Insufficient attention allocation towards the driving task impairs driving performance and increases the risk of SPADs. This pilot study explores the impact of the behaviour of another person present in the driver’s cabin on attention allocation and driver performance of train drivers. A method using a train simulator has been developed to assess speed monitoring and task performance for routes with different complexity and for conditions when train drivers were driving alone, with a person present who was considerate of the driving task or with a person who was not. The presence of a person has a negative impact on driving performance: tasks were completed successfully more often when driving alone. Conversations were more often interrupted to focus on driving on routes with moderate and high complexity, indicating that conversations increased workload. An increase in conversations had a negative impact on speed monitoring accuracy. Participants indicated that awareness of the impact of a person’s presence on driving performance improved as a result of participating in the experiment. It is anticipated that the findings of this pilot study and further work will provide more understanding of factors important to train driver performance.

Introduction

Dutch train drivers operate in a dynamic railway system, in which they have to perform multiple tasks while attending to different signals and devices. Driving trains in a safe manner requires that train drivers are aware of the situation they operate in. Many constructs are used to understand train driver performance (McLeod et. al, 2005), amongst them is situation awareness. Adaptations of the
model developed by Endsley (1997) have been used to define situation awareness specifically for train driving performance (Figure 1). Situation awareness, for instance, contributes to route knowledge which gives train drivers the opportunity to react effectively to the situation at hand. Translated to the driving task, the three levels of situation awareness can be defined as follows: first the train driver has to allocate attention to relevant information (e.g. signal aspects), then the train driver has to understand the perceived information and finally, the driver has to make decisions based on this information to operate appropriately in the dynamic system (see also, Tschirner et al. 2013).

![Figure 1: Adaptation of Situation Awareness Model Endsley](image)

The issue with constructs like situation awareness is that they remain cognitive constructs which are difficult to operationalise in applied research. Like Dekker and Hollnagel (2004) argue, these constructs have to be reduced to individual aspects to be able to operationalise them. Furthermore, constructs such as situational awareness are difficult to falsify. Therefore, the current study focuses on relations between more specific constructs in the model of situation awareness (highlighted in Figure 1). There are multiple factors that contribute to situation awareness, one of the important features that individuals use to achieve situation awareness is attention (Endsley & Jones, 1997). Attention allocation among train drivers plays an important role in identifying and attending to signals effectively (Merat et al, 2002). Attention can be defined in different ways (Corbetta et al. 1991, Lavie, 1995), in the context of train driver performance, attention is broadly defined into two categories. The first is vigilance, which is similar to concentrating for a prolonged period of time. The second is dynamic selective attention, in which the train driver focuses vision, hearing and cognitive resources towards a specific object or task (selective attention), or shares focus between multiple tasks (divided attention). The current study targets a train driver’s (visual) attention allocation when another person is present in the cabin.
Multiple studies show that distraction is a risk for attention (Ranney, 2008). In the context of road traffic much research has focused on driver distraction (Young, Lee & Regan, 2008). Train drivers are exposed to various potential sources of distraction, including the presence of a second authorised person (e.g. supervisor) in the cabin while driving. The study of Laberge and colleagues in the context of road traffic shows that the mental workload of drivers increases when engaged in a conversation with the passenger. This has a negative impact on attention allocation towards the driving task. Subsequently a driver’s response time to critical events increases (Laberge et al., 2004). In the context of train driver performance, insufficient attention allocation towards the driving task and failure to effectively respond could increase the risk of signals passed at danger (SPADs). Evidence of other studies suggest however, that a passenger could support the driver in his task by directing attention to the traffic situation, especially in complex situations (Gaspar et al. 2013, Drews et al. 2008). Since it is common for train drivers to operate alone in the cabin, it is expected in the current study that the behaviour of another person present increases the workload of train drivers and will have a negative effect on driver performance.

Currently, there is insufficient understanding of the extent to which the presence of another person in the driver’s cabin influences driver performance. Specifically this pilot aims to understand the impact of the person’s behaviour on attention allocation of the train driver, and subsequently on driving behaviour. In this pilot study a method has been developed to assess attention allocation and driver performance, using a simulator setup which mimics naturalistic situations for the train driver. This is the first study to assess performance of Dutch train drivers in such a manner. Findings from this pilot can be used to further develop methods to assess train driving performance in a realistic setting.

We expect that train drivers will be more often and for longer periods in conversation with a person who is not considerate of the driving task, compared to a considerate person. In addition, the frequency of visual attention allocated to the authorised person will be higher when the non-considerate person is present. Attention allocation towards the person present will be less on high complexity routes. As a result and in line with the findings of Laberge et al (2004) we expect that driving performance will be less accurate when a person is present and when the complexity of the route increases. Speed will be monitored less carefully when a person is present and critical tasks (e.g. following assignments from the dispatcher) will be performed less accurately.

Method

Participants
Fifteen experienced train drivers (12 male, 3 female) participated in this study, ranging in age from 25 to 57 years (M = 45.2, SD = 9.1). Train driving experience ranged from less than one year to 34 years (M = 14, SD = 10.9). Participation was voluntarily and participants were selected based on schedule availability. All participants were familiar with the simulator setting and fully
capable to operate in the simulator. Eleven participants had route knowledge of all three routes used in this pilot study.

**Stimuli and Apparatus**

A Multifunctional Simulator was used in the present study. This simulator includes a cabin steering table, which entails the same functionalities as a train cabin. In front of this steering table a screen was placed, on which the route is projected (Figure 2). The Multifunctional Simulator can be operated from the simulator operation table (Figure 3), with a dispatcher module and screens to monitor train driver operations, the location on route and the speed of the simulated train during the experiment.

![Figure 2: Multifunctional Simulator](image1.png)  ![Figure 3: Simulator operation table](image2.png)

Three cameras were used in to register the output of the simulator experiment. The researchers opted not to use eye-tracking equipment in order to avoid participant suspicion of the purpose of the study. This would possibly influence the behaviour of the participants. The participants were informed about the cameras beforehand. Two cameras were placed in the simulator setting, the first was placed in front of the steering table and faced towards the train driver, to register the (visual) attention allocation of the train driver. The second camera was placed behind the train driver and this camera gives an overview of the train driver actions to operate the train. The placement of the cameras ensures that the visual field of the driver was not obstructed. The third camera was placed facing the simulator operating table. From this viewpoint the image of the route, speed and train driver operations could be monitored. The setup of the cameras made it possible to monitor the attention allocation and operations of the train driver in relation to the specific route and speed at a certain moment in time during the simulation.

**Procedure**

The experiment contained three passenger train routes, ranging from 10-15 minutes each, with short breaks in between. Participants completed three routes with different levels of complexity which were designed to mimic naturalistic situations for the train driver. Participants were instructed to drive safely and apply current regulations. The train driver had to attend to signs and signals on the route and TPS warning signals in the cabin to monitor train speed. In the low complexity condition two unexpected situations were programmed in the simulation (e.g. a signal out in the adjacent tracks and a cow alongside the
The driver had to contact the dispatcher when these situations occurred and the task was deemed to be completed successfully when both situations were noticed. In the moderate complexity condition the train had to make stops at train stations. During the simulation the participant received an assignment from the dispatcher to reduce speed at a specific location. Reaction to this critical task was correct when the speed of the train was reduced by the participant to a maximum of 40 km/h at the instructed sign and did not increase before the end of the designated location. In the high complexity condition the train had to stop at train stations and the train driver had to attend to a signal out on the route. The participant received an assignment from the dispatcher to reduce speed to a maximum of 10 km/h at a railway crossing because of a defect. Reaction to this critical task was correct when train speed was reduced sufficiently at the railway crossing and did not increase before the end of the designated location.

There were a number of conversation conditions. During the first ‘driver-alone’ route the participants completed the simulation alone. During the second route the participant was seated at the steering table and the person present was situated to the right of the driver, just as an authorised person would in a real life cabin. The person was instructed to engage in a conversation with the participant during the simulation. The accomplice in the ‘considerate’ condition was instructed to engage in a conversation about work related topics, and to take the driving task into account while present. This condition is similar to the situation when a train driver is accompanied by a supervisor. The accomplice was instructed to actively pay attention to the simulated route, however he was not to comment on or intervene in the actions of the participant. The accomplice in the ‘non-considerate’ condition was instructed to engage in a conversation and actively ask the participant questions about the contents of his work. The accomplice is instructed to maintain a constant conversation and engage again in a conversation in case of interruptions. Furthermore, the accomplice actively tries to make eye contact with the driver and does not take the driving task into account.

After providing informed consent, the participants were introduced to the simulator environment and instructed about the tasks they had to complete. All participants had previous experience with the simulator. Counterbalancing was used to assign participants to a specific sequence of the three routes with different complexity levels. The order of conversation conditions was the same for each participant: The first route was completed while driving alone, the second route the driver was joined by a research accomplice who took on the considerate role (e.g. supervisor) and the third route was completed while the non-considerate accomplice was present. The participants were not familiar with the accomplices. The entire experiment took approximately 1 hour to complete.

**Measures**

The first measure was for attention allocation. Unlike the study of Merat et al (2002) no eye tracking equipment was used in this pilot. Since this study measures output of behaviour, it is difficult to determine whether the person’s
attention is truly allocated towards the driving task when he looks at the screen. Therefore the participant’s attention allocation was measured through the frequency the participants focused visually on the person present. Following the studies of Drews et al. (2008) and Gaspard et al. (2013) attention was also measured through conversation, since maintaining a dialogue requires attention towards the topic and the content of the conversation. Therefore the percentage of the route spent in conversation with the person and the frequency of interruptions of conversations were monitored.

The second measure was for driving performance. Multiple measures of train driving performance were taken. The focus of this study is the output of performance, not the cognitive aspects of behaviour itself, thus decision making in the model of Endsley (2000) was left out of scope. On the operational level, the performance on the driving task was measured through the amount of times the train protection system (TPS) issued warning signals, indicating that the speed exceeds the required limit and that the train driver should brake. This is a possible indication that the train driver did not monitor speed sufficiently. On the strategic level, driver performance was assessed by the reaction to critical tasks (i.e. the ability to follow assignments correctly or to notice unexpected situations) and speed limit transgression at time of the task.

Results

Attention allocation.
The following analyses include the data of 14 participants in the non-considerate condition, since one of the participants asked the accomplice to leave the cabin because he caused to much distraction. Attention allocation was operationalised through the percentage of the route the train driver was in conversation with the person, the frequency of interruptions of conversations and the frequency of visual focus on the person present (Table 1).

One way ANOVAs were used to determine the effect of the behaviour of the person in the cabin on attention allocation. Participants were significantly more in conversation with the non-considerate person compared to the considerate person $F(1, 28) = 11.4, p < .005$. As shown in Table 1, interruptions in conversations to be able to focus on the driving task seem more frequent when the considerate person is present compared to the non-considerate person. Means for frequency of visual focus on the person seem to indicate that the train driver

<table>
<thead>
<tr>
<th>Table 1: Results for attention allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Route complexity</td>
</tr>
<tr>
<td>Route in conversation (%)</td>
</tr>
<tr>
<td>Mean focus on person (SD)</td>
</tr>
<tr>
<td>Mean interruptions (SD)</td>
</tr>
</tbody>
</table>

One way ANOVAs were used to determine the effect of the behaviour of the person in the cabin on attention allocation. Participants were significantly more in conversation with the non-considerate person compared to the considerate person $F(1, 28) = 11.4, p < .005$. As shown in Table 1, interruptions in conversations to be able to focus on the driving task seem more frequent when the considerate person is present compared to the non-considerate person. Means for frequency of visual focus on the person seem to indicate that the train driver
allocated attention more often to the non-considerate person compared to the considerate person. Differences in frequency of conversation interruptions or frequency of visual focus on the person did not reach significance ($p's > 0.29$).

In the moderately demanding driving condition, the percentage of the route the driver was in conversation was significantly less compared to the low or high demanding driving conditions $F(2, 28) = 5.86, p < .05$. The frequency of interruptions was significantly lower for the route with low complexity compared to the more demanding driving conditions $F(2, 28) = 5.87, p < .05$. No significant differences were found between driving conditions for frequency of visual focus on the person in cabin.

**Driving performance**

Table 2 shows the amount of warning signals issued by the TPS, the amount of critical tasks performed correctly and mean speed limit transgression at time of the critical task. Univariate analyses were used to determine the effect of the person’s presence and route complexity on driving performance.

<table>
<thead>
<tr>
<th>Route complexity</th>
<th>Considerate person</th>
<th>Non considerate person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alone</td>
<td>High</td>
</tr>
<tr>
<td>TPS warnings</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Task correct</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Mean speed</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>transgression(SD)</td>
<td></td>
<td>(4.3)</td>
</tr>
</tbody>
</table>

For TPS warning signals there were no significant differences between the condition when the driver operated alone and the conditions were the considerate or non-considerate person were present ($p > .1$). Notable is the absence of TPS warning signals in the moderately demanding driving condition. The amount of issued TPS warning signals for this condition differs significantly from TPS warning signals for the other routes $F(2, 43) = 8.72, p < .005$. On a strategic level, driver performance was assessed by the reaction to critical events (i.e. the ability to follow assignments correctly or to notice unexpected situations). Figure 4 shows that task performance is more accurate when driving alone compared to driving with a person present. A significant effect was found for the presence of a person in the cabin on task performance $F(2, 43) = 3.47, p < .05$. Drivers in the non-considerate condition were four times more likely to fail correct task completion compared to participants who operated alone. Drivers in the considerate condition were a third less likely to complete the instructed task successfully compared to drivers in the alone condition. No differences were observed between route complexity conditions for task performance ($p > .05$).
Regression analyses were used to further analyse the relationship between attention allocation and performance. For visual attention there were no significant effects on TPS warning signals or speed limit transgression (p’s > .05). A significant regression equation was found for the amount of route in conversation to predict the amount of TPS warning signals $F(1,28) = 4.62, p < .05$, with an $R^2$ of .146. The amount of TPS warning signals increased with the amount of the route the train driver was in conversation with the person present. However, the amount of route in conversation appeared not to be a significant predictor for speed transgression ($p > .05$). Also, there was no direct effect found for the amount of conversation or visual attention towards the person present on successful task completion ($p’s > .05$).

**Conclusion and discussion**

The findings of this pilot study indicate that the presence of a person in the cabin has a negative impact on driving performance. Train drivers completed tasks successfully more often when driving alone compared to driving with a considerate or non-considerate person in the cabin. These findings are in line with the results of the study of Laberge et al (2004) where driving performance was more accurate when driving alone. There were no significant differences between conditions for TPS warning signals. For speed limit transgression the data suggests that in case of exceeding speed limits, the transgression was less when a considerate person was present. In line with Gaspar et al (2013) this suggests that the presence of a considerate person has a positive impact on speed monitoring behaviour of drivers. These findings were not significant, but are none the less promising for further research. A possible explanation for the findings is that the presence of a considerate person who is familiar with the driving task (e.g. supervisor) improves shared situation awareness, which in turn could prompt a more defensive driving style.

Considering route complexity, speed monitoring by train drivers was most careful when operating on a route with moderate complexity. Notable is the absence of TPS signals in this condition. A possible explanation for this finding
is that there were less speed limit changes in the route with moderate complexity compared to the other routes. Subsequently, the TPS required less attention of the train driver in this condition. No differences were observed between route complexity conditions for task performance or speed transgression.

For attention allocation this study found that train drivers were more in conversation with the non-considerate person compared to the considerate person. The data for visual attention allocation and amount of conversation interruptions to focus on the driving task indicated similar findings, however these proved not significant in the current study. In addition, the study shows that train drivers allocated less attention towards the person present when driving routes with moderate complexity. Currently there is no explanation for this finding. For interruptions we found that these occurred less when the driver operated on a route with low complexity compared to the conditions with more complex routes. A possible explanation for this finding would be that in routes with moderate or high complexity more interruptions are needed to decrease workload, which would support the findings of Laberge et al (2004).

Following the results for attention allocation we found that the time that the train driver was in conversation is a significant predictor for the amount of TPS signals. The amount of warning signals increased when the train driver was more often in conversation, again in agreement with Laberge et al (2004) that attention allocation towards the person has a negative impact on speed monitoring. This effect was not found for task performance. This relationship between attention allocation and performance was also not proven for visual attention allocation or the amount of interruptions on speed monitoring or task performance.

This pilot study is the first practical simulator based research used by Dutch Railways to gain insight into train driver performance. The simulation design used for this study mimics naturalistic situations for train drivers in which it is possible to assess performance. In this pilot ways were developed to assess output of attention allocation. Future work should focus on the development of additional ways to assess attention allocation, specifically for the train driving task. Based on the TPS-findings for route complexity the simulated conditions should be further developed to be able to distinguish between realistic workload conditions. In future research, workload assessment could be improved by using a mental workload scale. In addition, the design of this pilot can be enhanced by using a full scope simulator. Also, a familiarisation trial should be used to make sure the participants are familiar with the simulator. An important limitation of this pilot study is the amount of participants available for the experiment. Additional analyses with larger amounts of participants are necessary to verify the findings of this pilot, and to further explore interaction effects. Furthermore it is advised to study the impact of a person’s behaviour on train driver performance when the person is present for a prolonged amount of time.

The findings of the current pilot study indicate the importance of limiting distraction by a second person in the driver’s cabin. Based on these findings,
Dutch Railways revised cabin policy with a more strict authorisation process. Also, people who are authorised to join the train driver in the cabin during driving receive additional instruction. Train drivers who took part in the simulator setting indicated that their awareness of the risk of distraction from the driving task when a person is present and the impact on driving performance improved as a result of participating in the experiment. These findings were used to improve train driver awareness on this subject.

Acknowledgements

This paper is based on data collected by J.M.M.C. Hakkert on behalf of Dutch Railways, NS. The author would like to thank the NS Simulatorcentrum in Amersfoort and J.M.M.C. Hakkert for their support.

References


Endsley, M., Jones, W., M. 1997, Situation Awareness Information Dominance & Information Warfare, (Logicon Technical Services Inc.).


