

# Driving experience matters! Comparison of experienced and inexperienced drivers in driving situations of varying complexity.

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## Abstract

Studies have shown that competences as they are acquired usually pass through knowledge-, rule-, and skill-based stages (Rasmussen, 1987). As the most advanced level of competence has been reached reactions become widely automatic, demanding comparatively low resources. Consequently, additionally available resources can be used to improve performance in complex situations. In a simulator study we compared driving performance and workload of drivers with different skill levels in situations that varied in complexity.

Results showed that drivers were able to adapt driving behavior and workload to roadways of increasing complexity. Differences were observed with experienced drivers varying their speed to a greater extent than their inexperienced counterparts. An analysis of eye movement did not show such differences. Contrary to our expectations, not driving experience but only roadway complexity had an impact on mental workload.

Results indicate that drivers of different skill levels apply their knowledge to a different extent. Largely automatic and appropriate vehicle operation skills need time to develop whereas adequate visual scanning is likely to occur already at an early level of skill acquisition.

## Theory

Maneuvering a vehicle, particularly in dynamic and dense traffic, is a highly complex task requiring well developed skills. Complex tasks such as controlling a vehicle can be described in terms of Rasmussen's (1987) model of human control and behavior including the knowledge-, rule-, and skill-based framework. With experience, behavior control processes move from a knowledge-based level and a rule-based level towards a skill-based level. Cognitive control and mental workload required for the operation continuously decrease and fewer attentional resources are required. Thus, a larger amount of available resources may be allocated to other relevant objects, such as neighboring traffic. This might result in a better handling of complex traffic situations. The aim of the present study was to compare the driving behavior of differently skilled drivers in traffic situations of increasing complexity.

Several previous studies investigated both driving experience and roadway complexity. Patten, Kircher, Ostlund, Nilsson, and Svenson (2006) showed that inexperienced drivers had longer reaction times to a peripheral stimulus than experienced drivers. Additionally, in both groups workload increased when encountering unexpected complex traffic situations. Due to less automatic vehicle operation skills, inexperienced drivers rated cognitive workload higher compared to more experienced drivers.

Delhomme and Meyer (1998) varied roadway complexity by manipulating the presence of people and vehicles at different road crossings. Depending on roadway complexity, experienced drivers showed a larger variance in speed regulation than inexperienced drivers.

Further studies examined the influence of experience on eye movement measures while driving through traffic situations of different complexity. Experienced drivers showed a greater variance of fixations on the horizontal axes (Crundall & Underwood, 1998). According to the type of road, experienced drivers selected appropriate visual strategies. By contrast, novice drivers were not able to apply flexible strategies to changing road demands.

The present study investigated the influence of driving experience and traffic situations of different complexity on workload, driving behavior, and eye movement. According to previous studies, we hypothesized that both driving experience and roadway complexity would be important factors when measuring behavior while maneuvering a vehicle. Additionally, we expected to find differences between inexperienced and expert drivers encountering various changes in traffic.

## Method

Forty-five participants (23 inexperienced drivers, 22 expert drivers) took part in the experiment. The inexperienced drivers with a mean age of 26.3 years had held their driver's license for about 7.8 years and had driven 8,404 km on average. The 22 experts were bus drivers who were employed by local public transportation agencies. Their mean age was 42.3 years and they had held their drivers' license for around 30 years. The median of kilometers driven was 300,000 km.

We used the STISIM Drive driving simulator. A head-mounted eye-tracking system (SMI) measured eye movement behavior. Workload data were collected by Schiebl's (2007) workload measurement scale.

The simulation track included six intersections of different complexity. The complexity was manipulated by different numbers (two vs. four vs. six objects) of objects (e.g. pedestrians, cars) that were part of the traffic situation at the same time. In addition, the relevance of these objects for traffic safety varied. Thus, relevant (e.g. walking pedestrian on the sidewalk) and less relevant traffic objects (e.g. walking pedestrian on sidewalk behind railing) were included.

While driving, both eye movement and driving behavior were recorded simultaneously. Afterwards, participants watched their driving records in playback mode. Occasionally, on predetermined track positions, the recording was interrupted and participants evaluated their workload (Schiebl, 2007).

## Results

To test the influence of drivers' experience and traffic complexity on driving behavior and workload we calculated multifactorial ANOVAs for repeated measures for all dependent variables. When the homogeneity of correlations between the values of all pairs of the conditions was violated we used the Huynh-Feldt correction. Eye movement data of four inexperienced drivers could not be analyzed due to technical problems during data recording.

### Influence of drivers' experience

A large difference between inexperienced and experienced drivers was found for the standard deviation of speed (see Fig. 1 and 2). Inexperienced drivers varied more in their speed ( $M=0.49$  km/h,  $SD=0.34$ ) than expert drivers ( $M=0.75$  km/h,  $SD=0.68$ ). The result of the ANOVA showed a significant main effect of experience,  $F(1, 43) = 8.14$ ,  $p = .007$ ,  $\eta_p^2 = 0.16$ . No significant effect of experience was found in the proportion of fixation duration that was used to fixate objects on the horizontal or vertical plane (see Tab. 1). In addition, inexperienced drivers rated their workload slightly higher ( $M=5.54$ ,  $SD=2.67$ ) than experts ( $M=5.28$ ,  $SD=2.96$ ). That difference did not prove to be statistically significant.

### Complexity

The complexity of the traffic situations was manipulated by the number and relevance of dynamic objects. Workload increased with an increasing number of objects. In situations with two objects the mean value was 4.48 points ( $SD=2.34$ ). Workload increased up to 5.40 points

( $SD=2.62$ ) in situations with four objects and with 6.40 points ( $SD=3.11$ ) the workload rating reached the maximum in situations with six objects. Between different numbers of objects we found a significant and strong difference effect,  $F(1.81, 77.93)=37.23, p<.001, \eta^2_p=0.46$ .

The different relevance levels of objects also influenced the rated workload. In situations including relevant objects participants rated workload significantly higher than in situations with less relevant, dynamic elements ( $F(1, 43)=39.03, p<.001, \eta^2_p=0.48$ ). There was an interaction between number and relevance of objects. Workload increased more with an increasing number of relevant objects than with an increasing number of less relevant objects,  $F(1.90, 81.85)=13.24, p<.001, \eta^2_p=0.24$ .

Figure 1 and 2 show that complexity also influences the standard deviation of speed. There was a significant main effect of the number of objects ( $F(1.37, 58.70)=24.19, p<.001, \eta^2_p=0.36$ ) and of relevance of objects,  $F(1, 43)=19.69, p<.001, \eta^2_p=0.31$ . Furthermore, a two-way interaction between the number and relevance of objects reached statistical significance,  $F(1.69, 72.15)=11.65, p<.001, \eta^2_p=0.21$ .

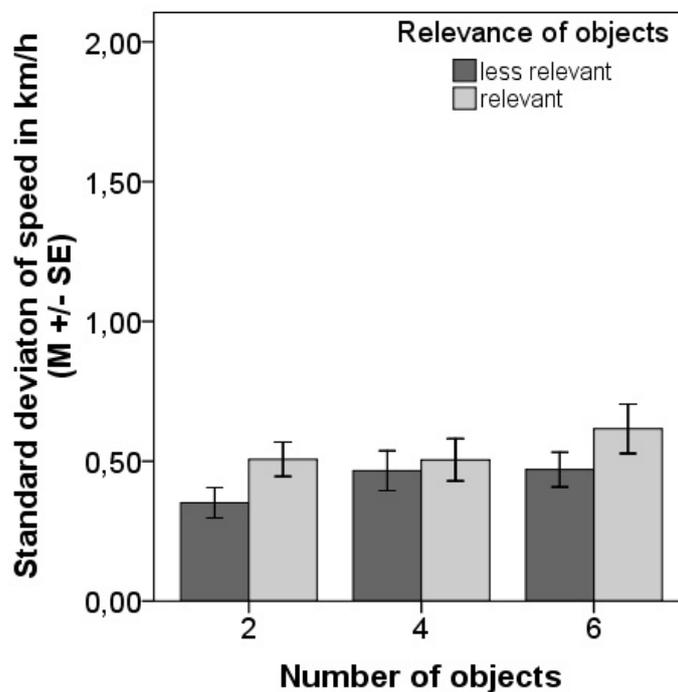


Fig.1: Mean standard deviation of speed (+/- standard error SE) per condition for inexperienced drivers and for the variables number and relevance of objects.

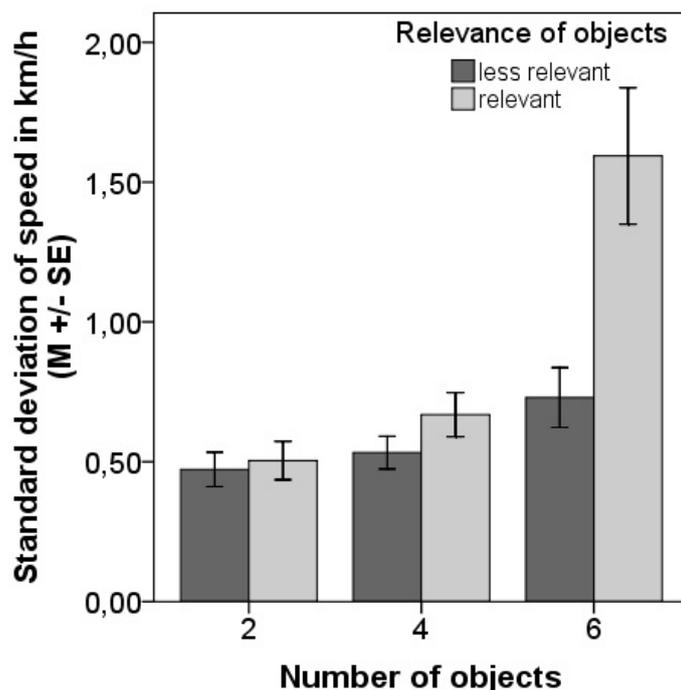


Fig.2: Mean standard deviation of speed (+/- standard error SE) per condition for expert drivers and for the variables number and relevance of objects.

Participants looked at dynamic elements in the horizontal plane with a higher proportion of fixation duration when situations included a higher amount of objects and/or more relevant objects. Regarding fixations on objects in the vertical plane, the proportion of fixation duration decreased (see Tab. 1). There was a significant main effect of number of objects for fixations on the horizontal plane ( $F(2, 78)=90.76, p<.001, \eta^2_p=0.70$ ) and for fixations on the vertical plane,  $F(1.55, 59.04)=10.92, p<.001, \eta^2_p=0.22$ . The variable relevance had a partial influence on eye movement behavior (horizontal:  $F(1, 39)=9.57, p=.004, \eta^2_p=0.20$ , vertical: n.s.). The two-way interactions between number and relevance of objects also proved to be significant (horizontal:  $F(1.99, 77.63)=12.75, p<.001, \eta^2_p=0.25$ , vertical:  $F(1.53, 58.31)=8.43, p=.002, \eta^2_p=0.18$ ).

### Experience and complexity

The analyses of the standard deviation of speed showed two significant two-way interactions (Fig. 1 and 2). Experience interacted significantly with the variable number of objects ( $F(1.37, 58.70)=13.36, p<.001, \eta^2_p=0.24$ ) and relevance of objects,  $F(1, 43)=4.99, p=.031, \eta^2_p=0.10$ . Furthermore, we found a significant three-way interaction between number, relevance, and experience,  $F(1.68, 72.15)=9.68, p<.001, \eta^2_p=0.18$ . When analyzing eye movement data only a few interactions were significant. Relating to the proportion of fixation duration that was used to fixate the objects on the horizontal plane, number of objects and experience interacted significantly,  $F(2, 78)=5.50, p=.006, \eta^2_p=0.12$ . Additionally, the analysis of the three-way interaction between number, relevance, and experience led to a significant result,  $F(1.99, 77.63)=4.16, p=.019, \eta^2_p=0.10$ . For the vertical gaze behavior, the interaction between relevance and experience was found to be significant,  $F(1, 38)=4.46, p=.041, \eta^2_p=0.10$ . Regarding drivers' workload there was no significant interaction between experience and complexity.

Tab.1: Sample means and standard deviations of the proportion of fixation duration (in %) that was used to measure fixations of objects on the horizontal or vertical plane, for each single condition, for inexperienced and expert drivers

Condition		Horizontal				Vertical			
Num	Relev	Inexperienced <sup>b</sup>		Experts <sup>c</sup>		Inexperienced <sup>b</sup>		Experts <sup>c</sup>	
		M	SD	M	SD	M	SD	M	SD
2	R	31.5 5	10.1 3	36.0 9	13.7 1	37.4 1	12.6 1	38.7 1	12.4 1
	LR	29.3 8	14.2 0	29.5 1	15.1 4	46.2 0	15.2 6	44.2 2	17.9 5
4	R	36.7 0	11.8 7	38.0 5	14.9 5	40.2 9	17.0 5	44.9 8	18.2 5
	LR	35.4 1	12.7 1	43.5 3	13.8 1	38.4 7	15.7 1	36.4 4	14.4 2
6	R	45.6 8	14.4 7	54.9 3	14.7 1	31.6 1	13.7 0	31.9 4	14.0 1
	LR	36.5 7	12.5 7	46.9 4	14.5 8	41.1 5	14.4 9	34.4 2	15.7 5

*Comments.* *M*= mean, *SD*= standard deviation, R = relevant objects, LR = less relevant objects.

<sup>a</sup> *n* = 41 for each condition. <sup>b</sup> *n* = 19 for each condition. <sup>c</sup> *n* = 22 for each condition.

## Discussion

According to our expectations workload, variation in speed and fixation duration on the horizontal plane increased in parallel with the complexity of the traffic situation. Regarding the eye movement on vertical plane, fixation duration decreased. The observed driving behavior provides support for previous studies (e.g. Delhomme & Meyer, 1998; Patten et al., 2006). Results indicate that experienced drivers operate their vehicle and scan neighboring traffic depending on the number of objects and the objects' safety relevance. Regardless of people's skill acquisition, considerable rule-based knowledge is being applied when experiencing everyday traffic situations. However, various complex situations occupy various mental capacities of working memory. Therefore, mental capacity should not be overloaded. Road design might initially help balance mental capacity and secondly help trigger important relevant knowledge.

When drivers operated their vehicle, differences were observed as a function of driving experience and roadway complexity with experienced drivers varying their speed to a greater extent than their inexperienced counterparts. Operating a vehicle in traffic of different complexity seems to be a rather skill-based, automatic behavior (Rasmussen, 1987). Regarding speed variations we were able to show that inexperienced drivers can be allocated to the knowledge- or rule-based level of skill acquisition. They were not yet able to apply knowledge about different traffic situations to their speed adjustment behavior. Reactions of skilled drivers operating on a skill-based level of performance are able to react appropriately due to automatic behavior.

However, a comparison of experienced and inexperienced drivers did not reveal differences in all cases. In general, both groups glanced at objects on the horizontal and vertical plane to a similar extent, indicating that similar visual scanning shows similar attention allocation. Results of eye movement measures suggested that inexperienced drivers are likely to apply rule-based knowledge to visual scanning of neighboring traffic. Although for both groups glance behavior data did not reveal differences due to inattentional-blindness, conclusions about actual attention allocation to objects that are encountered while driving can not be drawn (Strayer, Drews, & Johnston, 2003). According to Ericsson and Kintsch (1995) automatic reactions result in decreasing mental workload. In contrast to our expectations, the results do not indicate that skilled drivers experience less workload in general. This is surprising, given that we were expecting a rather large effect by comparing high versus low mileage drivers. Those expectations were drawn from Tränkle and Beiler's (1996) arguments that a bus driver's job is especially demanding. We assume that roadway complexity such as was used in the present study was not complex enough to reveal differences. For follow-up studies we recommend continuing to increase traffic complexity (e.g. to let oncoming traffic pass when making a left turn) in order to investigate workload assessments. The procedure used for varying traffic complexity seems to be a helpful and important tool.

## Conclusion

Well-developed driving and glance behavior is necessary in order to react to relevant information or hazards. As drivers become more experienced they adapt their driving behavior to a greater extent depending on the complexity of the given traffic situation. Thus, experience does matter for applying rule-based knowledge while operating the car. However, we were not able to fully answer the question whether high vs. low skilled drivers differ in the extent to which they apply their knowledge to scan objects in neighboring traffic.

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