Validation of a Telephone Manager for stressful driving situations

Linda Köhler1, Klaus Bengler2, Christian Mergl3, Kathrin Maier4, & Martin Wimmer1
1AUDI AG, Ingolstadt
2Institute of Ergonomics, Technische Universität München
3Brose Fahrzeugteile GmbH, Coburg
4Institute of General Psychology, Katholische Universität Eichstätt-Ingolstadt

Germany

Abstract

Today we face highly complex urban driving situations including high information density, short decision times and a variety of stimuli acting. Crossing an intersection where drivers have to give way to crossing traffic has been identified as an example of one type of stressful situation. Several studies show that telephone calls while driving affect various aspects of driving performance. Additional stress for the driver is assumed. In order to pursue the aim of comfortable and safe driving with minimum stress even in complex situations, a suitable user interface solution including a Telephone Manager is introduced. A driving study was conducted with 27 participants validating a Telephone Manager suppressing incoming calls in stressful driving situations. Both the driving situations (turn left vs. go straight) and the telephone call (being answered vs. being suppressed) were tested against the driver’s perceived mental workload, driving performance and acceptance. The results show a higher stress level for the driver in intersection situations. Furthermore, it confirmed that phone calls lead to additional stress, which can be reduced by call suppression in stressful situations. Moreover, the questionnaires confirmed that the telephone manager is highly accepted.

Introduction

Motivation

Complex urban driving situations are posing a big challenge in everyday car journeys. The Cooperative UR:BAN Project, supported by the Federal Ministry for Economic Affairs and Energy, deals with such challenging settings. In the sub-project “Mensch im Verkehr”, the main focus lies on the human being as an actor and scheduler in traffic with its requirements and needs. Challenging situations include, inter alia, temporary dynamics, a large number of static and moving objects, interaction with urban traffic and little space for manoeuvres.

In former research, crossing intersections can be identified as one of the most stressful urban driving situations (e.g. Praxenthaler, 2003; Köhler et al., 2013). T-junctions, in particular, where drivers have to give way to crossing traffic implying a high level of stress for the driver (Köhler et al., 2013). These results can be explained using cognitive psychology approaches concerning driver behaviour, described below.

Driving task and workload

In general, the driving task can be divided into three main subtasks: primary (driving process), secondary (reactions or activities deriving from the current traffic situation) and tertiary tasks (satisfaction of needs concerning the driver’s comfort, information or communication) (Bubb, 2003). Furthermore, models with three hierarchy layers of the primary driving task – divided into navigation, guidance and control – have been postulated (Bubb, 2003; Donges, 1982). By splitting it into its components, it becomes apparent how complex the driving task is. This includes reaching the destination safely whilst adhering to the traffic rules. The driver has to carry out different behaviour patterns simultaneously. Cognitive demand increases for an experienced driver from the lowest level “control”, via “guidance” up to “navigation” (Reichart & Haller, 1995). Rasmussen (1983) proposed the SRK taxonomy to distinguish between the different strengths of mental workload. It defines skill-based, rule-based and knowledge-based behaviour. When merging the approach by Donges (1982) with the SRK taxonomy by Rasmussen (1983), the guidance (secondary level) and the control level (tertiary level) include skill- and rule-based activities. Based on practice and experience the driver can handle these activities – e.g. performing certain driving manoeuvres or staying with a lane – mostly unconsciously. Navigation (primary level), implies knowledge-based processes (Rasmussen, 1983), for instance perception of relevant route information. The model distinguishes between three categories with varying degrees of cognitive workload: control and guidance, in particular, are tasks which can be carried out with a low level of cognitive effort after having been learnt (rule-based processes) (Donges, 2012). Other subtasks of the primary, the secondary and the tertiary driving task follow skill- or knowledge-based modes of behaviour which place more strain on the driver’s cognitive resources.

The overall construct, with regard to the availability or allocation of cognitive resources, is human attention. For the phenomenon, that attention is limited and information has to be selected, several explanatory approaches exist, two examples being bottleneck models of attention (Broadbent, 1958) and capacity models of attention (Kahneman, 1973). As De Waard (1996, p.12) proposed, on the one hand there are “concepts of a limited processing capacity” and on the other hand there are “resources calculated as the amount of processing facilities”. Furthermore, the approach used to describe output losses is marginal. However, it is crucial to say that mistakes are made if too many tasks have to be fulfilled simultaneously.

In relation to the driving task, De Waard (1996, p.24) postulated an adequate model considering the driver’s workload, performance and demand. The optimum is described as being a low cognitive workload that obtains a maximum result (optimal performance). By increasing demand, a higher, task-related effort will be necessary to keep the level of performance. If the demand exceeds the capacity limit the result
is mental overload. Because of the sharp rise in workload, there is a rapid decline of performance as a consequence.

In this context mental workload can be defined as “the result of reaction to demand; it is the proportion of the capacity that is allocated for task” (De Waard, 1996, p.17). When developing advanced driver assistance systems (ADAS) and information systems, it is essential to consider the mental workload of the driver. Not least because this is encumbered by a large number of vehicle systems, followed by an even larger number of status messages. All of them are being presented to the driver in almost any situation at almost any time. So, the aim should be a minimization of workload caused by the tertiary driving task. This means that situational workload management has been developed.

**Workload manager**

There are many different approaches for reducing the driver’s mental workload. For instance, Muigg produced an implicit workload management system. He focuses on the avoidance of non-essential driver distraction caused by messages inside the car that are inappropriate for the situation (Muigg, 2009). Another example is the information manager by Seitz (2013), which has been developed for utility vehicles. Seitz’s information management system estimates the driver’s current workload based on the given driving situation and the environmental conditions. Most approaches are generated, needing plenty of different pieces of information about the driver, traffic and car. In consequence, it is the aim to develop an easy to handle, easy to implement (in the car), transparent and consistent workload management system. The Information Manager by Köhler et al. (2013) describes in detail why incoming information (such as low fuel signals or windscreen washer signals) should be suppressed in stressful driving situations. Several studies show that making telephone calls while driving affect various aspects of driving performance. The driver is placed under additional stress (Tractinsky et al., 2013; Rosenbloom, 2006; Shinar et al., 2004).

An important question when considering the environment is: Will a Telephone Manager that suppresses telephone calls whilst the driver is managing stressful situations work just as well? The hypothesis is that the Telephone Manager can reduce the driver’s workload while crossing an intersection and will be accepted.

**Driving study**

A driving study has been conducted focusing on the following questions: Can increased workload, caused by incoming calls, be proven whilst driver is managing urban scenarios? Will the suppression of incoming calls in stressful driving situations lower the level of mental workload? Will a Telephone Manager that suppresses incoming calls in stressful driving situations be accepted by the driver? In addition the validation of the intersection scenario as an example for stressful driving situations is part of the study.

Therefore, the central hypotheses are as follows: 1) A crossing situation is more stressful than going straight on. 2) A telephone call whilst driving is more stressful than no call. 3) Transferring a telephone call whilst driving in comparison to suppressing the call increases mental workload. 4) The Telephone Manager will be
accepted. Therefore, two different driving situations (crossing a T-junction by turning left vs. going straight) and three different telephone conditions (no incoming telephone call vs. call being answered vs. call being suppressed) were analysed. To standardise the contents of the telephone calls, arithmetic problems had to be solved (see also Shinar et al., 2004).

There are several methods used for measuring workload – self-report, performance and physiological measures (De Waard, 1996). In this study, performances of driving task (average speed) and telephone task (including mean time to respond to the call) (McKnight & McKnight, 1993; Shinar et al., 2004; Tractinsky et al., 2013), as well as subjective values (NASA TLX) (Hart & Staveland, 1988) were used as indicators. Personal attitudes towards the Telephone Manager were tested with the Van der Laan Acceptance Scale (Van Der Laan et al., 1997) – an instrument containing the two dimensions usefulness and satisfaction.

**Materials and methods**

**Participants**

A total of twenty seven volunteers took part in this study, being recruited through a mailing list. The sample consisted of eleven female (41%) and sixteen male (59%) participants with an average age of 35.93 years ($SD_{age} = 12.7$) ranged from 20 to 58 years. All of them were native German speakers in possession of a valid driving licence for at least three years (M = 17.4). 78% of the participants cover a driving distance of at least 10,000 km per year. Seventeen participants (63%) are physically able to connect their mobile phone with their private car, while 63.2% of them use this functionality at least occasionally (“occasionally” = 15.8%, “often” = 5.3%, “always” = 42.1%). Because of technical problems, two participants had to be excluded.

**Apparatus**

An Audi A6 Saloon with an integrated Driver Information System with 7” colour display and a Multi Media Interface (control panel operating a separate MMI display) was used as a test vehicle. The Audi A6 had an automatic transmission. A telephone was connected to the vehicle via mobile telephone preparation with a Bluetooth interface, meaning that hands-free calls were possible using the microphone. The whole study was conducted at the testing ground of the Universität der Bundeswehr in Munich, Neubiberg. At the testing ground urban driving scenarios were created. To record data, both situations – crossing a T-junction whilst giving way to crossing traffic and going straight on – were tagged by trigger points which were detected by the A6 using DGPS. Both situations covered a route of 110m and were subdivided into six successive phases, as seen in Köhler et al. (2013). An Audi Q7, driven by a professional examiner, constituted the (critical) crossing traffic.

**Procedure**

At the start, each participant received a short briefing, including being asked to answer incoming calls while driving. The test subjects had to solve arithmetic problems,
communicated by the speaker on the telephone. For every correct calculation they would receive a bonus of 50 cents. The briefing was followed by a few manoeuvres to become familiar with the test vehicle. Whilst they got to know the Audi A6, participants received two incoming test calls – one whilst stationary and one whilst driving.

The test drive was made up of five laps of the course with each lap including one of the five test scenarios. Participants were instructed to keep a speed limit of 30 km/h, follow the traffic laws and, if they wished, to answer incoming telephone calls. The participants had to go through five scenarios (see settings in Figure 1): 1) Crossing a T-junction by turning left a) without a telephone call; b) with an incoming call (followed by an arithmetic problem); c) with a message (via Driver Information System) about a suppressed call after passing a trigger point 5 metres behind the junction. 2) going straight on for 110 metres a) without a telephone call; b) with an incoming call (followed by an arithmetic problem).

While crossing the intersection, the Q7 was the crossing traffic. All situations were permuted for each participant. The participant had to fill in the NASA TLX for measuring the perceived driver’s mental workload after every scenario. Furthermore, in scenarios with incoming calls the examiner logged the time the participants took to answer the call and time taken to solve the arithmetic problem. At the end, the functionality of the Telephone Manager was explained to the participants. The Van Der Laan Acceptance Scale had to be completed, followed by personal information. In total, one test took about one hour and fifteen minutes per participant.

Analyses

A significance level of $\alpha=5\%$ was assumed for testing the hypotheses. In order to
allow inferential statistics, all scales of measurement were metric. NASA TLX was adopted as recommended by Hart & Staveland (1988) ascertaining weights for each item when calculating a total amount. Recorded driving data was analysed starting from the point of a potential call (shown in figure 1). Statistical outliers were also adjusted.

A two-way repeated measure, ANOVA, was used to investigate differences in driving scenarios (turn left, go straight) and in telephone conditions (call being delivered, no telephone call). For that purpose, the amount of the NASA TLX and the average speed were used. The same measures were used for testing differences between the three telephone conditions (no telephone call, call being delivered, call being suppressed) in a univariate ANOVA with repeated measures. To compare all three telephone conditions (no incoming telephone call, call being answered, call being suppressed), a t-test (predisposed individual comparisons) was used for testing subjective and objective data. The mean time to respond to the call and the mean time to solve the arithmetic problem were compared for the scenarios turning left and going straight using a t-test for paired samples. A t-test for paired samples was used to find the difference between the two telephone conditions (telephone call while driving, no telephone call). Finally, the acceptance of driving with the functionality of the Telephone Manager and without the functionality was compared by means of a t-test. The subscales of usefulness and satisfaction have been calculated for this.

Results

The subjective evaluation concerning drivers’ mental workload shows no difference between turn left (M=19.15; SD=14.07) and go straight (M=15.68; SD=13.56). Even though there was no significant main effect for the subjective amount of the NASA TLX, F(1,25) = 3.65, p = .07, η² = .13, ns., a tendency emerged, approved by the p-value and the effect size. This trend has been confirmed by the mean time to respond to the incoming call – while crossing the T-junction (M=2.4s; SD=0.82s) participants took significantly longer to respond compared with going straight (M=2.16s; SD=0.78s), t(21) = -1.73, p < .05 (Figure 2). However, the mean time to solve the problem on the phone did not differ significantly, t(21) = 0.97, p > .05, ns. For calculating participants needed as much time by turning left (M=3.19s; SD=4s) as by going straight (M=4.25s; SD=4.51s).
By comparing conditions with and without an incoming call, a significant effect can be shown using NASA TLX, $F(1,25) = 23.69$, $p < .001$. Without a phone call participants stated lower mental workload ($M=9.53$; $SD=10.25$) in comparison to answering an incoming call while driving ($M=25.3$; $SD=19.22$). The average speed did not depend on the telephone condition, $F(1,20) = 0.97$, $p > .05$, ns. Nevertheless, by considering individual comparisons for crossing the intersection, according to the hypothesis, deviations in the average speed with ($M=19.25$km/h; $SD=3.2$km/h) and without phone call ($M=20.87$km/h; $SD=2.31$km/h) were significant, $t(23) = 5.02$, $p < .001$. For driving straight on it did not show any deviation, $t(21) = -0.41$, $p > .05$, ns.

Comparing the scenario intersection, the three different telephone call conditions differed significantly, $F(2,50) = 14.55$, $p < .001$ (Figure 3). Answered call shows the highest level of mental workload ($M=27.04$; $SD=20.51$), by contrast to call being suppressed ($M=13.49$; $SD=12.98$), $t(25) = 3.74$, $p < .001$, and no incoming call ($M=11.27$; $SD=11.9$) which are almost equal, $t(25) = -1.09$, $p > .05$, ns.
Figure 3. The three different telephone conditions (no incoming telephone call vs. call being answered vs. call being suppressed) at the scenario “turn left” compared by their level of mental workload (NASA TLX).

Objective data gave proof of this effect, as well. The average speed was significantly concerning the factor “telephone call”, $F(2,46) = 14.19$, $p < .001$. During an incoming call ($M=19.38\text{km/h}; \text{SD}=3.21\text{km/h}$) in comparison to the scenario with a suppressed call ($M=20.86\text{km/h}; \text{SD}=2.26\text{km/h}$), participants drove significantly slower, $t(24) = -3.51$, $p = .001$. There was no difference measured between suppressed call and no call ($M=20.87\text{km/h}; \text{SD}=2.31\text{km/h}$), $t(23) = 0.06$, $p > .05$, ns.

The Van Der Laan Acceptance Scale is able to assess system acceptance in two dimensions – a Usefulness Scale and a Satisfying Scale. Comparing the Usefulness Score, a significant difference between a car with the functionality of a Telephone Manager ($M=-0.84; \text{SD}=1.0$) and without the functionality ($M=-0.2; \text{SD}=0.92$) has been shown, $t(26) = -2.14$, $p < .05$ (Figure 4).
The comparison of the Satisfying Score showed statistically significant differences, 
\[ t(26) = -3.16, \ p < .01 \]. The Telephone Manager (M=-0.89; SD=0.98) is evaluated as being more satisfying than a car without the functionality (M=0.13; SD=1.13).

**Discussion**

The study aimed to confirm the Telephone Manager as a function that decreases workload in stressful driving situations. The Manager was implemented by suppressing incoming phone calls while the driver had to handle a left turn at a T-junction and give way to crossing traffic. In detail the functionality is suppressing incoming calls in phases of high driver’s mental workload (compare Figure 1: phases of high driver’s mental workload are phase 2, 3, 4 and 5).

First of all, crossing the intersection had to be identified as a stressful driving situation. The first hypothesis expects a higher workload for the scenario *turn left* in comparison to the scenario *go straight*. Subjective data (NASA TLX) showed a small tendency but no statistical significance. An identical effect can be shown with the mean time of solving the arithmetic problem on the phone. Only the mean time to respond to an incoming call confirmed the hypothesis. Referring to Rasmussen’s classification
(1983) going straight relies on skill-based processes (guidance and control); as opposed to crossing the intersection, which requires rule-based processes and therefore demands cognitive control. More time taken to respond to the call indicates that more attention is needed to manage the primary driving task (Rasmussen, 1983). Longer processing times are a result of the apportionment of mental resources split through driving task and secondary task (Kahnemann, 1973). During the easier scenario (going straight) the telephone ringing was captured earlier. An explanation is the availability of more capacities for the secondary task (resource models) or the lower charged processing channel (1-channel-model) (De Waard, 1996). The environmental conditions at the testing ground in Neubiberg were causing only a low level of mental workload for the driver in general. There were no pedestrians, no cyclists and one Audi Q7 forming the crossing traffic. Transferred to urban traffic situations, differences in workload will rise up as shown by Köhler (2013). Besides, NASA TLX scores showed high values of standard deviation. This can be explained by the small number of participants.

The second hypothesis relates to mental workload caused by telephone calls while driving a car. On the subjective level it can be proven that telephone calls increase drivers’ mental workload in both scenarios. On the objective level the impact merely appears to be at the intersection. In this scenario, participants reduce speed when making a telephone call. Compared to going straight, where the average speed does not depend on incoming calls. This phenomenon can be interpreted by reference to the keynote by De Waard (1996). The fact that performance declines in the intersection scenario but not in the going straight scenario – even if NASA TLX shows a high level for both of them – can be explained by the region model (Figure 5; De Waard, 1996, p.24).

![Region model by De Waard (1996, p. 24) depicting the relation between demand, workload and performance in 6 regions.](image)

As shown in Figure 5 and referring to theoretical assumptions, region A3 can be characterised as follows: “[...] performance measures still do not show a decline, but the operator is only able to maintain the level of performance by increasing effort.” (De Waard, 1996, p. 23). This is consistent with the scenario going straight and answering an incoming telephone call – even if driving performance (average speed)
doesn’t show an impact of the phone call, subjectively the mental workload increases (NASA TLX). Compared to the second scenario (making a phone call whilst crossing the intersection), driving performance is affected, as shown in region B (De Waard, 1996). In this context, performance deficits can be explained based on limited resources. Crossing an intersection was identified as a rule-based action, needing more processing capacity than going straight. Because resources have to be shared for the incoming call, driving performance deficits arise (Rosenbloom, 2006; Shinar, 2004). For confirming the Telephone Manager by disclosing its benefits, a third hypothesis was defined to identify a decrease in mental workload caused by the function. The Telephone Manager suppresses incoming phone calls in stressful driving scenarios. In the study “crossing the intersection” was used as an example for such situations. The results confirm a decrease in the driver’s mental workload when calls were suppressed compared to answered calls. The subjective evaluation (NASA TLX) as well as objective data (average speed) identified a significantly higher level of mental workload when calls are answered in the stressful driving scenario “intersection” (turn left). Suppressed calls show a low level of workload as well as the condition “no call”. Because of the suppression of the call, additional workload can be prevented. By consequence, all processing capacities will be available for managing the driving scenario.

A fourth hypothesis was put forward to confirm whether the Telephone Manager will be accepted by the driver. The validated Acceptance Scale by Van Der Laan yields a significant impact in the Usefulness Scale and the Satisfying Scale. Participants prefer the new functionality for stressful driving situations. The Telephone Manager is accepted.

Conclusion

In brief, the study shows that telephone calls while driving cause a higher mental workload. Also, the Telephone Manager – suppressing incoming calls in stressful driving situations – decrease the level of drivers’ workload level significantly. Even though crossing an intersection couldn’t be identified as such a stressful scenario, workload can be lowered here as well. Besides, the developed concept will be accepted by the driver. In this context, it is important to note, that the stressful driving scenario usually does not take longer than thirty seconds. Hence, there are only a few occasions where an incoming call will be suppressed entirely. A solution could be to only suppress the initial ringing.

In summary, this study shows the usefulness of the Telephone Manager and encourages its introduction for stressful driving situations. As this functionality just bases on predictive road data, its implementation will be less complicated compared to other Workload manager approaches, which require a more complex technical infrastructure like interior sensors, on-board network or bus data.

References

