, West, & French, 1993; Elvik, Christensen, & Amundsen,

* Corresponding author at: Delft University of Technology, Biomechanical Engineering, Faculty of Mechanical, Maritime and Materials Engineering, Mekelweg 2, 2628 CD Delft, The Netherlands.

E-mail address: P.M.vanLeeuwen@TUDelft.nl (P. M . van Leeuwen).

[1] Joint first authors.

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2004; Evans & Wasielewski, 1982; Organisation for Economic Co-operation & Development, 2006; Parker, Reason, Manstead, & Stradling, 1995). Speeding is a factor in between 10% and 40% of accidents on European roads (Organisation for Economic Co-operation & Development, 2006; Treat et al., 1979). McKenna (2005) reported that 33% of 9470 surveyed speeding offenders indicated that they were in a hurry at the time of their speeding offence. Another survey study by Collinson (2014) indicated that 77% of 150 people who were caught speeding did so because they lacked time to make the journey.

Several factors may explain why drivers decide to speed and violate the traffic rules. This includes personality factors, such as thrill seeking, pleasure in fast driving, and aggressiveness, as well as environmental factors, such as peer pressure, and perhaps most importantly, a shortage of available time (e.g., Beck, Daughters, & Ali, 2013; Beck, Wang, & Yan, 2012; Cœugnet, Miller, Anceaux, & Naveteur, 2013; Cœugnet, Naveteur, Antoine, & Anceaux, 2013; Matthews, 2002; Rendon-Velez, Horvath, & Van der Vegte, 2012; Rothengatter, 1988). Note, however, that a time constraint alone is not a necessary condition for speeding; the driver also has to *believe* it is important to complete the task in time (Benson & Beach, 1996; Cœugnet et al., 2013).

1.2. Models that describe how time pressure influences (driver) performance

A model of Wickens, Lee, Liu, and Gordon-Becker (2004) describes how (1) information input, (2) information-processing efficiency, and (3) task performance are influenced by external 'stressors' (such as pressure to complete a task in time). Specifically, Wickens et al.'s model illustrates that external stressors have *direct* influences on the quality of the information input and task performance (e.g., through increased levels of noise, lighting, or vibrations). The direct consequence of driving faster is that a higher amount of information has to be processed per unit of time. Thus, driving speed has a *direct* influence on the information input rate. Stress also has *indirect* psychological influences. For example, having to complete a task in a short amount of time could lead to high mental workload, anxiety, frustration, and anger, which in turn reduces information processing efficiency.

Maule and Hockey (1993) describe the effects of time pressure by means of a two-level control model. According to this model, the human cognitive system is self-regulatory. On the lower control level, small discrepancies between the current and target mental state are regulated by subconscious corrective actions (e.g., changes in speed, memory use, timing). When the discrepancy between the current and target state is large and subconscious control strategies are inadequate, control temporarily shifts to a higher level of cognitive (conscious) control (Maule & Hockey, 1993; see also Robert & Hockey, 1997). At this higher level, four modes are available to cope with high task demands: (1) increasing effort (trying harder) and accelerating control actions, (2) adopting a strategy that requires less effort, (3) changing the environment by removing stressors (e.g., re-negotiating the time deadline), or (4) doing nothing to reduce task demands (for further studies, see Edland & Svenson, 1993; Miller, 1960; Wright, 1974). When a driver adopts mode 1, this will be reflected in measures of speed as well as physiological measures associated with the activity of the sympathetic nervous system (Maule & Hockey, 1993). Modes 3 and 4 are usually not feasible when having to drive to a destination in a fixed amount of time, as the driver can control the state of his own vehicle in the environment but can hardly modify the environment itself. In this paper, our focus is on modes 1 and 2. That is, in the present study, we evaluated whether drivers modify their lateral/longitudinal driving behavior, posture, and gaze patterns by increasing their effort (mode 1) or by modifying their behavior in such a way that the driving task becomes easier to carry out (mode 2) while maintaining a high average driving speed in order to arrive at the destination in time.

1.3. Previous research that investigated the effects of time pressure on driving performance

Several previous studies have demonstrated the effects of time pressure on measures of driving performance. Van der Hulst, Rothengatter, and Meijman (1998) studied car following behavior in fog conditions using a driving simulator. Participants who were instructed to drive on a fixed time schedule showed less variability in their time headway due to decelerations of lead vehicles compared to a control group instructed to drive as they would normally do. The improved precision in the control of the vehicle suggests that the drivers adapted to the time constraint by increasing their level of alertness (Van der Hulst et al., 1998), an effect that corresponds to mode 1 (trying harder) in the model of Maule and Hockey (1993). Cnossen, Rothengatter, and Meijman (2000) instructed drivers to drive as fast as possible in a simulated environment. The results showed that participants had poorer lane keeping accuracy when they drove as fast as possible compared to when asked to adhere to the speed limits as if they were taking a driving test. In another driving simulator study, Zhai, Accot, and Woltjer (2004) found that drivers slowed down when they were required to maintain lane position accurately. Conversely, when the lane width increased, drivers were able to drive faster. These latter two studies suggest that the effects of time pressure can be described as a speed-accuracy tradeoff (see also Szalma, Hancock, & Quinn, 2008, for a meta-analysis on the effects of time pressure on measures of speed and accuracy).

Performance measures of speed and accuracy are advantageous for driver assessment applications because they represent an objective and observable state of the vehicle in its environment. Another advantage of these measures is that they are closely related to safety and accidents (Aarts & Van Schagen, 2006; Cooper, 1997; Lajunen, Karola, & Summala, 1997). A disadvantage of performance measures of speed and accuracy is that they cannot readily be used to identify whether a driver is subjected to time pressure or not, because these measures are highly situation-dependent (e.g., Cantin, Lavallière, Simoneau, & Teasdale, 2009). For example, a driver under time pressure may be stuck in a traffic jam, as a result of which