# Mental Workload Influence of Drivers Reaction Time on Unexpected Events: A Driving Simulation Study

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## Extended Summary

Driver's significant role in serious accidents causation, highlights the need for further investigation of the human element for the improvement of road safety. Given the predominance of the information processing approach in driver's behaviour research field, an important psychological construct, Mental Workload (MWL), has been introduced to study driver's behaviour. It includes both cognitive load and stress, describing the amount of mental resources required for performing a task [1], [2]. It is a multidimensional concept, as it is determined not only by the requirements of the activity performed, but also by the given, each time, conditions, and by the driver [2]–[5]. The correlation between the factors that affect driving behaviour and the MWL's variance is a significant parameter in the science of road safety. It is widely observed, that when demands begin to exceed driver's capacity, there is the possibility of either compensate by adjusting the strategy (e.g. lower speed, stop interacting with passengers) or else performance necessarily degrades, leading inevitably to an accident [3], [6]–[9]. Every task performed by the driver is conscious, requires attention and gives feedback to the driver, through a controlled process. When such tasks are repeated often, they begin to become more automated, as the course of their execution does not require close monitoring by the driver, and therefore are performed almost unconsciously While the driver engages to more automatic tasks, arises the danger of being absorbed in the automated driving, failing to perceive any emergency that may arise on the road (e.g. unexpected event), requiring an immediate reaction through a controlled action [10]. An unexpected situation demands priority, activating a compensation process to ensure safety [11]–[13]. The way each driver handles an unexpected situation, depends on the nature of the event, and the driver characteristics, i.e., parameters related to the human factor. As regards the nature of the event, the driver's reaction is affected by the type of event, its expectancy, how urgent the situation is, but also how dangerous it is for the driver or other road users [12], [14]–[16]. Concerning the human factor, the influence of the driver's MWL is important, as drivers who are engaged in a secondary task, and therefore presenting higher MWL, react differently to an unexpected event (e.g. react to fewer events, record longer reaction times), compared to drivers who are focused exclusively on driving task [12], [15], [17]. Furthermore, dual tasking drivers present difficulties in detecting unexpected events based on their type (driving incongruent/congruent events) and even when these events are being detected, Reaction Time (RT) is significantly longer than RT of drivers not engaged in a secondary task [15]. The two most common actions that the driver is required to take when an emergency is perceived, are to maneuver, if possible, the vehicle away from the obstacle, or to use the brake pedal to decelerate or stop the vehicle to avoid conflict. Relevant literature prove that the vast majority of drivers choose to brake, as initial response to an unexpected event, even when a steering maneuver is feasible [14], [16], [18]. When studying the driver's reaction to external stimuli, it is observed that it does not follow a linear model, as time delays are recorded [19]. A significant percentage of road accidents are due to some delay related to the human factor, such as delay in risk

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perception, delay in decision making or implementation, etc. [5], [10], [20]. Important influence of driving, MWL and age on RT is proved by previous research [23], [21], [22], [31], [23]. Findings confirmed that with the increase of the difficulty of performing an activity, the difference in the RT related to age is also increased. The importance of drivers' awareness that additional MWL affects driving behavior is also highlighted, reporting drivers' decision for compensatory behavior, e.g., by reducing vehicle speed. The study of driver behavior includes conditions and situations that considered dangerous, increasing the likelihood of an accident occurrence. For this reason, relevant researches regarding driver behavior are being implemented mainly with the use of a driving simulator [23], [24]. The laboratory environment ensures the safety of the participants, which is of high importance when studying the condition of the driver. Furthermore, the driving simulator allows the complete control of the studied conditions and the repeatability of the studied conditions. In addition, it facilitates the use of measurement equipment [10], [24]–[27]. On the other hand, the researcher should always take into consideration the high cost of a driving simulator experiment and the fact that the actual driving conditions can be simulated only approximately [10], [24], [27], [28]. Additionally, the researcher should always be alert for identifying simulator sickness indications observed while driving, which may lead to impaired driving behavior altering research results, or even in the resignation of the driver from the experimental process.

Based on the above, the objective of the current paper is the investigation of the effect of increased MWL on driver behavior and specifically the changes in driver's RT while driving under increased MWL (1-back digit recall task). To this end, a driving simulator experiment took place, and through the statistical analysis performed, driving performance was analyzed based on relevant parameters (RT, accident occurrence, maneuver performance). The present study is part of a wider research that takes place in the context of a doctoral dissertation concerning the study of out-of-the-vehicle factors that influence driving behavior. The approach focuses on Greek drivers, emphasizing driver's reactions to visual stimuli.

## 1. Methodology

The experiment conducted in the Driving Simulator of the Hellenic Institute of Transport which is part of the Centre for Research and Technology Hellas. The driving scenario developed for the present research consists of a 6km drive in a rural environment. during which, four (4) unexpected events occur. The 2nd unexpected event (vehicle1: a parked vehicle behind another parked vehicle at the side of the road, leaves its parking slot, drives in front of driver and parks again later at the side of the road) and the 4th unexpected event (vehicle2: beside a parking, there are a lot of parked vehicles, the last one -in the row- leaves its parking slot, drives in front of driver and parks again later at the side of the road) are caused by relevant to the driving task sources, which exist in the direct road environment; thus, the driver is aware of them, but an unexpected motion of them requires driver reaction to maintain safe vehicle trajectory (relevant source unexpected events). The 1st unexpected event (donkey: a donkey stands behind a bush and crosses the road when the driver approaches) and the 3rd unexpected event (child: opposite a farmhouse, behind a parked vehicle, a red ball runs in the road and a child follows crossing the road), derive from irrelevant to the driving task sources (animal, child). They are characterized as unexpected situational events, since the objects that cause the events do not belong to the direct driving environment, but their unexpected motion also requires driver reaction to ensure road safety (irrelevant source unexpected events).

For the simulation of the increased MWL conditions during driving, a secondary task was employed. To this end, the MIT AgeLab Delayed Digit Recall Task (n-back) (DDRT) [29] in the 1-back version was adapted to current research needs. The DDRT increases driver's MWL by employing his/her short memory while driving. It is implemented via recorded auditory stimuli, in which drivers respond verbally. A soundtrack of 10 single digits (0-9) presented in random order, at an interval of 2.25 seconds between each digit, initiated during the drive asking of the driver, each time, to recall the 1-back digit. The DDRT commenced after the first two unexpected events, so as to let happen in each state (No MWL/With MWL), one event of each type.
Along with the driving procedure, the participants filled in an online questionnaire, which was divided in two parts. The first part, including demographic and driving data, was filled before driving, and the second part, including data regarding the driving experience during the measurement process and the Rating Scale of Mental Effort (RSME), without and with the DDRT, was filled afterwards.

In the present study, 60 drivers participated in the experiment, with 4 of them encountering serious difficulties in driving task due to simulator sickness, not managing to properly complete the drive. Thus, the final sample of the present study is 56 drivers, with 48% of them female and 52% male. As regards age distribution, four age groups were created [(18 – 25), (26 – 40), (41 – 55), (> 56)], and the distribution of the participants covered all age groups.

## 2. Analysis and Results

A two-way ANOVA was applied to investigate how the presence of additional MWL (No MWL/With MWL) and the type of the unexpected event (relevant/irrelevant source unexpected events), affect the RT of drivers to the unexpected events. The statistical significance level was set at .05 and the analysis showed that both MWL ($F=83.635$, $p<0.01$, Eta=0.282) and the type of event ($F=37.167$, $p<0.01$, Eta=0.149) are statistically significant. The estimated marginal means of RT are presented in Figure 1. Drivers reacted slower in the presence of additional MWL, with 80% of them demonstrating higher RT in higher MWL conditions. As regards the type of the unexpected event, drivers showed higher RT in unexpected events caused by relevant to the driving task sources.

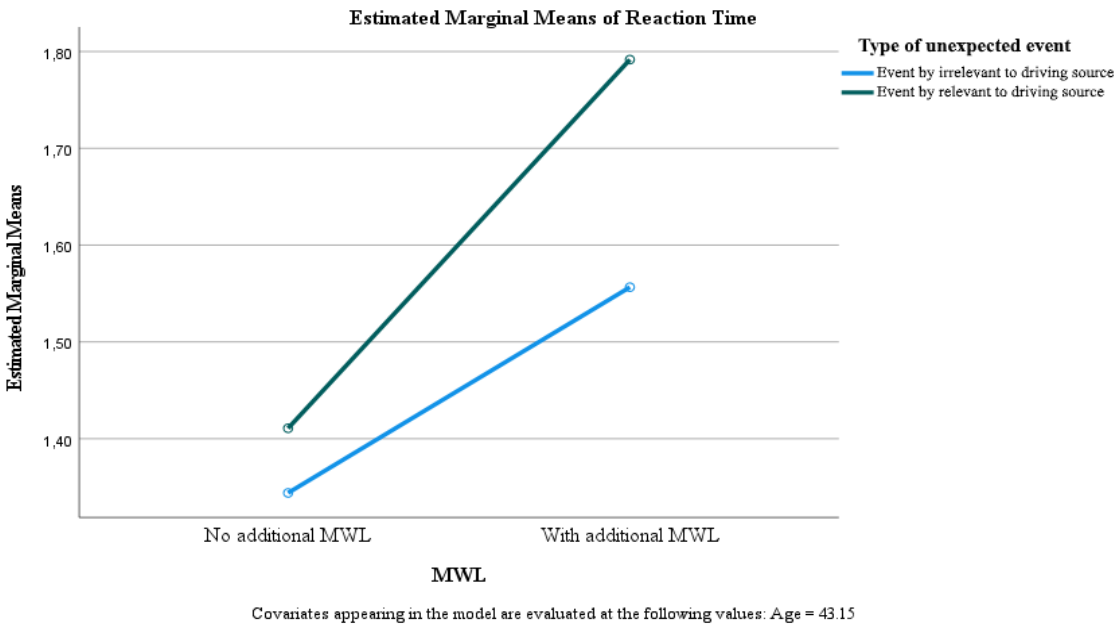


**Figure 1: Estimated marginal means of RT.**

Regarding the way drivers reacted to the unexpected events, most of the drivers (92%) employed the brake pedal, while only 30% of them performed a maneuver. Furthermore, in total of 224 unexpected events occurred during all drives, there were 6 cases (2%) where there was no reaction at all, leading inevitably to accident. Overall, 33 accidents occurred (15% of all 224 events), most of which happened in events caused by irrelevant to the driving task source (61% of accidents happened at irrelevant source events, 39% of accidents happened at relevant source events).

A binary logistic regression proved that only MWL ($B=1.032$, $p=0.001$, $Exp(B)=2.807$), and not the type of event ($B=-0.137$, $p=0.650$, $Exp(B)=0.872$) significantly affects the execution of a maneuver, apart from or along with braking, as a reaction of the driver to the unexpected event.

A second binary logistic regression performed to estimate the effect of MWL and type of the unexpected event, to accident occurrence. In this case, nor MWL ($B=0.407$, $p=0.349$, $Exp(B)=1.503$) or type of event ($B=0.340$, $p=0.415$, $Exp(B)=1.405$) significantly affected the realization of an accident.

## 3. Discussion and Conclusions

Results prove that higher MWL increases drivers’ RT, deteriorating driving performance in the majority of the participants, confirming the literature [3], [30], [31]. Furthermore, the number of participants showing lower RT in the presence of high MWL, as already stated in literature could be attributed to the fact that they may be employing adaptive control behaviours to counterbalance the increased MWL [3], [6]–[9], [32]. The type of the unexpected event, plays also a significant role in driver’s reaction [12], [15], [17], but contrary to the findings of

Briggs et al. [15] pertaining that dual tasking drivers present more difficulties in detecting items that are driving incongruent, current research's findings demonstrate that most drivers show higher RT in events that derive from relevant to the driving task sources: the two vehicles leaving their parking slots, entering suddenly the road. This may be ascribed to the fact that drivers do not perceive the parking vehicles as possible hazard, since they are frequently encountered in the driving environment, and thus drivers are accustomed to them. On the contrary, at the two unexpected events caused by irrelevant to driving sources, the donkey crossing the road, and the child following her ball on the road, drivers are probably more alerted, once becoming aware of the donkey or the ball/child besides the road, demonstrating lower RT. Regarding the way drivers react to the unexpected events, as expected by the literature review [14], [16], [18], results reveal a significant dominance of the brake use, alone or along with the execution of a maneuver. With the latter being significantly affected by the presence of high MWL, since drivers tend to "forget" to maneuver in conditions of high MWL. The process of automation of the driving task [3], [10], during which the driver devotes the minimum effort on driving, driving almost unconsciously, may shed light to the driver's choice of braking on a critical situation, failing to opt for a steering maneuver, even when this choice would be more efficient.

Limitations of the present study derive mainly from the research environment of the driving simulator in which the study took place, which affect both the driving conditions and the reaction of the drivers. The researcher should always interpret the results, considering these limitations and preceding studies proving the validity of simulator results on relevant conditions.

Bearing these in mind, as well as the driver's significant role in road safety, the need for further investigation of the human element for the improvement of road safety is emphasised. Overall, MWL proved to play an important role on driver performance, and thus further research on its consequences on driving performance, and the factors that influence its variance during driving, is imperative. Furthermore, during the study of critical situations created by unexpected events, the relevance to the driving task of the source creating the unexpected event, should be taken into consideration as it constitutes an important influencing factor of driver's RT. Finally, drivers' opt for braking or steering maneuver should be further investigated, aiming to a better understanding of this mechanism, to increase effective performance of steering maneuver when feasible.

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