Situation Awareness in Remote Train Operation: Effects of a Supplementary Task and Attention-Guiding Takeover Requests

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1 BACKGROUND AND OBJECTIVES

Automation in the railway sector offers the potential to enhance operational stability and capacity, improve safety, and reduce personnel costs by removing the train driver from the cab (Grippenkoven et al., 2020). However, as systems remain imperfect, human intervention will continue to be necessary to deal with unforeseen events. In Grades of Automation (GoA) 3 and 4, a remote operator (RO) stationed in a remote control centre will be responsible for acting when critical events require it (Grippenkoven et al., 2020). As in other transportation domains, critical events are expected to be infrequent but require situation awareness for an efficient reaction. However, disadvantageous working conditions such as a mostly passive monitoring task could lead to monotony and drowsiness, preventing the RO from remaining adequately aware of the situation (Brandenburger & Naumann, 2019; Merlhiot & Bueno, 2022). To mitigate such issues, ROs might engage in supplementary tasks (ST) during periods of low demand (Brandenburger & Naumann, 2019; Thomas-Friedrich et al., 2024). Yet, prior research in other domains suggests that STs can lead to delayed situation awareness and impaired take-over performance (Hungund & Kumar Pradhan, 2023). This study thus aims to assess the impact of a visually demanding ST on RO situation awareness and workload. Additionally, it investigates whether the use of attention-guiding take-over requests (AGTORs), which direct the RO's focus toward the most critical element of the scene, may help in mitigating potential negative effects of engagement with a ST. While AGTORs have shown promise in automotive research (Chen et al., 2023), their effectiveness in the remote train operation (RTO) domain is unknown. Finally, to measure the effect of previous work experience in a closely related context, a subsample of active train drivers was included in the study.

2 METHODS

An experimental online study was conducted with 160 participants, 28 of whom were active train drivers. The other participants had no real-life experience of driving trains. In a 2x2x2 mixed design, participants

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were randomly assigned to one of two take-over-request (TOR) conditions (AGTOR vs. simple warning tone). Each participant worked on two experimental blocks, one of which contained a ST (a mentally demanding visual search task) and one of which consisted of monitoring an RTO environment in phases when no TOR was issued. Within each of these blocks, participants were presented with four TORs, followed each by a ten-second video sequence depicting the RTO work environment in a scenario where a critical reason that induced the TOR had to be found and understood within the first five seconds of the video. This critical reason could be found either in the camera view, the train parameter overview or the notification window of the RTO work environment. Each scenario included a sequence of the train front camera view of the railway environment. The landscape type (e.g. urban versus natural, flat terrain vs. valley), the number of tracks, and track electrification were varied, and no other trains were included. After the video had been played, the environment was blanked out and participants were asked to report on the reason for the TOR. In addition, once per block and in random order using a SAGAT approach (Endsley, 1988), participants were asked to report a total of 16 items of information and to rate which information they felt was crucial for understanding the overall situation. The number of critical reasons correctly identified and the percentage of correct SAGAT responses were used as measures of situation awareness. After each of the two blocks, workload was measured using the DLR-WAT questionnaire (Grippenkoven et al., 2018). SAGAT and workload scores were analysed using mixed-effects linear regression, and critical recognition performance using mixed-effects logistic regression.

3 RESULTS

Participants recognised on average 5.3 of the eight reasons leading to the TORs. Working on the ST reduced the likelihood of detecting these critical reasons (OR = 0.66, p = .020). AGTORs improved the likelihood of detecting the critical reasons compared to simple warning tones (OR = 2.18, p = .003). There were no effects of experience regarding recognition performance. Further, participants averaged 52.3 % of the 16 SAGAT questions answered correctly. Working on a ST was associated with higher SAGAT scores (b = 5.46, p < .001, r = 0.31). Train drivers showed higher SAGAT scores than non-train drivers, especially in the no-ST (Δ_M = 5.95), compared to the ST condition (Δ_M = 0.57), but this effect was not significant (p = .160, r = 0.11). Participants reported higher levels of workload following the ST condition compared to the no-ST condition (b = 15.32, p < .001). Notably, in both conditions workload levels averaged above the optimum value of 100 (M_{ST} = 134.49, $M_{No\text{-}Task}$ = 119.35, scale from 0 to 200).

4 CONCLUSION

Engaging in a ST impaired recognition performance of critical take-over reasons but, unexpectedly, led to higher SAGAT scores. This finding may suggest that the ST helped maintain attention and

engagement, thereby facilitating broader information sampling. However, it may also have introduced detrimental task-switching effects that impaired performance in the first seconds following the TOR, increasing the risk of missing the reason for the take-over. As accurate identification of the reason for a TOR is essential for responding effectively, the design of an RTO environment should focus on supporting the RO during these initial moments. In the study, when attention was directed toward the critical reason first through an AGTOR, detection rates improved significantly without impairing overall situation awareness. Train drivers did not perform significantly better than others on the SAGAT or the critical recognition performance. As all participants were unfamiliar with the environment, it is possible that train driver-specific skills did not translate into improved orientation and subsequent situation awareness. However, descriptive trends towards better SAGAT performance in train drivers, especially in the no-ST condition, may also have failed to reach significance due to a small subsample size.

Overall, this study provides an initial foundation for further exploration of human factors in RTO systems. While STs may help maintain operator attention and enhance job satisfaction, practitioners need to prioritize strategies that support rapid comprehension of the initial moments after a TOR was issued.

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