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Masking Action Relevant Stimuli in dynamic environments – The MARS method

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ABSTRACT

We present the novel MARS (Masking Action Relevant Stimuli) method for measuring drivers' information demand for an action relevant stimulus in the driving scene. In a driving simulator setting, the traffic light as dynamic action relevant stimulus was masked. Drivers pressed a button to unmask the traffic light for a fixed period of time as often as they wanted. We compared the number of button presses with the number of fixations on the traffic light in a separate block using eye tracking. For the driving task, we varied the road environment by presenting different traffic light states, by adding a lead vehicle or no lead vehicle and by manipulating the visibility of the driving environment by fog or no fog. Results showed that these experimental variations affected the number of button presses as dependent measure of the MARS method. Although the number of fixations was affected qualitatively similar, changes were more pronounced in the number of fixations compared to the number of button presses. We argue that the number of button presses is an indicator for action relevance of the stimulus, complementing or even substituting the recording and analyses of gaze behaviour for specific research questions. In addition, using the MARS method did not change dynamic driving behaviour and driving with the MARS method was neither disturbing, nor difficult to learn. Future research is required to show the generalisability of the method to other stimuli in the driving scene.

1. Introduction

While driving certain elements of the driving scene have direct action implications. In order to perform the driving task appropriately, that is, to process the action relevant information and to respond accordingly, drivers need to allocate attention to this information. For example, when approaching traffic light intersections, drivers receive information from the traffic light to initiate a necessary stop or avoid an unnecessary one.

As researchers we aim to gain insight into the relevance of specific stimuli for the driver. This knowledge helps to improve the design and parameters of driver assistance systems, road structure and infrastructure elements. Considering the high complexity of the road environment and the increasing amount of information drivers have to process, it is crucial to understand whether and when specific elements of the driving scene are action relevant.

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To gain insight about action relevance of specific stimuli during driving the eye tracking method has been used. It can be assumed that increased number of fixations or increased fixation durations on a specific stimulus indicate increased attention allocation towards this specific stimulus, which is related to action relevance. This is because information needed for solving driving tasks is mainly visual (Gelau & Krems, 2004; Van Der Horst, 2004). Research has shown that gaze behaviour and attention are tightly linked and that measuring eye movements and fixations is a suitable method for determining drivers' visual attention (e.g., Konstantopoulos, Chapman, & Crundall, 2010; Shinar, 2008). The visual search patterns in dynamic driving situations are based on strategies that are defined by task context, goals and expectations (Engström, 2011). These allow for the anticipation of relevant information from the scene and potential demanding driving conditions (Shinoda, Hayhoe, & Shrivastava, 2001; Underwood, 2007). For example, eye movements have been recorded in order to measure drivers abilities to "acquire and asses" relevant information of the driving scene (Pradhan et al., 2005) and to determine if drivers with different levels of experience have appropriate mental models of a road scene (Underwood, Chapman, Bowden, & Crundall, 2002). Hence, the researchers assumed that visual attention towards risk relevant elements was crucial for a safe performance. The number and length of fixations on the risk relevant areas of the visual field were measured as an indicator for the correct interpretation of the driving scene. In summary, previous research points to the conclusion that increased number and durations of fixations on a certain stimulus can be interpreted in terms of an increased information demand because of action relevance of the stimulus.

Although measuring eye fixations is an appropriate method to assess drivers' attention (e.g., Corbetta et al., 1998; Hoffman & Subramaniam, 1995) and offers the opportunity to gain knowledge about drivers' information acquisition necessary for safe driving (Mourant & Rockwell, 1970; Rockwell, 1972), there are some disadvantages to this method when aiming to investigate action relevance of a stimulus. First, visual fixations do not necessarily reflect that drivers actually attend to the fixated locations. The classic "looked-but-failed-to-see" phenomenon is the best example for a visual fixation without attention (Greenberg et al., 2003). As mentioned by Shinar (2008), "the open eyes always fixate somewhere in space", while attention might be allocated elsewhere. Second, even if drivers look and attend to the specific stimulus we cannot differentiate if the fixation occurs because of action relevance of the stimulus or if drivers look and attend to the stimulus because they simply have to look somewhere in the road scene.[1] Third, we cannot be sure whether drivers indeed have to fixate stimuli in order to process current action relevant information. Drivers may covertly shift attention to relevant locations without fixating these locations (Posner, 1980). This is especially true for a highly salient stimulus like the traffic light where drivers may use peripheral vision and allocate attention without fixation. Fourth, although eye tracking technology has been improving, the procedure for calibrating and measuring fixations is still time consuming and difficult. Fifth, using eye tracking systems can be uncomfortable for drivers due to head or face mounted equipment, which leads to restrictions in study designs due to short experiment durations. And finally, the analyses of eye tracking data is especially challenging for objects with variable positions in the recorded picture frames, as this is usually the case in dynamic driving tasks.

1.1. The MARS method

We propose a new method to measure information demand of a single action relevant stimulus in a dynamic driving environment. The concept of the method is based on occlusion techniques, even though the experimental goals differ from those elaborated in occlusion technique studies. Occlusion has been used for the "physical obscuration of vision for a fixed period of time" (Lansdown, Burns, & Parkes, 2004) for total or major parts of the driving scene (Senders, Kristofferson, Levison, Dietrich, & Ward, 1967). Using this method the de-occlusion can occur on driver demand (Tsimhoni & Green, 2001) and for fixed periods of time (Van Der Horst, 2004). In the novel MARS (Masking Action Relevant Stimuli) method, we propose to mask an action relevant element in the dynamic driving scene. The object is present, however, the crucial action relevant information is masked. While driving participants can unmask the stimulus on demand. After unmasking the stimulus there is a fixed time before the stimulus is masked again. We expect that the number of times the drivers unmask the relevant stimulus represents the degree of demand the drivers have for receiving the crucial information of the stimulus. We designed the MARS method with the goal of identifying the level of information demand drivers have for the action relevant stimulus.

1.2. Goals of the present study

The goal of the present driving simulator study is to investigate the sensitivity of information demand measured by the MARS method to different variations in the road environment. We compare the results of the MARS method to results retrieved from using the eye tracking method. As pointed out, eye tracking is an established method for measuring information demand. Additionally, we evaluate the applicability of the task for a usage in the driving simulator environment by comparing dynamic driving behaviour when to driving while using the eye tracking method. With that, we intend to ensure that the MARS method does not change driving behaviour. Finally, drivers subjectively evaluate driving with the MARS method.

[1] We thank an anonymous reviewer for mentioning this possibility.

In the driving simulator experiment, we used the traffic light as the relevant dynamic stimulus in the driving scene. The traffic light state was masked, but drivers were allowed to unmask the state to receive the information about the current phase whenever they wanted. For the driving task, participants have to demand information regarding the traffic light state to solve the driving task safely. Without knowing the current state, red light running or blocking traffic by inappropriate stops might occur. Thus, the masking is imbedded in a normal driving scene and no additional task other than driving safely needs to be instructed. We argue that with the MARS method we are able to measure the information demands that the drivers have for the traffic light state as specific action relevant element in the driving scene.

By means of the study goals, we differentiated between two main conditions: The MARS and the GAZE condition. Thereby, we compared the number of information demands drivers expressed by pressing a steering wheel button in the MARS condition with the number of fixations on the traffic light in the GAZE condition. Moreover, we introduced different factors influencing the information demands drivers might have in the driving simulator scenarios. First, different traffic light phases were introduced, as we recently demonstrated that driving behaviour differs between traffic light approaches with solid green or red traffic lights compared to transitioning red to green or green to red traffic lights in non-critical driving situations (Rittger, Schmidt, Maag, & Kiesel, submitted for publication). Second, participants either followed a lead vehicle or not. We expected that the lead vehicle's behaviour serves as a cue for the current traffic rules at the traffic light and thus changes drivers' information demands. Third, we varied visibility by introducing fog or no fog into the driving environment. Van der Hulst, Rothengatter, and Meijman (1998) have successfully used this method and we assume that visibility conditions influence drivers' information demand to relevant parts of the driving environment. We suggest that the data gained from the MARS method offers the possibility for measuring information demand because of action relevance. Based on the disadvantages for measuring information demand by eye tracking methods, we expect the MARS method to offer more accurate data than eye tracking data. Nevertheless, we expect that the number of information demands measured with the MARS method and by eye tracking in the GAZE condition are influenced qualitatively similarly by our variations of traffic and visibility.

In the following sections, we detail the methods used in our study. Following this, the results are presented and discussed. Finally, the novel MARS method is evaluated and recommendations for its future usage are provided.

2. Materials and methods

2.1. Participants

Twelve participants (four female) took part in the study and were paid for their participation. Their mean age was 26.8 (sd = 6.6) years. The mean self-reported annual driving experience was 13775 km, with 37.5% (sd = 22.3) experienced in urban environments. Participants were all well trained for driving in the static driving simulator.

2.2. Apparatus

The study took place in the static driving simulator of WIVW GmbH (Würzburg Institute for Traffic Sciences). The simulator had a 300° horizontal field of vision with five image channels each with a resolution of 1024 × 768 pixels. There were two LCD displays representing the rear view mirror and the left outside mirror as well as one LCD display for depicting the speedometer. Auditory output was presented by a 5.1 Dolby Surround System. Overall there were nine PCs (Intel Core 2 Duo, 3 GHz, 4 GB Ram, NVidia GeForce GTS 250) connected via 100 Mbit Ethernet. The update frequency was 120 Hz. The driving simulation software SILAB was used. During the experiment an experimenter observed all driver views on separate display screens and communicated with the participants via intercom. Gaze behaviour was recorded using the head mounted eye tracking system Dikablis of Ergoneers GmbH with an update rate of 25 Hz.

For the subjective evaluations when driving with the MARS method participants answered a questionnaire containing scales of six verbal categories (ranging from "do not agree at all" to "fully agree") and 16 numeric categories (0–15). The questionnaire covered items on the difficulty and disturbance of driving with the MARS method and the drivers' evaluation of the learnability of driving with the masked traffic light. Qualitative questions were asked about any strategies applied when driving with the MARS method and about situational circumstances that made driving with the MARS method easier.

2.3. Test track

The urban test track was 25 km long with approximately 600 m between two traffic light intersections. The layout of the 40 intersections was the same and only the environmental design (buildings, landmarks, plants) varied. In order to avoid giving the drivers further cues about the traffic scene, there was no other traffic than the occasionally occurring lead vehicle. There were three driving lanes in the intersection area. Drivers drove straight at each intersection and kept to the middle lane. The traffic light phases for the three lanes did not differ. Traffic light changes always occurred when the drivers passed a landmark 80 m in front of the intersection. The stop line at which drivers were supposed to stop was around 10 m in front of the traffic light, in order to make sure that drivers would be able to see the traffic light on the simulator screens when waiting at the stop line.

To analyse behaviour while approaching the intersection, the approach area of 10–100 m in front of the traffic light was divided into 9 sections, each 10 m in length. Recorded data were averaged for each 10 m segment. The 9 distance steps will be referred to by the upper borders of the respective distance section (e.g., 20 for the distance sections 10–20 m in front of the intersection). The distance section 0–10 m in front of the intersection was not considered in the analyses, because at this distance drivers already overdrove the stop line and the traffic light approach had been completed.

The traffic light phasing was according to German road traffic regulations. The red phase always ended with a combined presentation of red and amber light, whereas the green phase ended with an amber state. The amber phase as well as the combined red and amber phases lasted approximately 3.6 s. The red phase following the single amber state lasted for 32 s.

2.4. Design

The study had a full within-subject design. We compared behaviour in the MARS and the GAZE condition. In the GAZE condition, drivers' number and length of fixations on the traffic light when driving through the test track were measured while the traffic light was visible. In the MARS condition, drivers drove the same test track without eye tracking. When approaching the intersections, the traffic light was masked. Participants knew that the traffic light was masked, while the actual traffic light phasing programme was still running. In order to unmask the traffic light, drivers were instructed to press one of two possible buttons on the steering wheel. After pressing a button, the traffic light was unmasked for 800 ms (Fig. 1). Pre-tests have shown that this offered sufficient time to process the information from the traffic light. After 800 ms, the traffic light was masked again. Repeated button presses within the 800 ms unmasking interval and longer presses did not lead to longer unmasking intervals. To unmask the traffic light again after termination of the unmasking interval, the drivers had to press the button again. Participants were instructed to press the button at any time and as many times as they wanted.

Additionally, the factors traffic light phase (green, red to green, red, green to red), lead vehicle (yes, no) and fog (yes, no) were varied. The traffic light phases were either solid green or solid red, or transitioning from red to green or from green to red. The lead vehicle appeared in front of the drivers in the middle sections between two traffic light approaches and left after crossing the intersection through high acceleration. With the introduction of fog we manipulated visibility. Consequently, the traffic light was either visible at 182.3 m (sd = 40.3) or 90.9 m (sd = 7.5) in front of the intersection. The order of the factor combinations within one condition was randomised. The factor combinations with fog were repeated twice, whereas the non-fog conditions were presented three times. Overall, this resulted in a total amount of 40 intersection approaches within one condition. We assumed that drivers' information demands vary during the traffic light approaches. Thus, the influence of distance to the traffic light was investigated based on the 9 distance segments ranging from 100 to 20 m in front of the intersection.

As dependent variable, we considered the number of information demands. In the MARS condition, this was indicated by the number of button presses. In the GAZE condition, the number of fixations on the traffic light was captured. Additionally, we compared the time during which the traffic light was unmasked or fixated in relation to the total amount of time participants spent driving in each of the 9 distance segments. To determine eye fixations on the traffic light, we manually analysed the videos recorded during the experiment. Ellipses around the traffic light defined the area of interest. The size of the area of interest changed during the 100 m of approach (Fig. 2). For each 40 ms frame during the approach, eye movements were recorded. In the analyses we registered a fixation if participants fixated the area of interest for at least two consecutive frames. We did not differentiate whether participants fixated the traffic light at the top or at the right side. As soon as the participants moved their eyes away from the area of interest the fixation ended and any further fixation of the traffic light counted as a new fixation.

For the analyses of driving behaviour in the MARS and the GAZE condition, the driving simulator software recorded dynamic driving data. In particular, we investigated variations in driving speed and acceleration.

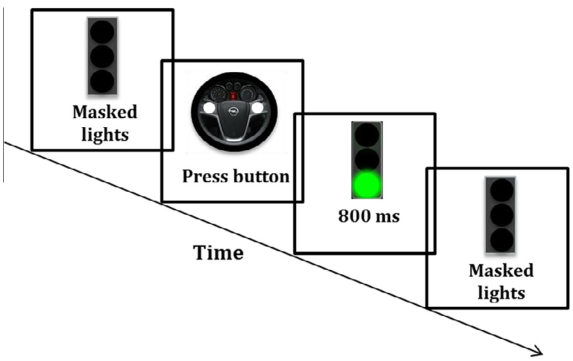


Fig. 1. Schema of the MARS method. Traffic light is masked while driving. If participants press one of two buttons located on the steering wheel (indicated by the white dots on the steering wheel) the traffic light is unmasked for 800 ms before it is masked again. Note that the traffic light is embedded in a natural driving scene.

Fig. 2. Screenshots of the traffic light as area of interest (white circles) from two different distances when approaching the intersection. The green cross with the red circle depicts the eye position as recorded by the eye tracker.

2.5. Procedure

Drivers were instructed about the objectives of the study and completed a data privacy statement. They were familiarised with the test track by driving a short practice track consisting of six intersections (with a combination of different traffic light phases, lead vehicle and fog conditions) with non-masked traffic light. Subsequently, participants drove the MARS condition and the GAZE condition as two consecutive blocks each consisting of 40 intersections. The order of the blocks was counterbalanced between participants. Participants wore the head-mounted eye tracker only in the GAZE condition. Before the GAZE condition, the eye tracking system was calibrated for each participant. Before the MARS condition, two masked intersections were presented as training to practice unmasking the traffic light by pressing the buttons on the steering wheel. After the MARS condition, drivers filled out a short questionnaire evaluating driving with the method. Overall, the experiment took about 2 h for each participant.

3. Results

For the analyses we averaged data for each intersection approach separately for all participants and for the combination of the factors MARS vs. GAZE condition, traffic light phase, presence of a lead vehicle and visibility, as well as the 9 distance sections. The reported analyses of variance (ANOVAs) were executed according to the repeated measurement design.

In the following we first report the results obtained from the comparison of information demand in terms of button presses and fixations in both experimental conditions, as well as the proportion of time spent with unmasked or fixated traffic light. To present results in a comprehensive form we report an overview of ANOVA results for each dependent variable, followed by their explanation and selected graphs. Second, we present a comparison of driving behaviour observed in the MARS and GAZE conditions. Detailed results for this section are attached in the Appendix. Third, the subjective evaluations of driving with the masked traffic light are presented.

3.1. Number of information demands

We conducted an ANOVA with the five factors condition, distance, traffic light phase, lead vehicle and fog. The dependent variable was the number of information demands. For the MARS condition this implies the number of button presses. For the GAZE condition this implies the number of fixations on the traffic light. The results of the ANOVA are presented in Table 1.

First, the number of information demands differed for the two main conditions as participants fixated the traffic light more often in the GAZE condition than they pressed the button to unmask the traffic light in the MARS condition. Information demands were more frequent as the driver neared the traffic light. The number of information demands were also higher for the traffic light phases solid red and transitioning green to red than for traffic light phases solid green and transitioning red to green. However, these main effects were all qualified by two-way, three-way and four-way interactions (see Table 1). The mean number of information demands respective to all five factors are presented in Appendix A. In the following, we decided to concentrate on the effects of condition and distance with the additional impact of traffic light phase, lead vehicle and fog, respectively.

In Fig. 3, the three-way interaction between condition, distance to the traffic light and traffic light phase is depicted. For the traffic light phases green and red to green (left graphs), there was no difference between the number of button presses and the number of fixations on the traffic light. For the traffic light phases red and green to red, the number of information demands increased as distance to the traffic light decreased. This is due to drivers fixating on the traffic light and unmasking it more often as they approached or waited at the red light. The increase was more pronounced in the GAZE condition than in the MARS condition, but was initiated at similar distances.

Fig. 4 shows the number of information demands in the MARS and GAZE conditions depending on the two factors distance to the traffic light and lead vehicle. Trivially, the number of information demands peaked earlier in the MARS and GAZE conditions when a lead vehicle was present (right graph) compared to without vehicle (left graph), because drivers had to stop further away from the intersection behind the lead vehicle. Again, the increase of information demands with

Table 1
Summary of ANOVA results for the number of information demands. Bold numbers mark significant effects.

Effect	df effect	df error	F	p	η^2_{partial}
Condition	**1**	**11**	**12.737**	**.004**	**.537**
Distance	**8**	**88**	**42.199**	**<.001**	**.793**
Lights	**3**	**33**	**89.177**	**<.001**	**.890**
Vehicle	1	11	3.318	.096	.232
Fog	1	11	1.270	.284	.103
Condition * distance	**8**	**88**	**11.268**	**<.001**	**.506**
Condition * lights	**3**	**33**	**19.991**	**<.001**	**.645**
Distance * lights	**24**	**264**	**52.901**	**<.001**	**.828**
Condition * vehicle	1	11	4.025	.070	.268
Distance * vehicle	**8**	**88**	**76.523**	**<.001**	**.874**
Lights * vehicle	**3**	**33**	**6.178**	**.002**	**.360**
Condition * fog	**1**	**11**	**14.099**	**.003**	**.562**
Distance * fog	**8**	**88**	**3.462**	**.002**	**.239**
Lights * fog	**3**	**33**	**3.296**	**.032**	**.231**
Vehicle * fog	**1**	**11**	**18.747**	**.001**	**.630**
Condition * distance * lights	**24**	**264**	**11.129**	**<.001**	**.503**
Condition * distance * vehicle	**8**	**88**	**12.912**	**<.001**	**.540**
Condition * lights * vehicle	**3**	**33**	**4.994**	**.006**	**.312**
Distance * lights * vehicle	**24**	**264**	**50.873**	**<.001**	**.822**
Condition * distance * fog	**8**	**88**	**2.861**	**.007**	**.206**
Condition * lights * fog	3	33	1.132	.350	.093
Distance * lights * fog	24	264	1.311	.156	.106
Condition * vehicle * fog	**1**	**11**	**12.319**	**.005**	**.528**
Distance * vehicle * fog	**8**	**88**	**2.709**	**.010**	**.198**
Lights * vehicle * fog	3	33	0.740	.536	.063
Condition * distance * lights * vehicle	**24**	**264**	**9.009**	**<.001**	**.450**
Condition * distance * lights * fog	**24**	**264**	**2.238**	**.001**	**.169**
Condition * lights * vehicle * fog	8	88	1.076	.387	.089
Condition * distance * vehicle * fog	3	33	1.454	.245	.117
Distance * lights * vehicle * fog	**24**	**264**	**1.943**	**.006**	**.150**
Condition * distance * lights * vehicle * fog	24	264	1.407	.102	.113

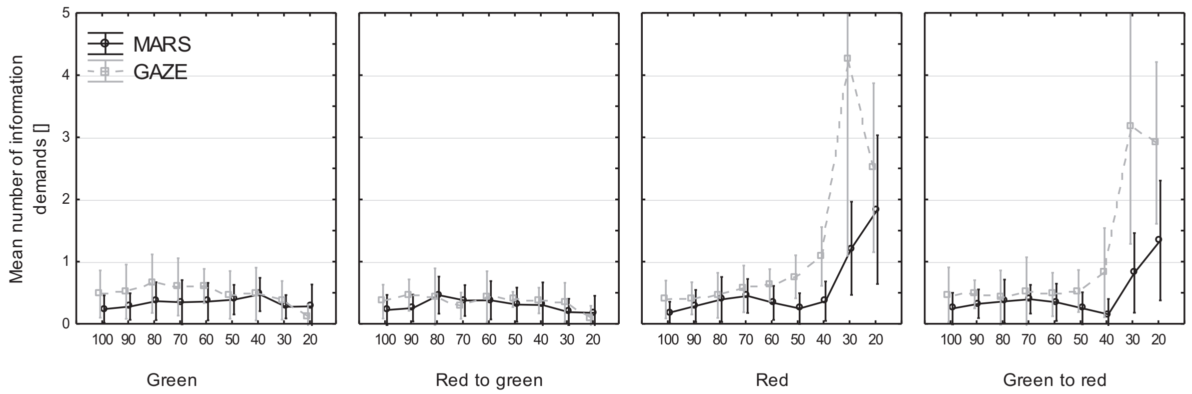


Fig. 3. Mean number of information demands depending on the factors distance to the traffic light and traffic light phase. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

decreasing distance to the traffic light was more pronounced in the GAZE condition than in the MARS condition but started at similar distances.

Fig. 5 shows the number of information demands in the MARS and GAZE conditions depending on the distance to the traffic light and fog. Without fog (left graph) the number of fixations exceeded the number of button presses regardless of distance. With fog (right graph) the number of fixations exceeded number of information demands only as distance to the traffic light decreased. Again, the increase of information demands with decreasing distance to the traffic light was more pronounced in the GAZE condition than in the MARS condition irrespective of the factor fog. Also, the increase began at similar distances.

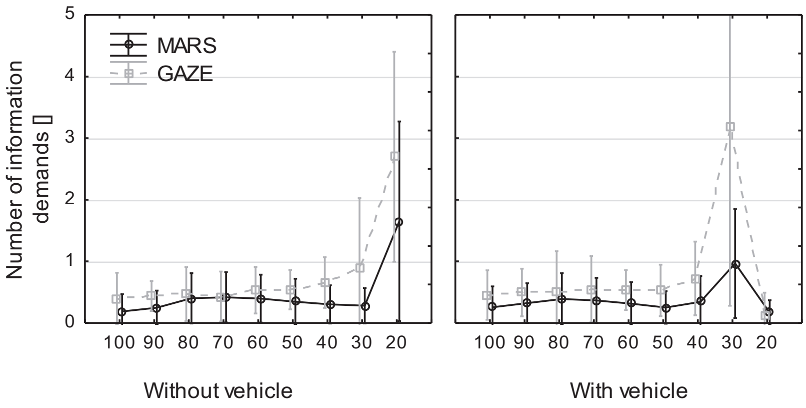


Fig. 4. Mean number of information demands depending on the factors distance to the traffic light and lead vehicle. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

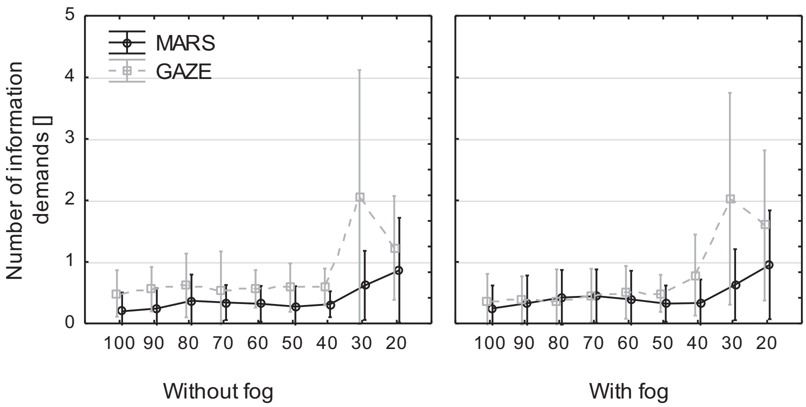


Fig. 5. Mean number of information demands depending on the factors distance to the traffic light and fog. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

3.2. Duration of information demands

In an additional analysis we investigated the proportion of time the traffic light was unmasked or fixated in relation to the total time spent for driving through each of the nine distance sections. Analogue to the previous analysis, we conducted an ANOVA with the five factors condition, distance, traffic light phase, lead vehicle, and fog. Results are presented in Table 2.

The proportion of time demanding the information from the traffic light was higher in the GAZE compared to the MARS condition, i.e., drivers fixated on the traffic light for longer periods of time in the GAZE condition than the traffic light was unmasked in the MARS condition. The duration of the unmasked and fixated intervals changed during the approach of the intersection. The information demand duration increased up to a peak at 80 m in front of the intersection, before the durations decreased to its minimum at 20 m in front of the intersection. The proportion of time spent with unmasked or fixated traffic lights was higher for traffic light approaches with solid green or solid red lights compared to approaches with red to green or green to red lights. With lead vehicle, the proportion of time fixating or unmasking the lights was lower than without lead vehicle. With fog drivers unmasked and fixated the traffic lights for longer proportions of time compared to traffic light approaches without fog.

These main effects were qualified by two-way and three-way interactions. In the following we focus on the presentation of the effects of condition and distance with the additional impact of traffic light phase, lead vehicle and fog, respectively. The mean values for the information demand duration in relation to total duration for all five factors are presented in Appendix B.

Fig. 6 shows the proportion of information demand time for the interaction between condition, distance to the traffic light and traffic light phase. In all traffic light phases, the proportion of time fixating the traffic light exceeded the proportion of unmasking time in the initial sections of the traffic light approach (100–80 m). For the traffic light phases green and red to green (left graphs) the MARS and the GAZE curves assimilated in the final sections of the traffic light approach. For the traffic light phases red and green to red, the proportion of time fixating the traffic light exceeded the proportion of unmasking time in all distance sections, with one exception at 70 m in front of the intersection in the green to red condition.

Table 2
Summary of ANOVA results for the duration of unmasking or fixation time in relation to total duration driving in each condition. Bold numbers mark significant effects.

Effect	df effect	df error	F	p	η^2_{partial}
Condition	**1**	**11**	**69.878**	**<.001**	**0.864**
Distance	**8**	**88**	**28.035**	**<.001**	**0.718**
Lights	**3**	**33**	**15.164**	**<.001**	**0.580**
Vehicle	**1**	**11**	**44.464**	**<.001**	**0.802**
Fog	**1**	**11**	**36.696**	**<.001**	**0.769**
Condition * distance	**8**	**88**	**24.259**	**<.001**	**0.688**
Condition * lights	**3**	**33**	**15.330**	**<.001**	**0.582**
Distance * lights	**24**	**264**	**8.276**	**<.001**	**0.429**
Condition * vehicle	**1**	**11**	**12.141**	**0.005**	**0.525**
Distance * vehicle	**8**	**88**	**3.967**	**<.001**	**0.265**
Lights * vehicle	**3**	**33**	**6.214**	**0.002**	**0.361**
Condition * fog	**1**	**11**	**25.760**	**<.001**	**0.701**
Distance * fog	8	88	1.463	0.182	0.117
Lights * fog	3	33	2.739	0.059	0.199
Vehicle * fog	1	11	0.001	0.980	0.000
Condition * distance * lights	**24**	**264**	**5.704**	**<.001**	**0.341**
Condition * distance * vehicle	8	88	0.869	0.546	0.073
Condition * lights * vehicle	3	33	0.425	0.737	0.037
Distance * lights * vehicle	**24**	**264**	**4.588**	**<.001**	**0.294**
Condition * distance * fog	**8**	**88**	**3.523**	**0.001**	**0.243**
Condition * lights * fog	**3**	**33**	**4.309**	**0.011**	**0.281**
Distance * lights * fog	**24**	**264**	**1.810**	**0.013**	**0.141**
Condition * vehicle * fog	1	11	1.061	0.325	0.088
Distance * vehicle * fog	8	88	0.268	0.975	0.024
Lights * vehicle * fog	3	33	0.451	0.718	0.039
Condition * distance * lights * vehicle	24	264	1.402	0.105	0.113
Condition * distance * lights * fog	24	264	0.968	0.509	0.081
Condition * lights * vehicle * fog	3	33	1.940	0.064	0.150
Condition * distance * vehicle * fog	8	88	0.908	0.448	0.076
Distance * lights * vehicle * fog	24	264	0.965	0.513	0.081
Condition * distance * lights * vehicle * fog	24	264	1.058	0.393	0.088

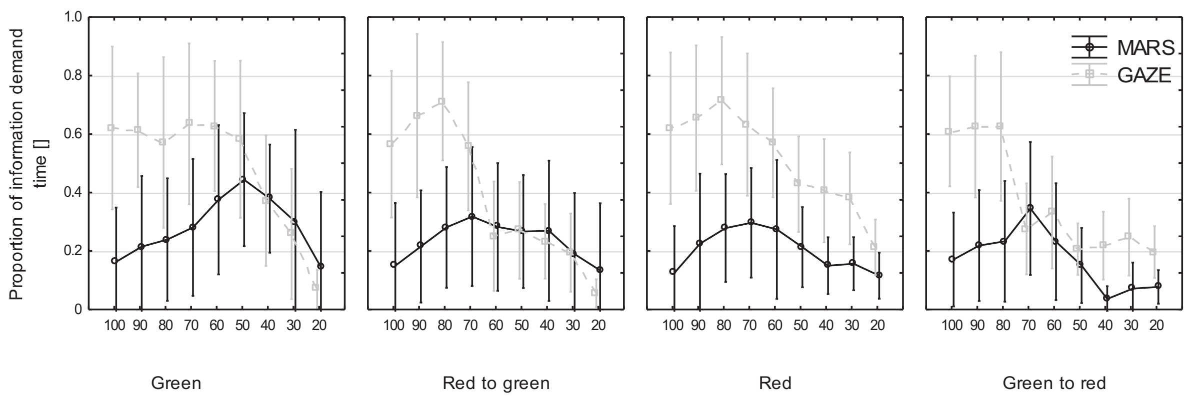


Fig. 6. Mean proportion of time demanding information depending on the factors distance to the traffic light and traffic light phase. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

Fig. 7 shows the proportion of time for demanding information in the MARS and GAZE conditions depending on the distance to the traffic light and the presence of the lead vehicle. The presence of a lead vehicle did not change the interaction between condition and distance to the traffic light significantly. In all but one condition, the proportion of time fixating on the traffic light exceeded the proportion of time driving with unmasked traffic light.

Fig. 8 shows the proportion of time drivers unmasked or fixated the traffic light depending on the factors condition, distance to the traffic light and fog. The time spent with fixating the traffic light exceeded the duration of the unmasking intervals in all factor combinations. In the final distance section (20 m), the proportion of time fixating and unmasking the traffic light assimilated. With fog drivers fixated the traffic light for longer periods of time in the initial distance sections (100–60 m) compared to approaches without fog.

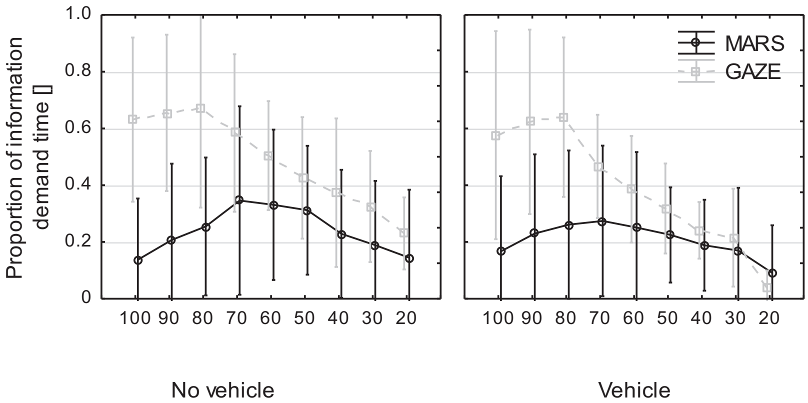


Fig. 7. Mean proportion of time demanding information depending on the factors distance to the traffic light and lead vehicle. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

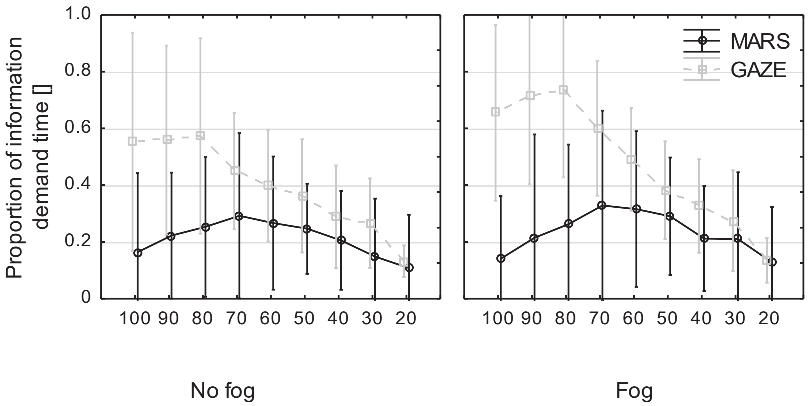


Fig. 8. Mean proportion of time demanding information depending on the factors distance to the traffic light and fog. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

3.3. Driving behaviour

In order to estimate the influence of the MARS method on driving behaviour, we compared basic driving behaviour in the MARS and the GAZE condition. We conducted an ANOVA with the factors condition, distance to the traffic light, traffic light phase, vehicle and fog. The dependent variable was the mean driving speed. All main effects except the main effect condition were significant. As expected, distance to the traffic light, traffic light phase, lead vehicle and fog had significant influences on the driving speed, $F(8,88) = 354.298$, $p < .001$, $\eta^2_{\text{partial}} = .970$, $F(3,33) = 872.790$, $p < .001$, $\eta^2_{\text{partial}} = .988$, $F(1,11) = 12.288$, $p = .005$, $\eta^2_{\text{partial}} = .528$ and $F(1,11) = 19.476$, $p = .001$, $\eta^2_{\text{partial}} = .639$, respectively. Hence, the experimental variation was successful.

There was a significant interaction between the factors condition, distance to the traffic light and traffic light phase, $F(24,264) = 13.347$, $p < .001$, $\eta^2_{\text{partial}} = .548$ (Fig. 9). When drivers approached the green or the red to green traffic light phase they drove slightly faster in the GAZE compared to the MARS condition (left graphs). In the solid red traffic light condition, drivers reduced speed earlier in the GAZE compared to the MARS condition. For an overall summary of all ANOVA effects see Appendix C.

In a further ANOVA, we investigated mean acceleration depending on the factors condition, distance, traffic light phase, lead vehicle and fog. All main effects except the main effect condition were significant. As expected, the distance to the traffic light, the traffic light phase, the lead vehicle and the fog had significant influences on acceleration, $F(8,88) = 68.563$, $p < .001$. $\eta^2_{\text{partial}} = .862$, $F(3,33) = 672.010$, $p < .001$, $\eta^2_{\text{partial}} = .984$, $F(1,11) = 168.745$, $p < .001$, $\eta^2_{\text{partial}} = .939$ and $F(1,11) = 8.631$, $p = .014$, $\eta^2_{\text{partial}} = .440$, respectively. Again, we focus on the presentation of the significant interaction of the factors condition, distance to the traffic light and traffic light phase, $F(24,264) = 8.506$, $p < .001$, $\eta^2_{\text{partial}} = .436$ (Fig. 10). For the green traffic light, there was no difference in acceleration behaviour between the MARS and the GAZE condition (left graph). When approaching the red to green

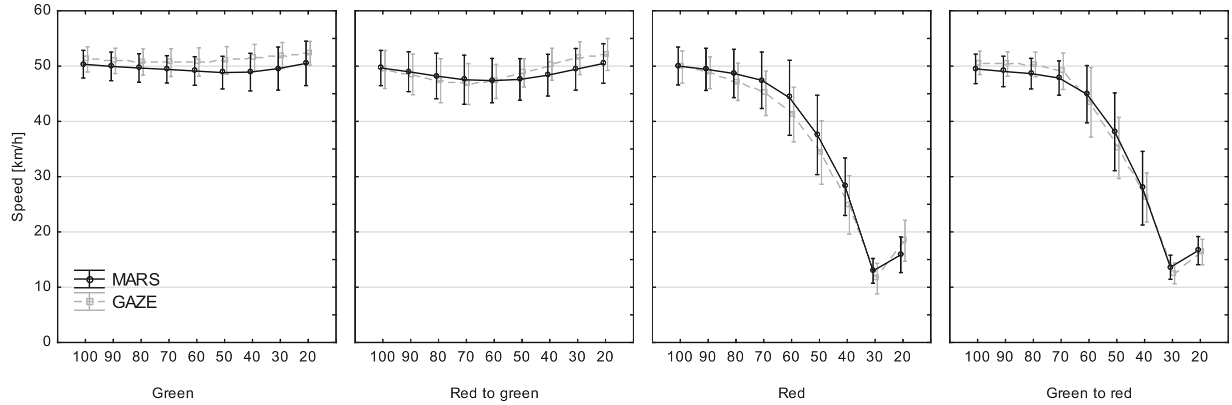


Fig. 9. Mean speed depending on the factors distance to the traffic light and traffic light phase. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

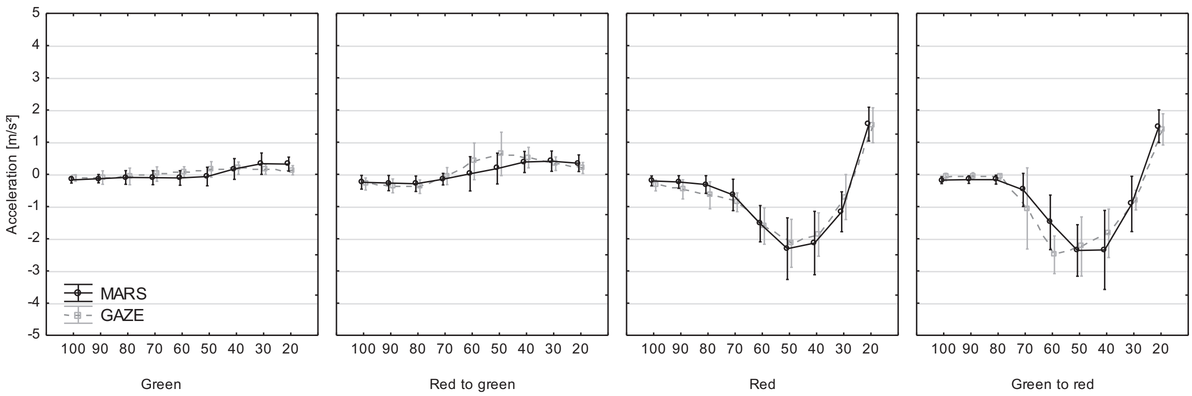


Fig. 10. Mean acceleration depending on the factors distance to the traffic light and traffic light phase. *X*-axis shows the upper boarders of the respective distance sections. Graph shows means with 0.95 confidence intervals.

traffic light acceleration in the GAZE condition slightly exceeded acceleration in the MARS condition within the distance 60 and 50 m in front of the traffic light (middle left graph). During green to red traffic light phase, drivers decelerated stronger around 70 and 60 m in front of the traffic light in the GAZE compared to the MARS condition. For an overall summary of all ANOVA effects see Appendix D.

3.4. Subjective evaluation of driving with the MARS method

The subjective evaluations of drivers when driving with the MARS method were measured on a 15-point scale with six verbal categories ranging from "I do not agree at all" to "I fully agree". As can be seen in Fig. 11, drivers expressed that driving with the masked traffic light was not difficult. Most drivers responded that they were only slightly disturbed by the masked traffic light. They perceived that driving with masked objects would be easier with increasing experience in using the MARS method.

When participants were asked about their strategy when driving with the MARS method many of them replied to have chosen strategic points in the traffic light approach at which they pressed the button (e.g., "last point when I should brake in case of red", "point when avoiding braking is possible in case the light changes from red to green"). Additionally, 8 of the 12 drivers stated that driving with the masked light was easier when there was a lead vehicle.

4. Discussion

The MARS method has been developed in order to gain knowledge about the drivers' information demand to an action relevant stimulus in a dynamic driving scene. The specific driving scenario we investigated was approaching traffic light

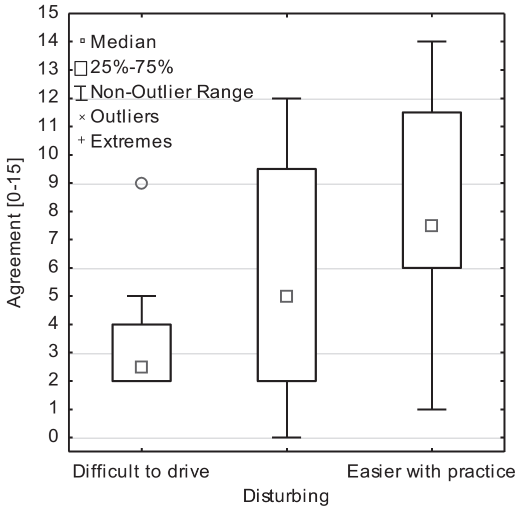


Fig. 11. Subjective evaluations of the MARS method. The questions were "it was difficult to drive with masked traffic light", "it was disturbing that the traffic light was masked" and "the more I drove with the masked traffic light, the easier was driving". Graph shows boxplots on the scale from 0 (do not agree at all) to 15 (fully agree).

intersections. We assumed that increases in driver's information demand for the traffic light are represented by increases in the number of button presses to unmask the traffic light.

We compared the results gained with the MARS method with the results gained by using eye tracking technology, as a standard method to measure drivers' fixations on an action relevant stimulus. We tested the sensitivity of the MARS method against variations in different factors that we expected to influence information demand and driving behaviour. Moreover, we investigated if driving with the MARS method changes driving behaviour compared to driving with the eye tracker and how participants subjectively evaluate driving with the masked traffic light. In the following sections, we discuss the results, evaluate the novel method and provide limitations and suggestions for its future application.

4.1. Interpretation of results and advantages of the MARS method

The number of button presses and the number of fixations on the traffic light depended on the distance to the traffic light, the traffic light phase, the presence of the lead vehicle and fog. Overall, drivers pressed the button and fixated on the traffic light more often at shorter distances to the traffic light when the traffic light was red or changed to red. The analysis of information demand durations showed that fixation and unmasking durations decreased with decreasing distance to the traffic light in all conditions. Hence, the higher number of information demands is based on longer times spent in the final distance sections when decreasing speed in preparation for a stop at the red light. As expected, when drivers observed a traffic light change the amount of time spent with unmasked or fixated traffic light decreased in comparison to the respective solid traffic light state (i.e., green compared to red to green, red compared to green to red), because drivers were able to predict traffic light phasing for the further approach more easily. Thus, when observing a phase transition, information demand decreased. The lead vehicle seemed to serve as a source of information for drivers, which was able to substitute information from the traffic light and decreased information demand for the traffic light. Information demand in terms of fixation and unmasking times was higher in the distance sections between 100 and 60 m in front of the traffic light when approaching with fog compared to approaches without fog, because at this distance the traffic light became visible for the first time in foggy conditions.

Overall, the increases in the number of information demands were more pronounced in the GAZE compared to the MARS condition. Fixations occurred more often than button presses and in the majority of distance sections and factor combinations, the time drivers spent fixating on the traffic light exceeded the duration of the unmasking intervals. Especially in the initial distance sections (100–60 m in front of the traffic light), it can be assumed that drivers fixated on the traffic light for longer periods of time than actually necessary. Interpreting the number of driver's fixations in the different conditions might overestimate the importance of the traffic light for solving the driving task. While the driving task was of low complexity and naturally the traffic light played an important role in the experimental setting, the drivers fixated on the traffic light more often than necessary to proceed through the track correctly. Consequently, the number of button presses recorded in the MARS condition might allow to better estimate the action relevance of the traffic light in the current setting. With this, the MARS method could reduce the likelihood for a "looked-but-failed-to-see" phenomenon, i.e., fixations without attention as well as fixations without action relevance, because drivers consciously decide to press the button. In these moments there might be no mind wandering while fixating somewhere (Shinar, 2008), but drivers actually process the information they receive from the traffic light. In addition, the MARS method does not allow for peripheral processing of action relevant information and it is thus not possible that drivers covertly shift attention to relevant locations. In contrast, drivers always have to demand the information they consider as currently action relevant. Depending on the research question, the data on information demand obtained with the MARS method could reveal more reliably whether and when a specific information is action relevant than data obtained by eye tracking techniques.

With the observation that drivers fixated the traffic light more often and for longer periods of time than they unmasked the traffic light state we can rebut a possible flaw of the MARS method. It might be argued that the MARS method guides drivers' attention towards the relevant object. Therefore, results could overestimate the attention to the area of interest, because drivers would attend to it more often than they would do without the emphasis by the masking. However, our findings show no hint for an increased awareness of the masked objects, because there were not more button presses than number of fixations.

The interpretation that we measure action relevance with the MARS method is supported by the free comments participants gave after performing the MARS method. Subjectively, participants mentioned that they related the information demands by pressing the button to actual driving behaviour. Hence, the traffic light was unmasked in order to receive information about the required driving behaviour at the intersection and drivers tried to base the position and timing of the button presses on the influence the information will have on their driving behaviour. Overall, the subjective evaluations participants made for using the MARS method showed that understanding the task and driving with the masked traffic light was easy and low disturbing.

The driving behaviour data indicate that the MARS method did not substantially interfere with the driving task and absolute differences in driving behaviour were small. Further research is necessary to quantify the relevance of the influence of the MARS method on driving behaviour. This is crucial in order to ensure that the primary driving task is not changed in the first place and external validity is not reduced. Concluding from the present data, we observed that drivers conducted the driving task correctly and were not irritated by the masked traffic light.

During the experimental procedure, the MARS method does not require calibration of the eye tracker. The anatomy of participants' faces or the presence of glasses do not limit the application of the MARS method. Moreover, the length of the experiment is not limited by increasing discomfort with extended use of the eye tracker equipment. For the data analyses, we interpreted the dependent variables average number of button presses and time spent with unmasked traffic lights in terms of the amount of information the driver actually needed in the specific scenarios. The button press events were recorded by the driving simulator software as additional variable in the data logs, which allows for an easy processing of the data for statistical analysis. In comparison, the preparation of eye tracking data for the statistical analyses is complex and quality of the recorded data is not consistent between participants.

4.2. Limitations and suggestions for future usage of the MARS method

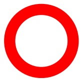
Even though the results of the study seem promising, this has only been the first study testing suitability of the MARS method for one specific type of information. Some restrictions have been identified and need to be addressed in future research.

A limitation when measuring the number of information demands by button presses in the MARS method is that it does not allow for measuring short and quick consecutive fixations. It might be that participants fixated at a traffic light several times during an 800 ms interval to gain information on the status of the traffic light and recheck. Measuring gaze behaviour might here still be a more accurate method for determining information demands of various lengths and sequences. For future evaluation of the method we recommend using eye tracking and MARS method combined in a single experimental block in order to gain further insight in the differences between number of fixations and number of button presses. The combined setting could ensure that drivers actually fixate on the traffic light when they unmask it, if unmasking occurs without drivers fixating on the traffic light or with drivers fixating multiple times during one unmasking interval. We could then verify our interpretation of increased number of button presses as increased information demand from the relevant stimulus.

The analysis showed that in specific distance sections (e.g., 20 m when approaching a green or red to green light or at around 70–60 m when traffic lights changed), the unmasking interval duration exceeded the duration of fixations. In these cases the unmasking interval might be longer than necessary and drivers overall fixate for shorter than 800 ms. It could be that in conditions in which the information demand is in general low (e.g., when the decision on how to proceed has been made), the fixed unmasking interval leads to overestimations of information demand in the MARS method. In future research, we need to determine the consistency of these effects in order to verify our interpretations and further determine the unmasking intervals. In the current study, 800 ms were defined as appropriate length of the unmasking interval, because drivers were able to process the information during that period. However, in future the unmasking interval needs to be determined depending on the context, the hypotheses on the action relevance and the dynamic characteristics of the stimulus in various situations.

Additionally, in the current study, the driving simulator scenarios were simple and of low complexity. Future studies should show how driving behaviour as primary task is influenced by the masked stimulus as soon as driving conditions are more complex. For more complex scenarios the MARS method might be less useful, because drivers might chunk infor-

Table 3
Examples of action relevant stimuli for a future usage of the MARS method.

<table>
<tr><th>Action relevant stimulus</th><th>Masked</th><th>Unmasked</th></tr>
<tr><td>Road signs</td><td></td><td>
</td></tr>
<tr><td>Speedometer</td><td>
</td><td>
</td></tr>
<tr><td>Rear view mirror</td><td></td><td></td></tr>
</table>

mation demands into frequent sequences of variable lengths. As mentioned before, these short consecutive fixations are difficult to measure by using the MARS method.

In general, we suggest that the MARS method can be used for any action relevant area of interest in the driving scene. For example, outside the vehicle we suggest using it for traffic signs, other road users like vehicles or pedestrians, following vehicles, or the visibility of entire road sections (e.g., a crossing street). Within the vehicle, future research could apply the MARS method to elements of in-vehicle displays and parts of the HMI concepts for driver assistance systems, the speedometer, indicators or rear-view mirrors (examples see Table 3).

In comparison to measuring gaze behaviour, the MARS method can only be used for assessing the relevance of a low number of specific, pre-defined stimuli. With eye tracking technology, an exploratory investigation is possible, because information demand and attention to multiple stimuli can be recorded. For the MARS method, investigating information demand for multiple stimuli requires assignment of different buttons to different stimuli or double usage of buttons for different stimuli depending on the context. Future research should show, if masking more than one stimulus is feasible for drivers, or if masking only a single action relevant stimulus is recommended.

Moreover, the ability of the MARS method to identify differences between drivers could be investigated. For example, researchers have shown that younger drivers scan the driving environment in a different way than experienced drivers (e.g., Chan, Pradhan, Pollatsek, Knodler, & Fisher, 2010). Also, it has been shown that different mental workload levels (e.g., Kaul & Baumann, 2013), physical states (e.g., fatigue) or situational circumstances (Werneke & Vollrath, 2012) influence attention in driving. Therefore, we assume the MARS method might also be sensitive to variations in these variables and that it offers the opportunity to investigate different information demand patterns between different groups of drivers or different states within a single driver.

5. Conclusions

The first study using the MARS method showed that it is an appropriate measure for drivers' information demand to a stimulus. The number of button presses to unmask a dynamic action relevant stimulus and the proportion of time driving with unmasked stimulus were interpreted in terms of the degree of information demand drivers had for the element of the driving scene. More research is needed in order to ensure validity and generalisability of the method. Depending on the research question, the MARS method might be a useful alternative to measuring gaze behaviour and could be able to complement or substitute eye tracking methods.

Acknowledgments

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Appendix

Appendix A
Mean number of information demands in different experiment conditions.

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean number of info demands []	95% confidence interval for mean	
						Lower bound	Upper bound
MARS	20	Green	Without	Without	0.194	0.027	0.362
MARS	20	Green	Without	With	0.292	0.040	0.544
MARS	20	Green	With	Without	0.306	0.076	0.535
MARS	20	Green	With	With	0.333	0.126	0.540
MARS	20	Red to green	Without	Without	0.111	−0.054	0.276
MARS	20	Red to green	Without	With	0.250	−0.003	0.503
MARS	20	Red to green	With	Without	0.139	−0.029	0.307
MARS	20	Red to green	With	With	0.208	0.045	0.372
MARS	20	Red	Without	Without	3.444	2.345	4.544
MARS	20	Red	Without	With	3.708	2.442	4.975
MARS	20	Red	With	Without	0.111	0.007	0.215
MARS	20	Red	With	With	0.083	−0.040	0.207
MARS	20	Green to red	Without	Without	2.500	1.590	3.410
MARS	20	Green to red	Without	With	2.708	1.673	3.744
MARS	20	Green to red	With	Without	0.111	−0.027	0.249
MARS	20	Green to red	With	With	0.042	−0.050	0.133
MARS	30	Green	Without	Without	0.250	0.090	0.410
MARS	30	Green	Without	With	0.375	0.136	0.614
MARS	30	Green	With	Without	0.139	0.030	0.248
MARS	30	Green	With	With	0.333	0.126	0.540
MARS	30	Red to green	Without	Without	0.167	0.024	0.309
MARS	30	Red to green	Without	With	0.167	0.010	0.323
MARS	30	Red to green	With	Without	0.167	−0.002	0.336
MARS	30	Red to green	With	With	0.250	0.084	0.416
MARS	30	Red	Without	Without	0.528	0.281	0.774
MARS	30	Red	Without	With	0.417	0.119	0.714
MARS	30	Red	With	Without	2.083	1.355	2.812
MARS	30	Red	With	With	1.833	1.138	2.528
MARS	30	Green to red	Without	Without	0.139	−0.029	0.307
MARS	30	Green to red	Without	With	0.208	−0.004	0.421
MARS	30	Green to red	With	Without	1.472	0.870	2.074
MARS	30	Green to red	With	With	1.458	0.831	2.086
MARS	40	Green	Without	Without	0.444	0.256	0.632
MARS	40	Green	Without	With	0.458	0.206	0.710
MARS	40	Green	With	Without	0.528	0.360	0.696
MARS	40	Green	With	With	0.458	0.172	0.744
MARS	40	Red to green	Without	Without	0.278	0.079	0.476
MARS	40	Red to green	Without	With	0.333	0.051	0.615
MARS	40	Red to green	With	Without	0.306	0.138	0.473
MARS	40	Red to green	With	With	0.292	0.079	0.504
MARS	40	Red	Without	Without	0.361	0.132	0.591
MARS	40	Red	Without	With	0.375	0.136	0.614
MARS	40	Red	With	Without	0.389	0.153	0.625
MARS	40	Red	With	With	0.333	−0.142	0.809
MARS	40	Green to red	Without	Without	0.083	−0.012	0.179
MARS	40	Green to red	Without	With	0.083	−0.040	0.207
MARS	40	Green to red	With	Without	0.111	−0.027	0.249
MARS	40	Green to red	With	With	0.333	−0.123	0.789
MARS	50	Green	Without	Without	0.500	0.331	0.669
MARS	50	Green	Without	With	0.458	0.206	0.710
MARS	50	Green	With	Without	0.306	0.115	0.496
MARS	50	Green	With	With	0.292	0.079	0.504
MARS	50	Red to green	Without	Without	0.278	0.101	0.455
MARS	50	Red to green	Without	With	0.292	0.006	0.578
MARS	50	Red to green	With	Without	0.333	0.131	0.535
MARS	50	Red to green	With	With	0.333	0.177	0.490
MARS	50	Red	Without	Without	0.306	0.115	0.496
MARS	50	Red	Without	With	0.375	0.136	0.614
MARS	50	Red	With	Without	0.139	−0.003	0.280
MARS	50	Red	With	With	0.167	0.010	0.323
MARS	50	Green to red	Without	Without	0.222	0.034	0.410
MARS	50	Green to red	Without	With	0.333	0.051	0.615
MARS	50	Green to red	With	Without	0.111	0.007	0.215

(continued on next page)

Appendix A (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean number of info demands []	95% confidence interval for mean	
						Lower bound	Upper bound
MARS	50	Green to red	With	With	0.333	0.086	0.581
MARS	60	Green	Without	Without	0.306	0.095	0.517
MARS	60	Green	Without	With	0.458	0.206	0.710
MARS	60	Green	With	Without	0.333	0.153	0.514
MARS	60	Green	With	With	0.333	0.086	0.581
MARS	60	Red to green	Without	Without	0.472	0.261	0.683
MARS	60	Red to green	Without	With	0.375	0.100	0.650
MARS	60	Red to green	With	Without	0.250	0.090	0.410
MARS	60	Red to green	With	With	0.417	0.189	0.645
MARS	60	Red	Without	Without	0.389	0.171	0.607
MARS	60	Red	Without	With	0.375	0.100	0.650
MARS	60	Red	With	Without	0.250	0.090	0.410
MARS	60	Red	With	With	0.333	0.086	0.581
MARS	60	Green to red	Without	Without	0.333	0.153	0.514
MARS	60	Green to red	Without	With	0.458	0.206	0.710
MARS	60	Green to red	With	Without	0.222	0.014	0.431
MARS	60	Green to red	With	With	0.375	0.136	0.614
MARS	70	Green	Without	Without	0.250	0.067	0.433
MARS	70	Green	Without	With	0.375	0.100	0.650
MARS	70	Green	With	Without	0.389	0.190	0.587
MARS	70	Green	With	With	0.375	0.100	0.650
MARS	70	Red to green	Without	Without	0.389	0.212	0.566
MARS	70	Red to green	Without	With	0.583	0.286	0.881
MARS	70	Red to green	With	Without	0.361	0.150	0.572
MARS	70	Red to green	With	With	0.167	0.010	0.323
MARS	70	Red	Without	Without	0.278	0.126	0.430
MARS	70	Red	Without	With	0.583	0.400	0.767
MARS	70	Red	With	Without	0.389	0.212	0.566
MARS	70	Red	With	With	0.542	0.256	0.828
MARS	70	Green to red	Without	Without	0.333	0.206	0.461
MARS	70	Green to red	Without	With	0.542	0.329	0.754
MARS	70	Green to red	With	Without	0.333	0.094	0.572
MARS	70	Green to red	With	With	0.375	0.136	0.614
MARS	80	Green	Without	Without	0.333	0.112	0.555
MARS	80	Green	Without	With	0.375	0.100	0.650
MARS	80	Green	With	Without	0.417	0.233	0.600
MARS	80	Green	With	With	0.333	0.086	0.581
MARS	80	Red to green	Without	Without	0.306	0.076	0.535
MARS	80	Red to green	Without	With	0.583	0.355	0.811
MARS	80	Red to green	With	Without	0.417	0.193	0.640
MARS	80	Red to green	With	With	0.542	0.290	0.794
MARS	80	Red	Without	Without	0.417	0.193	0.640
MARS	80	Red	Without	With	0.417	0.119	0.714
MARS	80	Red	With	Without	0.278	0.025	0.531
MARS	80	Red	With	With	0.458	0.246	0.671
MARS	80	Green to red	Without	Without	0.444	0.217	0.672
MARS	80	Green to red	Without	With	0.333	0.126	0.540
MARS	80	Green to red	With	Without	0.333	0.094	0.572
MARS	80	Green to red	With	With	0.333	0.126	0.540
MARS	90	Green	Without	Without	0.222	0.034	0.410
MARS	90	Green	Without	With	0.292	0.040	0.544
MARS	90	Green	With	Without	0.139	0.030	0.248
MARS	90	Green	With	With	0.458	0.172	0.744
MARS	90	Red to green	Without	Without	0.194	0.053	0.336
MARS	90	Red to green	Without	With	0.208	−0.004	0.421
MARS	90	Red to green	With	Without	0.278	0.101	0.455
MARS	90	Red to green	With	With	0.333	0.086	0.581
MARS	90	Red	Without	Without	0.306	0.138	0.473
MARS	90	Red	Without	With	0.250	0.036	0.464
MARS	90	Red	With	Without	0.306	0.095	0.517
MARS	90	Red	With	With	0.292	0.040	0.544
MARS	90	Green to red	Without	Without	0.222	0.034	0.410
MARS	90	Green to red	Without	With	0.292	0.079	0.504
MARS	90	Green to red	With	Without	0.278	0.101	0.455
MARS	90	Green to red	With	With	0.500	0.265	0.735
MARS	100	Green	Without	Without	0.333	0.112	0.555
MARS	100	Green	Without	With	0.083	−0.040	0.207

Appendix A (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean number of info demands []	95% confidence interval for mean	
						Lower bound	Upper bound
MARS	100	Green	With	Without	0.194	0.053	0.336
MARS	100	Green	With	With	0.333	0.126	0.540
MARS	100	Red to green	Without	Without	0.194	0.053	0.336
MARS	100	Red to green	Without	With	0.125	−0.019	0.269
MARS	100	Red to green	With	Without	0.194	0.027	0.362
MARS	100	Red to green	With	With	0.375	0.136	0.614
MARS	100	Red	Without	Without	0.139	0.030	0.248
MARS	100	Red	Without	With	0.167	−0.040	0.374
MARS	100	Red	With	Without	0.167	0.024	0.309
MARS	100	Red	With	With	0.250	0.036	0.464
MARS	100	Green to red	Without	Without	0.167	0.024	0.309
MARS	100	Green to red	Without	With	0.292	0.040	0.544
MARS	100	Green to red	With	Without	0.194	0.027	0.362
MARS	100	Green to red	With	With	0.333	0.177	0.490
GAZE	20	Green	Without	Without	0.111	−0.077	0.299
GAZE	20	Green	Without	With	0.167	−0.115	0.449
GAZE	20	Green	With	Without	0.083	−0.012	0.179
GAZE	20	Green	With	With	0.125	−0.072	0.322
GAZE	20	Red to green	Without	Without	0.056	−0.027	0.138
GAZE	20	Red to green	Without	With	0.167	−0.040	0.374
GAZE	20	Red to green	With	Without	0.056	−0.027	0.138
GAZE	20	Red to green	With	With	0.125	−0.072	0.322
GAZE	20	Red	Without	Without	4.750	2.784	6.716
GAZE	20	Red	Without	With	4.917	3.577	6.257
GAZE	20	Red	With	Without	0.167	−0.025	0.358
GAZE	20	Red	With	With	0.208	−0.162	0.578
GAZE	20	Green to red	Without	Without	4.458	3.179	5.738
GAZE	20	Green to red	Without	With	6.958	5.190	8.727
GAZE	20	Green to red	With	Without	0.139	−0.052	0.330
GAZE	20	Green to red	With	With	0.083	−0.040	0.207
GAZE	30	Green	Without	Without	0.417	0.129	0.704
GAZE	30	Green	Without	With	0.375	0.100	0.650
GAZE	30	Green	With	Without	0.389	0.153	0.625
GAZE	30	Green	With	With	0.333	0.051	0.615
GAZE	30	Red to green	Without	Without	0.361	0.132	0.591
GAZE	30	Red to green	Without	With	0.417	0.151	0.682
GAZE	30	Red to green	With	Without	0.306	0.095	0.517
GAZE	30	Red to green	With	With	0.292	0.006	0.578
GAZE	30	Red	Without	Without	1.639	0.591	2.687
GAZE	30	Red	Without	With	2.000	0.722	3.278
GAZE	30	Red	With	Without	6.556	4.144	8.968
GAZE	30	Red	With	With	6.833	4.181	9.486
GAZE	30	Green to red	Without	Without	1.014	0.522	1.505
GAZE	30	Green to red	Without	With	0.958	0.392	1.524
GAZE	30	Green to red	With	Without	5.750	3.534	7.966
GAZE	30	Green to red	With	With	5.000	3.694	6.306
GAZE	40	Green	Without	Without	0.500	0.194	0.806
GAZE	40	Green	Without	With	0.667	0.041	1.292
GAZE	40	Green	With	Without	0.333	0.112	0.555
GAZE	40	Green	With	With	0.417	0.151	0.682
GAZE	40	Red to green	Without	Without	0.361	0.150	0.572
GAZE	40	Red to green	Without	With	0.333	0.086	0.581
GAZE	40	Red to green	With	Without	0.389	0.237	0.541
GAZE	40	Red to green	With	With	0.417	0.189	0.645
GAZE	40	Red	Without	Without	0.806	0.599	1.012
GAZE	40	Red	Without	With	1.167	0.826	1.508
GAZE	40	Red	With	Without	1.278	0.768	1.787
GAZE	40	Red	With	With	1.083	0.681	1.486
GAZE	40	Green to red	Without	Without	0.583	0.232	0.935
GAZE	40	Green to red	Without	With	0.833	0.492	1.174
GAZE	40	Green to red	With	Without	0.500	0.222	0.778
GAZE	40	Green to red	With	With	1.375	0.209	2.541
GAZE	50	Green	Without	Without	0.361	0.150	0.572
GAZE	50	Green	Without	With	0.417	0.119	0.714
GAZE	50	Green	With	Without	0.500	0.270	0.730
GAZE	50	Green	With	With	0.583	0.286	0.881

(*continued on next page*)

Appendix A (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean number of info demands []	95% confidence interval for mean	
						Lower bound	Upper bound
GAZE	50	Red to green	Without	Without	0.333	0.206	0.461
GAZE	50	Red to green	Without	With	0.417	0.189	0.645
GAZE	50	Red to green	With	Without	0.444	0.217	0.672
GAZE	50	Red to green	With	With	0.375	0.136	0.614
GAZE	50	Red	Without	Without	0.958	0.602	1.314
GAZE	50	Red	Without	With	0.708	0.456	0.960
GAZE	50	Red	With	Without	0.861	0.583	1.139
GAZE	50	Red	With	With	0.500	0.265	0.735
GAZE	50	Green to red	Without	Without	0.639	0.392	0.886
GAZE	50	Green to red	Without	With	0.500	0.197	0.803
GAZE	50	Green to red	With	Without	0.556	0.158	0.953
GAZE	50	Green to red	With	With	0.417	0.063	0.771
GAZE	60	Green	Without	Without	0.556	0.328	0.783
GAZE	60	Green	Without	With	0.708	0.338	1.078
GAZE	60	Green	With	Without	0.667	0.367	0.966
GAZE	60	Green	With	With	0.500	0.168	0.832
GAZE	60	Red to green	Without	Without	0.333	0.112	0.555
GAZE	60	Red to green	Without	With	0.417	0.189	0.645
GAZE	60	Red to green	With	Without	0.611	0.275	0.947
GAZE	60	Red to green	With	With	0.375	0.136	0.614
GAZE	60	Red	Without	Without	0.694	0.483	0.905
GAZE	60	Red	Without	With	0.583	0.355	0.811
GAZE	60	Red	With	Without	0.583	0.311	0.856
GAZE	60	Red	With	With	0.625	0.428	0.822
GAZE	60	Green to red	Without	Without	0.556	0.295	0.816
GAZE	60	Green to red	Without	With	0.417	0.119	0.714
GAZE	60	Green to red	With	Without	0.500	0.156	0.844
GAZE	60	Green to red	With	With	0.417	0.089	0.744
GAZE	70	Green	Without	Without	0.472	0.167	0.778
GAZE	70	Green	Without	With	0.500	0.229	0.771
GAZE	70	Green	With	Without	0.611	0.252	0.970
GAZE	70	Green	With	With	0.792	0.475	1.108
GAZE	70	Red to green	Without	Without	0.222	0.057	0.387
GAZE	70	Red to green	Without	With	0.167	−0.040	0.374
GAZE	70	Red to green	With	Without	0.444	0.140	0.748
GAZE	70	Red to green	With	With	0.333	0.086	0.581
GAZE	70	Red	Without	Without	0.667	0.357	0.976
GAZE	70	Red	Without	With	0.333	0.086	0.581
GAZE	70	Red	With	Without	0.833	0.541	1.126
GAZE	70	Red	With	With	0.417	0.189	0.645
GAZE	70	Green to red	Without	Without	0.486	0.059	0.913
GAZE	70	Green to red	Without	With	0.583	0.256	0.911
GAZE	70	Green to red	With	Without	0.472	0.026	0.919
GAZE	70	Green to red	With	With	0.500	−0.025	1.025
GAZE	80	Green	Without	Without	0.639	0.361	0.917
GAZE	80	Green	Without	With	0.792	0.295	1.289
GAZE	80	Green	With	Without	0.694	0.448	0.941
GAZE	80	Green	With	With	0.458	0.088	0.828
GAZE	80	Red to green	Without	Without	0.472	0.261	0.683
GAZE	80	Red to green	Without	With	0.292	0.128	0.455
GAZE	80	Red to green	With	Without	0.778	0.204	1.351
GAZE	80	Red to green	With	With	0.208	−0.004	0.421
GAZE	80	Red	Without	Without	0.472	0.210	0.735
GAZE	80	Red	Without	With	0.208	0.045	0.372
GAZE	80	Red	With	Without	0.861	0.530	1.192
GAZE	80	Red	With	With	0.292	0.006	0.578
GAZE	80	Green to red	Without	Without	0.556	0.169	0.942
GAZE	80	Green to red	Without	With	0.333	0.051	0.615
GAZE	80	Green to red	With	Without	0.472	0.210	0.735
GAZE	80	Green to red	With	With	0.333	0.086	0.581
GAZE	90	Green	Without	Without	0.500	0.270	0.730
GAZE	90	Green	Without	With	0.500	0.117	0.883
GAZE	90	Green	With	Without	0.694	0.376	1.013
GAZE	90	Green	With	With	0.375	0.136	0.614
GAZE	90	Red to green	Without	Without	0.583	0.360	0.807
GAZE	90	Red to green	Without	With	0.250	0.084	0.416

Appendix A (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean number of info demands []	95% confidence interval for mean	
						Lower bound	Upper bound
GAZE	90	Red to green	With	Without	0.556	0.347	0.764
GAZE	90	Red to green	With	With	0.458	0.206	0.710
GAZE	90	Red	Without	Without	0.569	0.365	0.774
GAZE	90	Red	Without	With	0.208	0.045	0.372
GAZE	90	Red	With	Without	0.361	0.132	0.591
GAZE	90	Red	With	With	0.500	0.168	0.832
GAZE	90	Green to red	Without	Without	0.556	0.328	0.783
GAZE	90	Green to red	Without	With	0.333	0.126	0.540
GAZE	90	Green to red	With	Without	0.639	0.448	0.830
GAZE	90	Green to red	With	With	0.375	0.100	0.650
GAZE	100	Green	Without	Without	0.472	0.282	0.663
GAZE	100	Green	Without	With	0.375	0.136	0.614
GAZE	100	Green	With	Without	0.528	0.265	0.790
GAZE	100	Green	With	With	0.542	0.148	0.936
GAZE	100	Red to green	Without	Without	0.389	0.153	0.625
GAZE	100	Red to green	Without	With	0.208	0.045	0.372
GAZE	100	Red to green	With	Without	0.500	0.331	0.669
GAZE	100	Red to green	With	With	0.333	0.086	0.581
GAZE	100	Red	Without	Without	0.542	0.298	0.785
GAZE	100	Red	Without	With	0.292	0.040	0.544
GAZE	100	Red	With	Without	0.444	0.200	0.689
GAZE	100	Red	With	With	0.292	0.079	0.504
GAZE	100	Green to red	Without	Without	0.417	0.102	0.731
GAZE	100	Green to red	Without	With	0.458	0.142	0.775
GAZE	100	Green to red	With	Without	0.611	0.375	0.847
GAZE	100	Green to red	With	With	0.375	0.136	0.614

Appendix B

Mean proportion of information demand durations in different experiment conditions.

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean proportion of info demand duration []	95% confidence interval for mean	
						Lower bound	Upper bound
MARS	20	Green	Without	Without	0.110	−0.014	0.235
MARS	20	Green	Without	With	0.186	0.019	0.353
MARS	20	Green	With	Without	0.163	0.028	0.299
MARS	20	Green	With	With	0.119	−0.003	0.240
MARS	20	Red to green	Without	Without	0.074	−0.041	0.188
MARS	20	Red to green	Without	With	0.141	−0.020	0.302
MARS	20	Red to green	With	Without	0.118	0.001	0.235
MARS	20	Red to green	With	With	0.202	0.065	0.338
MARS	20	Red	Without	Without	0.187	0.121	0.253
MARS	20	Red	Without	With	0.193	0.122	0.263
MARS	20	Red	With	Without	0.043	−0.007	0.092
MARS	20	Red	With	With	0.040	−0.024	0.104
MARS	20	Green to red	Without	Without	0.126	0.071	0.182
MARS	20	Green to red	Without	With	0.139	0.078	0.200
MARS	20	Green to red	With	Without	0.040	−0.002	0.082
MARS	20	Green to red	With	With	0.004	−0.004	0.012
MARS	30	Green	Without	Without	0.216	0.069	0.363
MARS	30	Green	Without	With	0.338	0.139	0.536
MARS	30	Green	With	Without	0.237	0.051	0.422
MARS	30	Green	With	With	0.408	0.209	0.607
MARS	30	Red to green	Without	Without	0.147	0.035	0.258
MARS	30	Red to green	Without	With	0.252	0.054	0.450
MARS	30	Red to green	With	Without	0.148	0.003	0.292
MARS	30	Red to green	With	With	0.212	0.079	0.345
MARS	30	Red	Without	Without	0.205	0.123	0.287
MARS	30	Red	Without	With	0.217	0.110	0.325
MARS	30	Red	With	Without	0.111	0.066	0.156
MARS	30	Red	With	With	0.092	0.056	0.128
MARS	30	Green to red	Without	Without	0.055	−0.010	0.119
MARS	30	Green to red	Without	With	0.081	−0.009	0.171
MARS	30	Green to red	With	Without	0.071	0.038	0.103

(*continued on next page*)

Appendix B (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean proportion of info demand duration []	95% confidence interval for mean	
						Lower bound	Upper bound
MARS	30	Green to red	With	With	0.080	0.048	0.112
MARS	40	Green	Without	Without	0.360	0.175	0.545
MARS	40	Green	Without	With	0.421	0.263	0.579
MARS	40	Green	With	Without	0.345	0.178	0.513
MARS	40	Green	With	With	0.391	0.244	0.538
MARS	40	Red to green	Without	Without	0.248	0.103	0.393
MARS	40	Red to green	Without	With	0.274	0.116	0.432
MARS	40	Red to green	With	Without	0.269	0.116	0.422
MARS	40	Red to green	With	With	0.287	0.137	0.436
MARS	40	Red	Without	Without	0.228	0.119	0.337
MARS	40	Red	Without	With	0.201	0.060	0.341
MARS	40	Red	With	Without	0.123	0.042	0.204
MARS	40	Red	With	With	0.047	−0.003	0.096
MARS	40	Green to red	Without	Without	0.054	−0.004	0.112
MARS	40	Green to red	Without	With	0.044	−0.030	0.119
MARS	40	Green to red	With	Without	0.015	−0.009	0.040
MARS	40	Green to red	With	With	0.030	−0.006	0.067
MARS	50	Green	Without	Without	0.467	0.296	0.638
MARS	50	Green	Without	With	0.522	0.357	0.687
MARS	50	Green	With	Without	0.455	0.302	0.608
MARS	50	Green	With	With	0.331	0.180	0.483
MARS	50	Red to green	Without	Without	0.260	0.104	0.415
MARS	50	Red to green	Without	With	0.313	0.117	0.510
MARS	50	Red to green	With	Without	0.234	0.098	0.370
MARS	50	Red to green	With	With	0.259	0.157	0.360
MARS	50	Red	Without	Without	0.249	0.110	0.387
MARS	50	Red	Without	With	0.388	0.221	0.556
MARS	50	Red	With	Without	0.102	0.033	0.171
MARS	50	Red	With	With	0.113	0.008	0.218
MARS	50	Green to red	Without	Without	0.118	0.020	0.215
MARS	50	Green to red	Without	With	0.178	0.057	0.298
MARS	50	Green to red	With	Without	0.088	0.013	0.163
MARS	50	Green to red	With	With	0.218	0.090	0.346
MARS	60	Green	Without	Without	0.381	0.208	0.554
MARS	60	Green	Without	With	0.407	0.215	0.600
MARS	60	Green	With	Without	0.299	0.174	0.424
MARS	60	Green	With	With	0.413	0.221	0.606
MARS	60	Red to green	Without	Without	0.307	0.189	0.425
MARS	60	Red to green	Without	With	0.283	0.123	0.442
MARS	60	Red to green	With	Without	0.285	0.147	0.423
MARS	60	Red to green	With	With	0.254	0.112	0.396
MARS	60	Red	Without	Without	0.300	0.114	0.486
MARS	60	Red	Without	With	0.347	0.147	0.546
MARS	60	Red	With	Without	0.212	0.077	0.348
MARS	60	Red	With	With	0.237	0.046	0.428
MARS	60	Green to red	Without	Without	0.214	0.071	0.358
MARS	60	Green to red	Without	With	0.408	0.253	0.564
MARS	60	Green to red	With	Without	0.132	0.018	0.246
MARS	60	Green to red	With	With	0.174	0.065	0.282
MARS	70	Green	Without	Without	0.278	0.108	0.448
MARS	70	Green	Without	With	0.336	0.150	0.522
MARS	70	Green	With	Without	0.304	0.143	0.465
MARS	70	Green	With	With	0.205	0.082	0.329
MARS	70	Red to green	Without	Without	0.329	0.155	0.503
MARS	70	Red to green	Without	With	0.430	0.234	0.626
MARS	70	Red to green	With	Without	0.230	0.114	0.346
MARS	70	Red to green	With	With	0.282	0.135	0.429
MARS	70	Red	Without	Without	0.320	0.198	0.442
MARS	70	Red	Without	With	0.354	0.211	0.496
MARS	70	Red	With	Without	0.216	0.072	0.360
MARS	70	Red	With	With	0.296	0.099	0.493
MARS	70	Green to red	Without	Without	0.381	0.196	0.565
MARS	70	Green to red	Without	With	0.341	0.146	0.536
MARS	70	Green to red	With	Without	0.278	0.113	0.444
MARS	70	Green to red	With	With	0.381	0.170	0.593
MARS	80	Green	Without	Without	0.199	0.040	0.358
MARS	80	Green	Without	With	0.232	0.096	0.369

Appendix B (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean proportion of info demand duration []	95% confidence interval for mean	
						Lower bound	Upper bound
MARS	80	Green	With	Without	0.301	0.174	0.428
MARS	80	Green	With	With	0.224	0.074	0.375
MARS	80	Red to green	Without	Without	0.246	0.133	0.359
MARS	80	Red to green	Without	With	0.348	0.186	0.510
MARS	80	Red to green	With	Without	0.239	0.129	0.349
MARS	80	Red to green	With	With	0.291	0.159	0.422
MARS	80	Red	Without	Without	0.227	0.120	0.333
MARS	80	Red	Without	With	0.310	0.127	0.494
MARS	80	Red	With	Without	0.266	0.128	0.404
MARS	80	Red	With	With	0.310	0.145	0.476
MARS	80	Green to red	Without	Without	0.283	0.153	0.413
MARS	80	Green to red	Without	With	0.190	0.062	0.319
MARS	80	Green to red	With	Without	0.265	0.095	0.435
MARS	80	Green to red	With	With	0.194	0.069	0.319
MARS	90	Green	Without	Without	0.210	0.066	0.354
MARS	90	Green	Without	With	0.214	0.017	0.410
MARS	90	Green	With	Without	0.193	0.074	0.312
MARS	90	Green	With	With	0.243	0.056	0.429
MARS	90	Red to green	Without	Without	0.164	0.061	0.266
MARS	90	Red to green	Without	With	0.204	0.024	0.383
MARS	90	Red to green	With	Without	0.272	0.150	0.395
MARS	90	Red to green	With	With	0.223	0.066	0.379
MARS	90	Red	Without	Without	0.278	0.152	0.404
MARS	90	Red	Without	With	0.180	0.031	0.328
MARS	90	Red	With	Without	0.222	0.035	0.409
MARS	90	Red	With	With	0.220	0.047	0.393
MARS	90	Green to red	Without	Without	0.251	0.098	0.403
MARS	90	Green to red	Without	With	0.157	0.041	0.273
MARS	90	Green to red	With	Without	0.189	0.068	0.310
MARS	90	Green to red	With	With	0.278	0.098	0.457
MARS	100	Green	Without	Without	0.245	0.076	0.415
MARS	100	Green	Without	With	0.078	−0.012	0.168
MARS	100	Green	With	Without	0.130	0.024	0.235
MARS	100	Green	With	With	0.199	0.069	0.329
MARS	100	Red to green	Without	Without	0.161	0.039	0.282
MARS	100	Red to green	Without	With	0.040	−0.024	0.104
MARS	100	Red to green	With	Without	0.187	0.017	0.358
MARS	100	Red to green	With	With	0.211	0.032	0.391
MARS	100	Red	Without	Without	0.140	0.028	0.253
MARS	100	Red	Without	With	0.115	0.002	0.229
MARS	100	Red	With	Without	0.159	0.029	0.289
MARS	100	Red	With	With	0.085	0.004	0.166
MARS	100	Green to red	Without	Without	0.129	0.045	0.213
MARS	100	Green to red	Without	With	0.190	0.017	0.363
MARS	100	Green to red	With	Without	0.160	0.030	0.289
MARS	100	Green to red	With	With	0.206	0.074	0.338
GAZE	20	Green	Without	Without	0.110	0.002	0.218
GAZE	20	Green	Without	With	0.067	−0.003	0.136
GAZE	20	Green	With	Without	0.060	0.001	0.119
GAZE	20	Green	With	With	0.044	−0.020	0.108
GAZE	20	Red to green	Without	Without	0.036	−0.018	0.090
GAZE	20	Red to green	Without	With	0.097	0.026	0.167
GAZE	20	Red to green	With	Without	0.037	0.002	0.072
GAZE	20	Red to green	With	With	0.054	−0.009	0.116
GAZE	20	Red	Without	Without	0.408	0.296	0.520
GAZE	20	Red	Without	With	0.379	0.264	0.494
GAZE	20	Red	With	Without	0.033	0.006	0.061
GAZE	20	Red	With	With	0.031	−0.019	0.081
GAZE	20	Green to red	Without	Without	0.353	0.251	0.455
GAZE	20	Green to red	Without	With	0.393	0.306	0.480
GAZE	20	Green to red	With	Without	0.019	0.002	0.037
GAZE	20	Green to red	With	With	0.021	−0.008	0.049
GAZE	30	Green	Without	Without	0.378	0.251	0.505
GAZE	30	Green	Without	With	0.230	0.083	0.377
GAZE	30	Green	With	Without	0.195	0.082	0.307
GAZE	30	Green	With	With	0.231	0.062	0.401
GAZE	30	Red to green	Without	Without	0.235	0.107	0.364

(*continued on next page*)

Appendix B (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean proportion of info demand duration []	95% confidence interval for mean	
						Lower bound	Upper bound
GAZE	30	Red to green	Without	With	0.186	0.090	0.282
GAZE	30	Red to green	With	Without	0.164	0.091	0.237
GAZE	30	Red to green	With	With	0.191	0.030	0.352
GAZE	30	Red	Without	Without	0.478	0.316	0.641
GAZE	30	Red	Without	With	0.527	0.395	0.659
GAZE	30	Red	With	Without	0.229	0.177	0.281
GAZE	30	Red	With	With	0.286	0.193	0.379
GAZE	30	Green to red	Without	Without	0.231	0.125	0.338
GAZE	30	Green to red	Without	With	0.334	0.186	0.481
GAZE	30	Green to red	With	Without	0.218	0.131	0.305
GAZE	30	Green to red	With	With	0.208	0.150	0.266
GAZE	40	Green	Without	Without	0.349	0.181	0.517
GAZE	40	Green	Without	With	0.479	0.321	0.636
GAZE	40	Green	With	Without	0.357	0.195	0.518
GAZE	40	Green	With	With	0.303	0.176	0.430
GAZE	40	Red to green	Without	Without	0.191	0.083	0.299
GAZE	40	Red to green	Without	With	0.252	0.090	0.414
GAZE	40	Red to green	With	Without	0.198	0.126	0.270
GAZE	40	Red to green	With	With	0.292	0.142	0.443
GAZE	40	Red	Without	Without	0.540	0.421	0.659
GAZE	40	Red	Without	With	0.566	0.421	0.710
GAZE	40	Red	With	Without	0.255	0.165	0.345
GAZE	40	Red	With	With	0.265	0.159	0.370
GAZE	40	Green to red	Without	Without	0.310	0.209	0.412
GAZE	40	Green to red	Without	With	0.304	0.186	0.421
GAZE	40	Green to red	With	Without	0.107	0.056	0.159
GAZE	40	Green to red	With	With	0.152	0.061	0.243
GAZE	50	Green	Without	Without	0.649	0.497	0.801
GAZE	50	Green	Without	With	0.583	0.404	0.761
GAZE	50	Green	With	Without	0.507	0.338	0.676
GAZE	50	Green	With	With	0.590	0.463	0.717
GAZE	50	Red to green	Without	Without	0.222	0.125	0.320
GAZE	50	Red to green	Without	With	0.298	0.160	0.436
GAZE	50	Red to green	With	Without	0.256	0.081	0.430
GAZE	50	Red to green	With	With	0.307	0.155	0.459
GAZE	50	Red	Without	Without	0.483	0.344	0.622
GAZE	50	Red	Without	With	0.605	0.489	0.720
GAZE	50	Red	With	Without	0.307	0.232	0.381
GAZE	50	Red	With	With	0.319	0.186	0.452
GAZE	50	Green to red	Without	Without	0.331	0.229	0.434
GAZE	50	Green to red	Without	With	0.236	0.113	0.360
GAZE	50	Green to red	With	Without	0.142	0.065	0.220
GAZE	50	Green to red	With	With	0.117	0.009	0.224
GAZE	60	Green	Without	Without	0.693	0.552	0.834
GAZE	60	Green	Without	With	0.667	0.516	0.819
GAZE	60	Green	With	Without	0.542	0.392	0.692
GAZE	60	Green	With	With	0.607	0.487	0.727
GAZE	60	Red to green	Without	Without	0.203	0.082	0.324
GAZE	60	Red to green	Without	With	0.374	0.219	0.528
GAZE	60	Red to green	With	Without	0.178	0.074	0.282
GAZE	60	Red to green	With	With	0.248	0.097	0.399
GAZE	60	Red	Without	Without	0.599	0.492	0.706
GAZE	60	Red	Without	With	0.641	0.530	0.752
GAZE	60	Red	With	Without	0.390	0.230	0.550
GAZE	60	Red	With	With	0.650	0.506	0.795
GAZE	60	Green to red	Without	Without	0.386	0.224	0.548
GAZE	60	Green to red	Without	With	0.472	0.288	0.656
GAZE	60	Green to red	With	Without	0.197	0.083	0.311
GAZE	60	Green to red	With	With	0.273	0.132	0.414
GAZE	70	Green	Without	Without	0.707	0.549	0.864
GAZE	70	Green	Without	With	0.692	0.537	0.848
GAZE	70	Green	With	Without	0.570	0.403	0.737
GAZE	70	Green	With	With	0.571	0.401	0.741
GAZE	70	Red to green	Without	Without	0.537	0.340	0.734
GAZE	70	Red to green	Without	With	0.784	0.650	0.918
GAZE	70	Red to green	With	Without	0.336	0.193	0.479
GAZE	70	Red to green	With	With	0.574	0.415	0.733

Appendix B (*continued*)

Condition [MARS; GAZE]	Dist [m]	Lights [green; red to green; red; green to red]	Vehicle [without; with]	Fog [without; with]	Mean proportion of info demand duration []	95% confidence interval for mean	
						Lower bound	Upper bound
GAZE	70	Red	Without	Without	0.532	0.366	0.697
GAZE	70	Red	Without	With	0.716	0.543	0.889
GAZE	70	Red	With	Without	0.514	0.393	0.635
GAZE	70	Red	With	With	0.767	0.628	0.906
GAZE	70	Green to red	Without	Without	0.257	0.151	0.362
GAZE	70	Green to red	Without	With	0.448	0.309	0.588
GAZE	70	Green to red	With	Without	0.146	0.054	0.238
GAZE	70	Green to red	With	With	0.251	0.086	0.417
GAZE	80	Green	Without	Without	0.622	0.467	0.777
GAZE	80	Green	Without	With	0.580	0.349	0.811
GAZE	80	Green	With	Without	0.468	0.295	0.640
GAZE	80	Green	With	With	0.614	0.422	0.807
GAZE	80	Red to green	Without	Without	0.631	0.479	0.783
GAZE	80	Red to green	Without	With	0.833	0.726	0.941
GAZE	80	Red to green	With	Without	0.537	0.402	0.671
GAZE	80	Red to green	With	With	0.848	0.738	0.958
GAZE	80	Red	Without	Without	0.593	0.456	0.730
GAZE	80	Red	Without	With	0.812	0.674	0.951
GAZE	80	Red	With	Without	0.585	0.455	0.715
GAZE	80	Red	With	With	0.866	0.720	1.012
GAZE	80	Green to red	Without	Without	0.615	0.444	0.787
GAZE	80	Green to red	Without	With	0.688	0.488	0.887
GAZE	80	Green to red	With	Without	0.534	0.377	0.691
GAZE	80	Green to red	With	With	0.666	0.524	0.809
GAZE	90	Green	Without	Without	0.626	0.498	0.755
GAZE	90	Green	Without	With	0.674	0.523	0.826
GAZE	90	Green	With	Without	0.535	0.384	0.687
GAZE	90	Green	With	With	0.617	0.434	0.799
GAZE	90	Red to green	Without	Without	0.581	0.408	0.753
GAZE	90	Red to green	Without	With	0.826	0.672	0.981
GAZE	90	Red to green	With	Without	0.589	0.438	0.741
GAZE	90	Red to green	With	With	0.655	0.446	0.865
GAZE	90	Red	Without	Without	0.515	0.356	0.674
GAZE	90	Red	Without	With	0.764	0.610	0.919
GAZE	90	Red	With	Without	0.592	0.404	0.780
GAZE	90	Red	With	With	0.747	0.587	0.907
GAZE	90	Green to red	Without	Without	0.522	0.373	0.670
GAZE	90	Green to red	Without	With	0.730	0.553	0.907
GAZE	90	Green to red	With	Without	0.510	0.373	0.646
GAZE	90	Green to red	With	With	0.740	0.586	0.894
GAZE	100	Green	Without	Without	0.584	0.431	0.737
GAZE	100	Green	Without	With	0.738	0.583	0.893
GAZE	100	Green	With	Without	0.557	0.330	0.783
GAZE	100	Green	With	With	0.604	0.400	0.808
GAZE	100	Red to green	Without	Without	0.563	0.386	0.741
GAZE	100	Red to green	Without	With	0.688	0.472	0.903
GAZE	100	Red to green	With	Without	0.521	0.404	0.637
GAZE	100	Red to green	With	With	0.489	0.250	0.727
GAZE	100	Red	Without	Without	0.617	0.455	0.780
GAZE	100	Red	Without	With	0.718	0.543	0.892
GAZE	100	Red	With	Without	0.543	0.361	0.725
GAZE	100	Red	With	With	0.602	0.409	0.795
GAZE	100	Green to red	Without	Without	0.490	0.316	0.664
GAZE	100	Green to red	Without	With	0.651	0.498	0.804
GAZE	100	Green to red	With	Without	0.545	0.359	0.731
GAZE	100	Green to red	With	With	0.751	0.571	0.932

Appendix C
ANOVA results for the dependent variable speed. Bold numbers mark significant effects.

Effect	df effect	df error	F	p	$\eta^2_{partial}$
Condition	1	11	0.099	0.759	0.009
Distance	**8**	**88**	**354.298**	**<0.001**	**0.970**
Lights	**3**	**33**	**872.790**	**<0.001**	**0.988**
Vehicle	**1**	**11**	**12.288**	**0.005**	**0.528**
Fog	**1**	**11**	**19.476**	**0.001**	**0.639**
Condition * distance	**8**	**88**	**5.611**	**<0.001**	**0.338**
Condition * lights	**3**	**33**	**10.940**	**<0.001**	**0.499**
Distance * lights	**24**	**264**	**432.582**	**<0.001**	**0.975**
Condition * vehicle	1	11	2.700	0.129	0.197
Distance * vehicle	**8**	**88**	**281.542**	**<0.001**	**0.962**
Lights * vehicle	3	33	1.696	0.187	0.134
Condition * fog	1	11	2.068	0.178	0.158
Distance * fog	**8**	**88**	**4.883**	**<0.001**	**0.307**
Lights * fog	**3**	**33**	**17.823**	**<0.001**	**0.618**
Vehicle * fog	**1**	**11**	**7.698**	**0.018**	**0.412**
Condition * distance * lights	**24**	**264**	**13.347**	**<0.001**	**0.548**
Condition * distance * vehicle	**8**	**88**	**2.869**	**0.007**	**0.207**
Condition * lights * vehicle	3	33	1.303	0.290	0.106
Distance * lights * vehicle	**24**	**264**	**209.817**	**<0.001**	**0.950**
Condition * distance * fog	8	88	0.570	0.800	0.049
Condition * lights * fog	**3**	**33**	**4.550**	**0.009**	**0.293**
Distance * lights * fog	**24**	**264**	**3.466**	**<0.001**	**0.240**
Condition * vehicle * fog	1	11	0.000	0.994	0.000
Distance * vehicle * fog	**8**	**88**	**2.285**	**0.028**	**0.172**
Lights * vehicle * fog	**3**	**33**	**4.268**	**0.012**	**0.280**
Condition * distance * lights * vehicle	**24**	**264**	**1.637**	**0.034**	**0.130**
Condition * distance * lights * fog	**24**	**264**	**2.651**	**<0.001**	**0.194**
Condition * distance * vehicle * fog	8	88	1.967	0.060	0.152
Condition * light * vehicle * fog	3	33	1.589	0.211	0.126
Distance * lights * vehicle * fog	**24**	**264**	**1.873**	**0.009**	**0.145**
Condition * distance * lights * vehicle * fog	24	264	0.963	0.515	0.081

Appendix D
ANOVA results for the dependent variable acceleration. Bold numbers mark significant effects.

Effect	df effect	df error	F	p	$\eta^2_{partial}$
Condition	1	11	0.029	0.868	0.003
Distance	**8**	**88**	**68.563**	**<.001**	**0.862**
Lights	**3**	**33**	**672.010**	**<.001**	**0.984**
Vehicle	**1**	**11**	**168.745**	**<.001**	**0.939**
Fog	**1**	**11**	**8.631**	**0.014**	**0.440**
Condition * distance	**8**	**88**	**7.811**	**<.001**	**0.415**
Condition * lights	**3**	**33**	**4.957**	**0.006**	**0.311**
Distance * lights	**24**	**264**	**76.432**	**<.001**	**0.874**
Condition * vehicle	1	11	1.729	0.215	0.136
Distance * vehicle	**8**	**88**	**70.877**	**<.001**	**0.866**
Lights * vehicle	**3**	**33**	**37.122**	**<.001**	**0.771**
Condition * fog	1	11	0.529	0.482	0.046
Distance * fog	**8**	**88**	**5.463**	**<.001**	**0.332**
Lights * fog	3	33	1.974	0.137	0.152
Vehicle * fog	1	11	0.196	0.666	0.018
Condition * distance * lights	**24**	**264**	**8.506**	**<.001**	**0.436**
Condition * distance * vehicle	**8**	**88**	**3.988**	**<.001**	**0.266**
Condition * lights * vehicle	**3**	**33**	**3.285**	**0.033**	**0.230**
Distance * lights * vehicle	**24**	**264**	**49.632**	**<.001**	**0.819**
Condition * distance * fog	8	88	0.875	0.541	0.074
Condition * lights * fog	3	33	0.735	0.538	0.063
Distance * lights * fog	**24**	**264**	**3.362**	**<.001**	**0.234**
Condition * vehicle * fog	1	11	0.047	0.833	0.004
Distance * vehicle * fog	8	88	1.271	0.269	0.104
Lights * vehicle * fog	3	33	2.340	0.091	0.175

Appendix D (*continued*)

Effect	df effect	df error	F	p	$\eta^2_{partial}$
Condition * distance * lights * vehicle	**24**	**264**	**1.870**	**0.010**	**0.145**
Condition * distance * lights * fog	**24**	**264**	**1.847**	**0.011**	**0.144**
Condition * distance * vehicle * fog	8	88	2.015	0.054	0.155
Condition * light * vehicle * fog	3	33	0.746	0.532	0.064
Distance * lights * vehicle * fog	**24**	**264**	**1.722**	**0.022**	**0.135**
Condition * distance * lights * vehicle * fog	24	264	0.455	0.988	0.040

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