Evaluation of training for passengers' interaction with an automated bus docking at a bus stop – a Virtual Reality Study

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Abstract *– The aim of this pilot study was to evaluate the effect of training on passengers' understanding and acceptance of an automated function used for a bus entering and exiting a bus stop. An HMI were used to inform the passengers that the bus was in automated mode. This was done with activation of lights in led strips around the steering wheel and the front window, together with an informative sound. The study used a virtual reality platform to simulate the scenario.*

Twenty participants took part in the study, with an equal balance between female and male passengers, and an age range of 25-60 years. Half of them participated in a training session, watching a short informative film, learning about the HMI and how to behave when approaching the bus. Data was collected using positioning in the simulation, eye tracking, various questionnaires, and a short interview.

All participants who received the training found it useful. From the debriefing interview it was clear that the training did increase the understanding of the system, but no significant effects of the training were found in behavior or in acceptance.

Keywords: *automated mobility, virtual reality, HMI evaluation, training, passengers' interaction.*

Introduction

Traveling with bus is generally safer than travel with car (Albertsson, Falkmer et al., 2006) but passengers are occasionally injured. Wretstrand, Holmberg et al. (2014) analysed hospital reported injuries for urban bus travelling showing that most injuries during bus travelling are when passenger fall while standing or moving on board (66%), and especially during hard accelerations and braking (85%). Many of these incidents occur when the bus is docking or accelerating from the bus stop (Wretstrand, Holmberg et al., 2014) and passengers are falling before being seated. This is the most critical part of the bus ride both for passengers and vulnerable road users (VRU) around the bus. The reason for hard accelerations and decelerations at bus stops is not fully understood but has been shown to be related to stressed drivers (Filtness, Anund et al., 2019). Most bus crashes occur due to humanerrors, which leads to an increased interest in developing an automated docking to reduce the load on the driver. However, successful implementation of such automated functions in buses requires passengers understanding of the concept, their acceptance and trust. This is not known to the best of our knowledge.

The aim of this pilot study was to evaluate the need of training and the effect of training on passengers' understanding and acceptance of automated docking a bus stops.

Previous studies investigating the acceptance of automated buses have focused on the development of HMI systems for communicating automation status (Mirnig, Gärtner et al., 2022). We have previously tested different HMI solutions, with lights in the steering wheel for communicating handover and automation status to the driver, lights in the windshield and external sound for communicating automation status to waiting passengers and other VRUs around the bus (Dahlman, Weidel et al., 2022). A solution with lights in the steering wheel and windshield and sound was most appreciated by both bus drivers and passengers participating in the study. The evaluation was done using VR simulation, which proved to be a useful tool for evaluating automated vehicle functions not yet available in real life. In the present study, the simulator scenario and preferred HMI from the previous study was used for the evaluation of training.

Methods

The study was conducted at the National Road and Transport Research Institute (VTI) in Sweden during 2021. In total, 20 participants were recruited, 10 females and 10 males in the age of 25-60 years old, most of them in their thirties and forties. Most were full time employed and a few were students. Since regular buses with an autonomous docking function did not exist at the time of the study, the experiment was performed as a VR study. Passenger interactions with a bus equipped with an autonomous docking function and a HMI system for communication to passengers were implemented in a Virtual Reality (VR) environment. The HMI had a blue light strip in the windshield and on the steering wheel, together with an external sound (like a bell) for communicating automation status when the automated bus was approaching the bus stop (Figure 1). A passenger training was developed and evaluated to understand if this was needed or not for VRUs to behave safely around and accept and trust automated buses.

When the participants arrived, one at a time, to VTI they were informed about the covid-19 safety measures effective at the time. They were also informed about the experimental procedures and had the opportunity to ask questions. After this they signed an informed consent. Half of the participants achieved training including a three-minute video that explained the HMI features and the function and limitations of the automated docking, and one video explaining the benefits for the driver. They were also informed about the importance of keeping the distance to the bus to reduce the risk of hard breakings and waiting until it stopped completely before entering the bus. The 10 participants who did not watch the training videos were not aware that the training existed and got their first introduction to the bus HMI system through the VR scenario.

A VR-headset from HTC (10 ms latency), with integrated Tobii eye tracking, headphones mounted to the VR system and two motion controllers were used to simulate the scenario. The participant had a 3 x 4-meter studio to move around in when waiting for the bus. The test leader acted as the bus driver and started the bus and drove it towards the waiting passenger. The scenario took place in daylight, representing an urban Swedish area. The participant acted as the passenger, waiting for the bus at the bus stop. The instructions were to behave like you normally would when waiting for the bus. There were nine bus stops in total in the scenario, the first three were for practice and not included in the analysis. At the first bus stop, the HMI was activated, at the second the bus arrived without HMI and at the third one the HMI was active again. The rest of the bus stops were in a random order, including three with HMI and three without. After the bus arrived and opened the door the participant could click on the hand controller to move on to the next bus stop. The full scenario took about 12 minutes to complete, including eye calibration that was done prior the experiment.

The participants' distance to the curb and eye gaze on specific areas of interest (AOI) were measured, starting from the moment the bus left the main road and entered the bus stop and ending when the participant moved to the next bus stop. The AOIs were the windshield, front of the bus, door, wheels, other parts of the bus and other things (i.e., not on the bus).

Figure 1. Bus with HMI activated.

After experiencing the scenario and leaving the VR room the participant was left alone to answer a set of questions. Including background questions, specific questions about the HMI and instruments for measure acceptance, usability, and trust of the automated docking function. The questionnaire comprised the technology acceptance questionnaire (VDL) (Van Der Laan, Heino et al., 1997), the SHAPE Automation Trust Index (SATI) by Dehn (2008), the User Experience Questionnaire (UEQ) by Schrepp, Hinderks et al. (2017) and specific questions about safety and willingness to use the system. There were also questions about the participants' opinions of the HMI. Participants who took part of the training session answered an extra set of questions specifically about the training. In addition, a short debriefing interview was conducted to capture thoughts and opinions about the system and its design.

Gaze data and distance to curb was compared between the group who participated in the training and the participants who did not, using a mixed model ANOVA with participant as a random factor, nested on training (IBM SPSS version 26). Fixed factor was HMI (1=activated; 0=not activated) and Training (1=training; 0=no training). The model included main effects for all factors, and the interaction between HMI and training. Questionnaire data were analyzed with a t test.

Results and discussion

Participants were generally satisfied with the experiment, despite some experiencing mild nausea from the VR equipment. However, the VR system had some issues with sound and sometimes glitches in the surrounding environment, such as passing cars, that made it difficult to focus on the HMI system of the bus. Some participants also noted that the VR scenario could have been more realistic with a more immersive surrounding, and that the equipment's resolution could be improved so the HMI would be visible from a further distance. Nonetheless, the VR worked well for most participants.

Questionnaires

Figure 2 illustrates the overall sentiment towards the system. Most participants expressed a favorable opinion, with 8 rating it very positively, 8 rating it somewhat positively, and 4 rating it neutrally. Notably, participants who did not receive training were more positive in their assessments. Most of the participants (11 out of 20) answered that they wanted a system like this. Thirteen out of twenty participants felt that the security would improve both inside and outside the bus with the implementation of such a system.

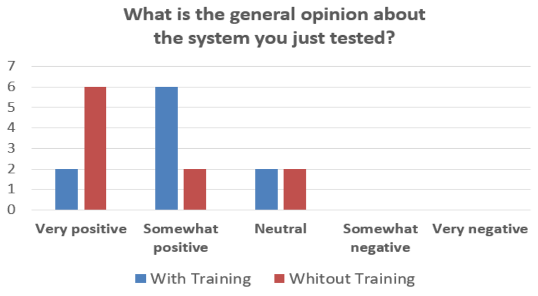


Figure 2. General opinion about the automated docking.

To assess trust in the system, the SHAPE Automation Trust Index (SATI) was used (Figure 3). The system received an overall trust score of M=4.67. For the group that did not receive training the score was slightly higher (M 5.04, SD 0.15) than for the group that did participate in the training session (M 4.60, SD 0.22.).

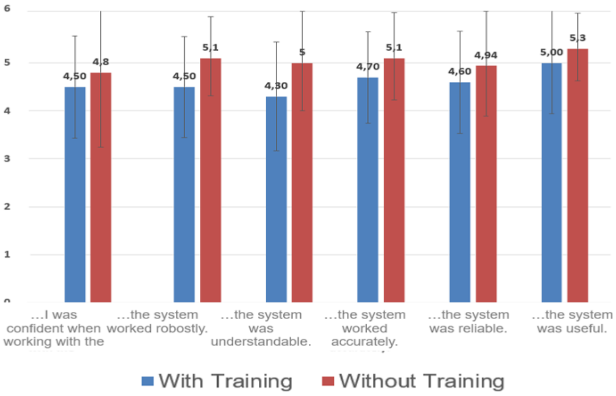


Figure 3. Subscale scores of the SATI. 0= never 6= always

Answers for VDL were overall positive. The system was rated with a high Usefulness score, (M 0.88, SD 0.17) for the trained group and (M1.1, SD 0,32) for the group that did not participate in the training. and a slightly lower Satisfying score for both the participants who received training (M 1.025, SD 0.45) training and the participants who did not receive training (M 1.124, SD). Scoring is from -2 (negative) to +2 (positive) and both ratings were positive.

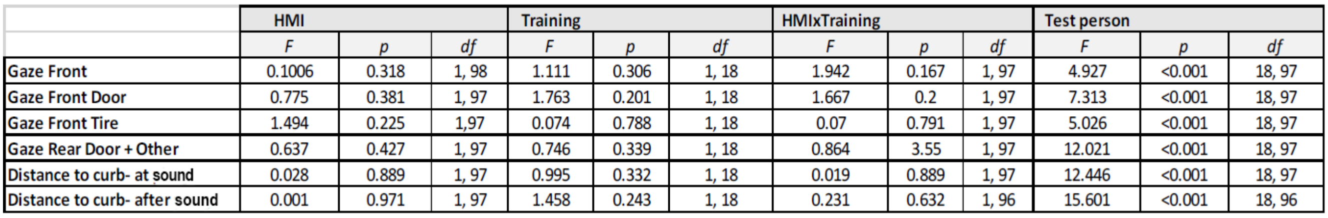
The results on the UEQ indicated overall positive feedback, with the highest scores recorded for perspicuity and efficiency, while the group without training had slightly higher mean scores for attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty compared to the group that participated in the training. There were no statistically significant differences between trained and not trained participants in VDL; SATI or UEQ scores (all p>0.05).

Sixteen out of twenty users (nine of those who had received the training and 4 who had not participated in the training) rated that it was clear that the bus was autonomous when the light and sound were activated.

In the evaluation of the training the 10 participants who received the training prior to experiencing the scenario provided overall positive feedback in the answers of 13 questions. They found the training to be easy to understand, clear, increased their acceptance of the system and made them more prepared to use the system. The questions receiving the lowest scores were about if the participant would benefit from the knowledge of the training. A few of the participants also wrote comments. Not being able to use the training and experience since this kind of system does not exist was mentioned twice in the comments.

Participant behaviour

The study analysed passenger gaze and distance from the curb while waiting for the bus. The data was analysed with a mixed model ANOVA. Overall, neither training nor HMI had a significant effect on



	HMI			Training			HMIxTraining			Test person		
	F	*p*	*df*	*F*	*p*	*df*	*F*	*p*	*df*	*F*	*p*	*df*
Gaze Front	0.1006	0.318	1, 98	1.111	0.306	1, 18	1.942	0.167	1, 97	4.927	<0.001	18, 97
Gaze Front Door	0.775	0.381	1, 97	1.763	0.201	1, 18	1.667	0.2	1, 97	7.313	<0.001	18, 97
Gaze Front Tire	1.494	0.225	1,97	0.074	0.788	1, 18	0.07	0.791	1, 97	5.026	<0.001	18, 97
Gaze Rear Door + Other	0.637	0.427	1, 97	0.746	0.339	1, 18	0.864	3.55	1, 97	12.021	<0.001	18, 97
Distance to curb- at sound	0.028	0.889	1, 97	0.995	0.332	1, 18	0.019	0.889	1, 97	12.446	<0.001	18, 97
Distance to curb- after sound	0.001	0.971	1, 97	1.458	0.243	1, 18	0.231	0.632	1, 96	15.601	<0.001	18, 96

Table 1. Results from the ANOVA.

the measured parameters. Additionally, there was no significant interaction between HMI and Training. Thus, participants behaved similarly around the bus irrespective of whether the HMI was on or off and the training did not affect participants' gaze pattern or distance to the curb. However, there were significant individual differences among participants for all factors, see **Fel! Hittar inte referenskälla.**.

Debriefing interview

The largest differences between trained and not trained participants were found in the debriefing interview. Those who did not receive prior information about the bus's function were confused and assumed it was autonomous at all times, some perceiving the bus driver avatar as a simulation error, while the trained group provided more suggestions for system improvement, including the notion that closer proximity to the curb would be safer with an autonomous bus, and feedback on the bus's sound varied from positive for aiding visually impaired individuals to some finding it annoying and suggesting a melody instead; additionally, two participants who did not watch the training videos missed the blue lights at the initial bus stops due to VR headset resolution, but found the sound informative about the bus's mode and position.

Conclusions

The study aimed to evaluate the impact of training and HMI activation on passenger understanding and acceptance of automated docking at a bus stop. A VR simulation platform was used to simulate the scenarios. The study focused on the passenger's view, and no significant effects were observed on objectively measured parameters, such as gaze and safety distance to the curb, for either training or HMI. However, there were significant individual differences among participants for all factors. The subjective ratings of the training, the HMI, and the automated system were positive. VDL, SATI, and UEQ questionnaire scores showed that the group with training generally were less positive towards the system, possibly because they were more aware of the limitations of the HMI and the automated docking, but the differences were not statistically significant. The group that received training had more comments on the system during the debriefing interview but were optimistic about the training. The lack of significant differences may be due to the small sample size. Increasing the number of participants was not an option due to budget restrictions. Future studies could investigate further how VR technology can be used to test HMI solutions and increase acceptance of new automated vehicles in situations that are not yet possible or too dangerous to study in the real.

Acknowledgement

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