The role of self-regulation in the context of driver distraction: A simulator study

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ABSTRACT

Objective: There is considerable evidence for the negative effects of driver distraction on road safety. In many experimental studies, drivers have been primarily viewed as passive receivers of distraction. Thus, there is a lack of research on the mediating role of their self-regulatory behavior. The aim of the current study was to compare drivers’ performance when engaged in a system-paced secondary task with a self-paced version of this task and how both differed from baseline driving performance without distraction.

Methods: Thirty-nine participants drove in a simulator while performing a secondary visual–manual task. One group of drivers had to work on this task in predefined situations under time pressure, whereas the other group was free to decide when to work on the secondary task (self-regulation group). Drivers’ performance (e.g., lateral and longitudinal control, brake reaction times) was also compared with a baseline condition without any secondary task.

Results: For the system-paced secondary task, distraction was associated with high decrements in driving performance (especially in keeping the lateral position). No effects were found for the number of collisions, probably because of the lower driving speeds while distracted (compensatory behavior). For the self-regulation group, only small impairments in driving performance were found. Drivers engaged less in the secondary task during foreseeable demanding or critical driving situations.

Conclusions: Overall, drivers in the self-regulation group were able to anticipate the demands of different traffic situations and to adapt their engagement in the secondary task, so that only small impairments in driving performance occurred. Because in real traffic drivers are mostly free to decide when to engage in secondary tasks, it can be concluded that self-regulation should be considered in driver distraction research to ensure ecological validity.

Introduction

Driver distraction and driver inattention have been known as relevant road safety issues for decades (Treat et al. 1979). There is considerable evidence that they are major contributing factors in car crashes (Gordon 2008; Kubitzki 2011; Ranney 2008; Stutts et al. 2005). Following Regan et al. (2011), driver distraction is a specific form of driver inattention. Driver inattention is defined as “insufficient, or no attention, to activities critical for safe driving” (Regan et al. 2011, p. 1775), whereas driver distraction is described as “the diversion of attention away from activities critical for safe driving toward a competing activity” (Regan et al. 2011, p. 1776). With the increasing use of technical devices in cars, new sources of distraction are emerging. During the last decades, intensive research was carried out in this field. Various types of studies have been conducted, including crash studies, experimental and driving simulator studies, as well as real-life (field) observations and behavioral studies.

The effect of driver distraction was investigated in a number of accident studies. These studies found risk increases of factors between 1.3 to 5.6 due to the use of mobile phones (McEvoy et al. 2005; Redelmeier and Tibshirani 1997; Violanti and Marshall 1996). Results of naturalistic driving studies indicate even higher crash risks when distracted, strongly depending on the specific task (Dingus et al. 2006; Fitch and Hanowksi 2011; Fitch et al. 2013; Klauer et al. 2014).

Experimental studies are often used for the controlled investigation of driver distraction. In experiments (in real vehicles or in driving simulators) the driver performs specific secondary tasks and the driving performance is recorded and analyzed. The main results of numerous studies can be summarized as follows: increased response times to unexpected traffic events (Drews et al. 2009; Hosking et al. 2009; Lee 2008; Regan and Hallett 2011); increased variability of speed (Drews et al. 2009; Horrey and Wickens 2006; Regan and Hallett 2011); increased variability in lateral position and poorer lane keeping (Drews et al. 2009; Hosking et al. 2009; Regan and Hallett 2011); greater variations in headway to vehicles in front (Hosking et al. 2009; Regan and Hallett 2011); and greater amount of relevant visual information and objects missed or not looked at (Harbuk et al. 2007; Strayer et al. 2011).

Though in most studies mandatory system-paced distraction was used, only few have taken the drivers’ strategical and tactical planning into account. In many studies, rigid experimental block designs were used, which prompt the drivers to engage in specific secondary tasks in predefined sections of the track. This may cause the participants to perform secondary tasks that...
they would generally not engage in voluntarily or only do so in less-demanding traffic situations. However, without consideration of this self-regulatory behavior, the reported performance decrements may lack ecological validity.

Following Young et al. (2008), self-regulation in the context of driver distraction can be understood as the way drivers “adjust their driving behavior in response to changing or competing task demands to maintain an adequate level of safe driving” (p. 336). These authors point out that self-regulatory behavior occurs at any level of the driving task identified by Michon (1985): strategic, tactical, and operational. Rauch et al. (2009) postulated a 3-level model of situational awareness for the underlying mental processes. Hence, at a strategic level it is determined whether and in what manner a driver will generally deal with secondary tasks. Whether the current driving situation allows for an engagement in a secondary task (tactical adaptation) is continually assessed during the trip. Finally, while performing secondary tasks the traffic situation is constantly monitored with short glances and the task is interrupted if necessary (operational adaptation).

In fact, self-report studies show that drivers do not perceive those secondary tasks they perform while driving in everyday life as being dangerous (Huemer and Vollrath 2012). Most drivers seem to believe that they have the skills to drive safely even while performing secondary tasks. In a simulator study, Metz et al. (2011) showed that drivers are able to successfully apply compensation strategies in dealing with secondary tasks. When the participants had a choice, they worked on a secondary task mainly in noncritical situations, and during task engagement they continuously monitored traffic with short control glances. Consistent with those results, Liang et al. (2015) found that drivers adjusted time-sharing behavior according to driving demands when performing secondary tasks while driving on a test track. Further evidence for self-regulation in dealing with secondary tasks comes from a naturalistic driving study by Tivesten and Dozza (2015), which showed that experienced drivers used information about current and upcoming driving demands to decide when to engage in visual–manual tasks.

However, it is not without controversy to what extent drivers choose times of low demand in the driving task to perform secondary tasks. In a closed track study by Horrey and Lesch (2009), drivers were well aware of the demands of specific traffic situations, but this had little influence on performing the secondary task. It was performed in both low- and high-demand driving situations. Consistent with this finding, Liang et al. (2015) showed that drivers did not wait for areas with lower driving demands when initiating a reading task. On the other hand, drivers avoided transitions from low to high demands when engaging in the secondary task.

The extent to which drivers are actually able to adapt to the situational circumstances while performing secondary tasks and what impact this has on driving performance was addressed in the current simulator study. For this purpose, one group of drivers was free to choose when to engage in a secondary task (self-regulation group) and another group went through a standard block design, in which they were prompted to perform the task in predefined situations (block design group). In contrast to previous self-regulation research (e.g., Liang et al. 2015; Metz et al. 2011), the secondary task was not only offered in defined critical and noncritical driving situations but at any time over the whole track. Using this approach we expected to obtain results closer to real-world driving. It was assumed that drivers would be able to adapt their engagement in the secondary task to different driving demands and that due to this self-regulation, performance decrements would be smaller in the self-regulation group than in the block design group.

Method

Participants

For this study, 39 participants (27 men, 12 women) were recruited from a study panel and agreed to participate on a voluntary basis. All participants were of young or middle age (mean age = 29 years, SD = 7.09, range 22–44) and had successfully completed a familiarization training in the simulator. Participants had an average of 10.13 years of driving experience (SD = 7.23) and their average annual mileage was 12,607 km (SD = 9,177).

The participants were randomly assigned to either the block design condition or the self-regulation condition. As expected, there were no significant group differences for age, F (2, 36) = 0.11, P = .90, nor for annual mileage, F (2, 36) = 0.75, P = .48.

BASt driving simulator

The experiment took place in the driving simulator of the Federal Highway Research Institute (BASt). The fixed-base driving simulator has a projection system that displays a 180° field of view to the front and to the side (Figure A1, see online supplement). The dynamics model simulates the behavior of a midsize car with automatic transmission. In this study, the touch display in the center console was used for presentation of the secondary task.

Simulated test track

The track had a total length of about 15.5 km. Within the first 11 km it led through rural roads. Then it passed into an urban area. Navigation through the track was always defined by the traffic routing. The track contained a number of specific traffic situations, which differed in driving demands (Table A1, see online supplement, or Table 1).

The test track contained situations for the investigation of self-regulation behavior in traffic situations representing primarily one of 3 main requirements in driving: lateral control, longitudinal control, and reaction time. For the statistical analysis of driving performance one traffic situation for each requirement was selected: “curvy forest road” representing lateral control, “car following” representing longitudinal control, and the first situation in which a pedestrian suddenly crosses the road representing the driver needing to react to a sudden event.

Secondary task

In order to simulate demands that are common to modern in-vehicle information and communication systems, a visual–manual task was implemented. Number sequences of 8
random digits, divided into 2 blocks of 4 digits, were presented on the touch panel mounted in the center console (Figure A2, see online supplement). The participants were instructed to enter these numbers quickly and accurately. For this purpose, a virtual numeric keypad was used. The digits entered by the subjects were shown below the given number sequence. Numbers entered incorrectly could be deleted with a backspace key and then reentered.

In the block design group the participants had a time limit of 10 s for each 8-digit sequence. The remaining time was shown by a progress bar. When the given number sequence was entered or the time limit was exceeded, the next task started immediately, which was indicated by a beeping sound. Thereby, the drivers were continuously prompted to engage in the secondary task. The reason for using such a forced-paced task was that the drivers of the block design group should be continuously distracted in a defined area of the test track. The highly distracted driving was compared to the driving performance of the self-regulation group and with nondistracted driving.

In the self-regulation group, the participants performed the same tasks but without a time limit. They were free to decide when to work on the secondary task and could adapt their workload to the demands of the particular traffic situation. In both groups the drivers were instructed to drive safely at all times but also to solve as many digit-entry tasks as possible.

**Arrangement of task blocks**

Two parallel groups were formed for the block condition. In both groups the secondary task was presented during 50% of the total distance driven. Between 2 task blocks, there was always a resting period in which the participants should fully concentrate on driving. This was done to avoid the occurrence of exhaustion or fatigue due to the high-demand forced-paced task. Each task block contained a specific relevant driving situation. The distribution of the secondary task blocks was exactly inverse in the 2 groups (Table 1). Therefore, for every area of the test track, data with and without distraction were available and could be compared with the performance of the self-regulation group. In the self-regulation group, the secondary task was unlocked over the entire track and could be performed whenever the drivers felt comfortable performing it.

**Procedure**

After a broad explanation of the study’s background, the subjects completed a brief driving practice. This included a free driving session and braking and evasive maneuvers were practiced to ensure that the subjects were prepared for the demands of the test track. Next, the secondary task was described and the subjects had the opportunity to practice the task without driving. Then the secondary task was practiced during driving until the subjects felt familiar with the task.

After an optional break, the experimental drive began, which took about 20 min. Beforehand, the participants were instructed to drive safely at all times but also to solve as many digit-entry tasks as possible. Driving data were recorded during the experiment. After completing the drive, the participants were asked to fill out a brief questionnaire about their experiences during the experiment.

**Experimental design and statistical analyses**

In this study, a between-subjects design with 3 experimental groups was used. As described in the Arrangement of Task Blocks section, there were 2 block design groups and a self-regulation group. In each specific situation they represent the factor levels distracted, not distracted, and self-regulation. For statistical testing of group differences one-way analyses of variance (ANOVAs) were calculated for individual traffic situations. These were supplemented by analyses of covariance (ANCO- VAs) with task engagement (number of digits entered) as a covariate. The dependent variable differed for each traffic situation: Standard deviation of lateral position (SDLP) in the curvy forest road, time headway to the vehicle in front in the car-following section, and reaction time for the pedestrian event.

A power analysis was calculated using the program G*Power 3.1.4 (Erdfelder et al. 1996). With the sample size of $N = 39$, an error probability of $\alpha = .05$ and a fixed power of $(1 − \beta) = 0.95 \ ( = \beta$ error of 0.05) effects of Cohen’s $f \geq 0.66$ could be detected. According to Cohen (1988), values of $f > 0.40$ reflect large effects. Therefore, a large existing difference between the experimental groups in this study could be found with a probability of $(1 − \beta) = 0.95$. If a null hypothesis could not be rejected, there was either actually no difference between the groups or only a small or medium effect.

**Results**

**Descriptive analysis of engagement in the secondary task**

Figure 1 shows the number of digits entered per minute along the test track as an indicator of task involvement. The figure illustrates how task involvement was adapted to the requirements of the specific traffic situations. The self-regulation group is of particular interest, because drivers were explicitly invited to adapt their task involvement to the changing demands of driving. For a better overview, mean values for every traffic situation

| Group            | Sharp bend | Broken-down car | Curvy forest road | Construction site | Car-following | Traffic lights | Pedestrian crosses (1) | Slow vehicle ahead | Pedestrian crosses (2) |
|------------------|------------|-----------------|-------------------|-------------------|---------------|---------------|------------------------|--------------------|----------------------|
| Group A (block design) | +          | −               | +                  | −                 | +             | −             | +                      | −                  | −                    |
| Group B (block design) | −          | +               | −                  | +                 | −             | +             | −                      | +                  | −                    |
| Group C (self-regulation) | +          | +               | +                  | +                 | +             | +             | +                      | +                  | +                    |

* A plus indicates that the secondary task was presented and a minus indicates that the task was not presented in a particular section.
Figure 1. Engagement in the secondary task (digits entered per minute along the track) for the self-regulation group (solid line) and block design group (broken line). Mean values for every traffic situation are shown. Relevant traffic situations are named; nonnamed sections were areas of free driving.

were calculated. In Figure 1, data for the 2 block design groups were combined; that is, for every area of the track, data for that group in which the secondary task was activated were used.

When taking a closer look at the self-regulation group, it becomes obvious that especially in short, critical traffic situations (sharp bend, broken-down car, pedestrian crosses) engagement in the secondary task was low. In these situations participants focused mainly on the driving task. In sections in which the demands remained stable over longer periods (curvy forest road, urban free driving sections), a medium processing rate in the secondary task was achieved. Engagement in the secondary task was highest in least demanding road sections (e.g., car-following) and in particular while driving at slow speed (slow vehicle ahead) or while waiting at traffic lights.

Drivers adapted their secondary task involvement even within each traffic situation, as can be seen in Figure 2. The section with the broken-down car is taken as an example here for a predictable traffic situation. In this figure, the time course of the number of digits entered within consecutive 50 m of the track is shown. A few hundred meters in front of the broken-down vehicle the road was straight without oncoming traffic. Many tasks were completed here. As soon as the warning triangle became visible and oncoming traffic joined in, the processing frequency decreased and was lowest while overtaking the broken-down vehicle. Immediately afterwards engagement in the secondary task increased again. Drivers in the block design groups consistently performed more tasks than the self-regulators. Interestingly, the drivers in the block design group adapted their workload in a way quite similar to the self-regulation group. However, the range of variations seemed to be smaller than in the self-regulation group.

Subjective data provide further insights into the strategies when dealing with the secondary task. Drivers in both experimental groups stated that they grouped the task into blocks of 2 or 4 digits. In addition, they reported that monitoring glances were made frequently and that they usually switched continuously between driving and the secondary task. According to their descriptions, drivers in the self-regulation group assessed the criticality of each situation. Crucial for the decision regarding whether to engage in the secondary task or not were the predictability and perceived difficulty of the situation. The task was interrupted if critical events—for example, near-collisions—occurred.

Analysis of driving performance

Parameters of lateral control

For investigation of lateral regulation, the situation “curvy forest road” was analyzed (Figure 3). As dependent variable the SDLP was used. An ANOVA showed a significant effect of the factor distraction, $F(2, 36) = 17.30, P < .001; \eta^2 = 0.49$. As expected, the distracted drivers in the block design condition had the highest SDLP ($M = 0.48$ m, $SD = 0.12$ m). In the other groups, SDLP was significantly lower (not distracted: $M = 0.32$, $SD = 0.08$; self-regulation group: $M = 0.29$, $SD = 0.04$). This was proven by post hoc tests (distracted vs. not distracted, $P < .001$; distracted vs. self-regulation, $P < .001$). The drivers in the self-regulation group did not perform worse than the drivers in the control condition: no significant differences were found (self-regulation vs. not distracted, $P = .61$).

For interpretation of the findings it should be considered that significantly more tasks were completed in the block design group than in the self-regulation group, $F(1, 24) = 28.08, P < .001; \eta^2 = 0.54$. In the block design condition, 73.08 digits were entered on average ($SD = 24.13$), whereas in the self-regulation group only 29.77 digits were entered ($SD = 16.92$).
To separate the impact of the secondary task type (system-paced vs. self-paced secondary task) from the mere intensity of task engagement (number of digits entered), an ANCOVA with task engagement as a covariate was calculated, $F(2, 23) = 14.46, P < .001; \eta^2 = 0.56$. The not distracted block design group was excluded for this analysis because for this group the covariate was not defined (no secondary task in this section of the track). There was a significant effect of the secondary task type (system-paced vs. self-paced) after controlling for intensity of task engagement, $F(1, 23) = 17.85, P < .001; \eta^2 = 0.44$. The covariate was not significantly related to SDLP, $F(1, 23) = 0.71, P = .41; \eta^2 = 0.03$.

Parameters of longitudinal control

For investigation of longitudinal control the car-following section was analyzed. Four drivers passed the leading vehicle and therefore had to be excluded from the analysis.

ANOVA results revealed a significant effect for the mean time headway to the vehicle in front, $F(2, 32) = 6.75, P = .004; \eta^2 = 0.30$. The largest distance was kept in the block design group with active secondary task (Figure 4; post hoc: distracted vs. not distracted, $P = .006$; distracted vs. self-regulation, $P = .02$). The mean time headway did not differ significantly between the other 2 groups (post hoc: self-regulation vs. not distracted, $P = .77$).

The drivers in the block design group while the secondary task was activated not only had the largest average time headway to the leading vehicle but they also had the highest variability in time headway (Figure 5). Group differences in the standard deviation of time headway were statistically significant, $F(2, 32) = 11.81, P < .001; \eta^2 = 0.43$. Post hoc analysis showed differences between the block design condition with active secondary task and the other two experimental groups (distracted vs. not distracted, $P < .001$; distracted vs. self-regulation, $P = .001$). Again the self-regulators achieved a performance level similar to the group that was not distracted (self-regulation vs. not distracted, $P = .71$).

Again it has to be considered that the self-regulators completed fewer tasks, $F(1, 24) = 36.98, P < .001; \eta^2 = 0.61$, than the drivers in the block design group (number of digits entered: $M_{self} = 56.00, SD_{self} = 15.90; M_{block} = 96.62, SD_{block} = 18.18$).

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**Figure 2.** Engagement in the secondary task (digits entered per minute) for the broken-down car situation for the self-regulation group (solid line) and block design group (broken line).

**Figure 3.** Mean SDLP in the curvy forest road situation. Error bars represent standard errors of the means.

**Figure 4.** Mean time headway in the car-following situation. Error bars represent standard errors of the means.
To separate the impact of the secondary task type (system-paced vs. self-paced secondary task) from the mere intensity of task engagement (number of digits entered), an ANCOVA for standard deviation of time headway with task engagement as a covariate was calculated, $F(2, 23) = 7.81, P = .003; \eta^2 = 0.41$. As described before, data for the not distracted block design group were excluded. The results showed no significant effect of the secondary task type (system-paced vs. self-paced) after controlling for the effect of task engagement, $F(1, 23) = 0.78, P = .39; \eta^2 = 0.03$. The covariate was not significantly related to time headway variability but explained more variance than the secondary task type, $F(1, 23) = 2.99, P = .10, \eta^2 = 0.12$.

**Reaction times and number of collisions**

To investigate the effects on reaction time and number of collisions, the first situation in which a pedestrian suddenly appeared behind a parked car was analyzed (Figure A3, see online supplement). Three drivers had to be excluded from the analysis here because they did not have their foot on the gas pedal when the pedestrian appeared. Thus, their reaction time times were not comparable to the other drivers.

A significant effect of distraction was found for braking reaction time, $F(2, 33) = 10.66, P < .001; \eta^2 = 0.39$. The slowest responses were observed in the block design group for the drivers engaged in the secondary task ($M = 1,208 \text{ ms}; \text{SD} = 169 \text{ ms})$. In the self-regulation group, drivers had a mean braking reaction time of 1,004 ms. (SD = 145). For the group of nondistracted drivers this value was 933 ms (SD = 140). The differences between the block design group with secondary task and the other 2 groups proved to be statistically significant (post hoc: distracted vs. not distracted, $P < .001$; distracted vs. self-regulation, $P = .01$).

Immediately before the pedestrian appeared, the most inputs for the secondary task were found in the block design group, $F(1, 24) = 15.71, P < .001; \eta^2 = 0.40$. In the last 50 m before the pedestrian suddenly appeared, 8.54 digits (SD = 2.79) were entered on average, whereas in the self-regulation group only 4.15 digits were entered (SD = 2.85). An ANCOVA was carried out to separate the impact of the different task types (system-paced vs. self-paced secondary task) from the mere task engagement, $F(2, 22) = 5.62, P = .01; \eta^2 = 0.36$. The not distracted block design group was excluded for this analysis because for this group the covariate was not defined (no secondary task in this section of the test track). The effect of the secondary task type (system-paced vs. self-paced) closely failed to be significant after controlling for the effect of task engagement, $F(1, 22) = 3.86, P = .06; \eta^2 = 0.15$. The covariate was not significantly related to brake reaction time and explained less variance than the secondary task type, $F(1, 22) = 0.92, P = .35, \eta^2 = 0.04$.

There were no significant group differences for the number of collisions ($\chi^2 = 0.84, \text{df} = 2, P = .66$). In the block design condition with the secondary task and the self-regulation group 5 collisions occurred; for the nondistracted drivers overall 7 collisions were counted. However, it should be noted that the mean speed at the appearance of the pedestrian significantly differed between the groups, $F(2, 36) = 9.94, P < .001; \eta^2 = 0.36$. The nondistracted participants drove fastest on average ($M = 47.8 \text{ km/h}; \text{SD} = 3.62$), whereas the drivers in the block design group performing the secondary task were significantly slower ($M = 37.1 \text{ km/h}; \text{SD} = 37.01$). The self-regulators drove 44.46 km/h on average ($\text{SD} = 7.14$). Post hoc analyses indicated that the participants in the block design group with distraction drove significantly slower than the drivers in the other groups (block with secondary task vs. block without secondary task, $P < .001$; block with secondary task vs. self-regulation, $P = .01$).

**Discussion**

The influence of distraction on driving performance was investigated in the current simulator study. To what extent drivers were able to adapt to the situational circumstances while performing secondary tasks and what impact this had on safety-related driving parameters were of particular interest. For this purpose, one group of drivers was free to choose when to engage in a secondary visual–motor task (self-regulation group with self-paced secondary task), whereas another group went through a standard block design in which they were prompted to perform the task in specific situations (block design group with system-paced secondary task).

The most substantial impairment in driving performance was measured during distracted driving in the block design group. In particular, high decrements were found for lateral vehicle control. These findings provide further evidence that visually distracting secondary tasks greatly affect lane-keeping performance (see also Drews et al. 2009; Regan and Hallett 2011; Rudin-Brown et al. 2011; Young et al. 2010, 2011).

Focusing on longitudinal vehicle control, the largest performance decrements were also found for the distracted drivers in the block design group. In the car-following section, these drivers showed the highest variability in time headway; however, they drove slower and thus had increased average time headway. These results are in line with previous research showing that drivers tend to decrease their mean speed when distracted in an attempt to reduce workload and to moderate their exposure to risk (Briem and Hedmann 1995; Young et al. 2010, 2011). In some way, this behavior can be understood as a different form of self-regulation. Though the drivers in the block design group were restricted in self-regulation regarding the secondary task engagement, they used the opportunity to self-regulate their driving behavior.
Finally, the slowest braking reaction times in critical events were found for the block design group while distracted. However, this did not lead to an increased number of crashes for this group. This can be explained by the fact that these subjects were driving slower in this section of the track. As described, this may have been a compensatory behavior to reduce workload and perceived risk when distracted.

The drivers in the self-regulation group, who were free to choose the right moments to engage in the secondary task, had significantly better lateral and longitudinal vehicle control than the distracted drivers in the block design group. In addition, their mean reaction times were significantly faster. Interestingly, in most cases their performance was at a level similar to drivers who were not distracted at all.

For a discussion of this finding, first it is useful to compare the number of inputs for the secondary task over the entire test track and within each traffic situation between the experimental groups. In all critical situations, the self-regulators worked significantly less on the secondary task than the drivers in the block condition. The drivers in the self-regulation group chose a degree of workload that was still convenient for them. In most critical situations they engaged relatively less in the secondary task. Thus, they were able to focus their visual, cognitive, and motor resources more on the driving task, which led to safer driving. Engagement in the secondary task was higher in less demanding situations with low traffic density and in particular when driving at slow speed or while waiting at traffic lights. Interestingly, the drivers in the block design group showed a quite similar adaptation in dealing with the secondary task. They performed consistently more tasks than the self-regulators, but the distribution of task engagement over the test track showed a similar shape (Figures 1 and 2). It can be assumed that the overall task workload was too high to deal appropriately with demanding traffic situations, which led to performance decrements in this group.

ANCOVAs were calculated to clarify whether the better driving performance in the self-regulation group was primarily caused by the self-paced working on the secondary task or just by their lower task engagement as indicated by the number of inputs. For SDL in the curvy forest road, there was a significant effect of the secondary task type (system-paced vs. self-paced) after controlling for the effect of task engagement. The opportunity to perform the secondary task self-paced was the main contributing factor for the better performance in this traffic situation. The results obtained for brake reaction time when a pedestrian suddenly appeared pointed in the same direction, although the ANCOVA closely failed to be significant after controlling for the effect of task engagement. In contrast, for the car-following section, the ANCOVA revealed that the lower task engagement was the main contributing factor. This finding might be explained by the different characteristics of these traffic situations. When driving along the forest road, curved and straight sections were alternating, resulting in changing demands. Similarly, in the section where the pedestrian appeared, demands were changing over time. In contrast, demands remained more or less constant while following the leading car. Because of the constant difficulty, no effective adaptation in performing the secondary task could be applied during car-following, whereas in the other situations self-regulation was more effective. However, as mentioned above, the drivers did demonstrate self-regulation in terms of lower driving speeds and increased time headway.

More insight into the role of self-regulation can be gained by comparing the self-regulation and the baseline condition without any distraction. In most cases, no substantial differences in driving performance could be found; in a few situations the self-regulators even performed better. Engagement in the secondary task was divided within the situations in such a way that always a high degree of situational control could be maintained. This is supported by self-reports of the participants, in which they stated that monitoring glances were made frequently and that they usually switched continuously between driving and the secondary task.

In most parts of the test track drivers were able to anticipate the demands of the traffic situation and to adapt their involvement into the secondary task, which is in line with the simulator study by Metz et al. (2011). These authors used predetermined points of the track to offer the choice to perform a secondary task or not. In contrast, the implementation of self-regulation used in the current study was fully self-initiated: The secondary task was unlocked over the entire track and could be performed whenever it seemed adequate for the drivers. The fact that these different approaches led to similar results can be seen as evidence for the impact of self-regulation in dealing with secondary tasks. The behavior of the drivers in the block design group in the current study is further evidence of attempts to self-regulate. Although instructed to perform the task system-paced, they demonstrated self-regulation in their task engagement and also in their driving behavior (e.g., slower speed, increased time headway).

The findings concerning the behavior of the block design drivers provide some implications for using forced-paced secondary tasks in driver distraction research. It can be assumed that, although restricted in their ability to regulate their engagement in the secondary task, drivers will still adapt their task engagement to a certain degree. Depending on the experimental approach, this could lead to unintended variance in the data. Further research on self-regulatory behavior under forced-paced task conditions could provide more insights on these effects.

The concentration on ecological validity in the current study is accompanied by some limitations. Because in the self-regulation group the secondary task could be performed whenever the drivers were comfortable doing so, there was no standardization in the number of tasks performed. First, this is a challenge for the comparison between the self-regulation and block design group. This was addressed by using ANCOVAs to control for the effect of task engagement. Second, the lack of standardization in the number of tasks performed leads to high within-group variance and mitigates statistical power. Moreover, when considering that a between-subjects design was used for this study, the sample size was relatively small. Further research is necessary to confirm and extend the findings of the current study. The use of gaze tracking, driver monitoring systems, and physiological measures for the assessment of workload could provide further insights into the mechanisms of self-regulation in dealing with different types of secondary tasks.
Overall, it can be summarized that self-regulated engagement in a secondary task while driving was associated with less impairment in driving performance compared to driving while prompted to perform the secondary task in predefined situations. Because in real traffic it is generally possible for the driver to decide when to engage in secondary tasks, self-regulation should be taken into account in research on driver distraction to ensure ecological validity. However, it strongly depends on the type of secondary task that is investigated; for example, whether the task is self-initiated or whether it can be easily interrupted.

Further research should address drivers’ capabilities for self-regulation in dealing with different kinds of secondary tasks. This would be a help for evaluation of existing and future findings on driver distraction. A comprehensive understanding of self-regulation would be useful in developing elaborated countermeasures against driver distraction; for example, in the field of road safety campaigns or in the design of in-vehicle information systems.

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