D33.4 Evaluation Report

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Document aim	This document presents the DCMS 5G CAL project final evaluation report based on the trials performed on site

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Version History

Version	Status	Date Amended	Amendment Summary
0.1	Draft		Table of contents
0.2	Final Draft	30th June 2022	Completed for review

Contents

1. Introduction

This deliverable addresses MS33 of the DCMS 5G CAL project, part of workstream 3 *Teleoperation Integration*. The workstream concludes the successful integration of 5G teleoperations with the Terberg trial vehicle on the live route at Nissan/ Vantec. This deliverable is the evaluation report based on completion of the trials.

The deliverable directly relates to D22.5 Evaluation Plan, which was submitted in claim period 4. That deliverable reported the testing schedule as it was envisaged at the time, proposing seven evaluation tasks covering both quantitative and qualitative data collection and analysis.

Evaluation Plans are inevitably 'living' documents produced early in a project and are subject to some changes based on events and circumstances affecting a project during its lifespan. This evaluation plan is no exception, and the resulting changes to the tasks in terms of scope and experimental design are explained in Chapter 3, with the results based on the revised evaluation plan presented in Chapter 4.

2. Final Test Schedule

The testing schedule organised by StreetDrone is shown in the figure below. Description of the different testing phases is provided in other deliverables. This deliverable focuses on activities that took place during the trial phase on the Nissan 'live' route during weeks 21-23.

Fig. 1 Testing Schedule (courtesy StreetDrone)

	February 2022			March 2022					April 2022				May 2022					
	Week 6	*Week 7*	*Week 8*	*Week 9*	*Week 10*	*Week 11*	*Week 12*	*Week 13*	*Week 14*	*Week 15*	*Week 16*	*Week 17*	*Week 18*	*Week 19*	*Week 20*	*Week 21*	*Week 22*	*Week 23*
Week commencing	07/02/22	14/02/22	21/02/22	28/02/22	07/03/22	14/03/22	21/03/22	28/03/22	04/04/22	11/04/22	18/04/22	25/04/22	02/05/22	09/05/22	16/05/22	23/05/22	30/05/22	06/06/22
Local Area																		
Self-driving	**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**													
Truck build																		
MRM																		
Teleoperation																		
Trials																		
Millbrook																		
Self-driving																		
Truck build																		
MRM																		
Teleoperation																		
Trials																		
Nissan Test Track																		
Self-driving						**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**								
Truck build																		
MRM						**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**								
Teleoperation						**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**								
Trials																		
Nissan "live" Route																		
Self-driving											**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**			
Truck build																		
MRM											**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**			
Teleoperation											**Terberg**	**Terberg**	**Terberg**	**Terberg**	**Terberg**			
Trials																**Terberg**	**Terberg**	**Terberg**
					D22.3 DBW Calibrated													
								D22.3 DBW Sign-off Compelete										
								D26.0 Heavy Haulage demonstrated on-site - Autonomous trailer towing demonstrated on test track at Nissan site										
								nabled Teleoperation Demonstration - Demonstration completed prior to full trial with Test track test report completed										
															D33.1 CAVL manoeuvres complete - Defined manoeuvres completed using heavy truck in logistics context on Nissan site			
																		D33.2 Trial period - Trial report on Vantec Road trial
																		D35 Vehicle to Infrastructure Demonstration Complete
																		D42.1 Public engagement workshop, D42.2 Media Event

3. Changes to Evaluation Plan

Since the Evaluation Plan was submitted during claim period 4, certain tasks or elements of the experimental design of those tasks have been changed. This is quite a common occurrence with evaluation plans, which are usually produced early in a project and represent an 'ideal' but tend to require some reactive measures or adjustments as a project proceeds. In some cases, the scope of a task necessarily becomes more refined or targeted because of events that take place during testing; in other cases, the experimental design needs to change because of organisational issues or changes to the project scope; occasionally, external events limit the scope of an activity, for example the impact of Covid on face-to-face data collection.

In the case of the evaluation plan for the 5G CAL project, some changes have been made. In the following table, the implemented evaluation plan is compared to the original plan, with full explanations provided where changes have occurred.

Original Experimental Tasks (D22.5 CP4)	Revised Experimental Tasks (D33.4 CP7)	Reason for change
1. Quantifying the impact of 5G on the performance and effective transition control of CAVL (Quantitative)	Evaluation of the decision-making effectiveness and performance of the teleoperation system (Quantitative)	*Minor change* *The experiment focuses less on 5G's impact and more about the actual performance of the transition control and is covered by the design of tasks 5 & 7*
2. Investigation of the influence of the Teleoperation Tactical Decisions on on-road fuel economy	NA	*The Terberg tractor is electric and as a proof-of-concept it has not been possible to do a like-for-like comparison of diesel and electric operations*
3. Evaluation of the influence of the HMI on the takeover control performance of the human driver on-board	NA	*On site H&S prohibits work directly with human safety driver. However, some findings have been elicited through interview*
4. Evaluation of the impact of Multitasking on the takeover control performance of the human driver on-board	NA	*On site H&S prohibits work directly with human safety driver. However, some findings have been elicited through interview*
5. Investigation of the effect of disengagement level on the takeover control performance of the remote operator	Investigation into the influence of mental disengagement on the takeover control performance of the remote driver (Quantitative)	**No change** **Experimental design – unchanged**
6. Remote Drivers as the Fallback Strategy: Qualitative Exploration of Users' Needs and Requirements towards the Human-Machine Interactions in the 5G enabled Level 4 Automated Vehicles		**No change** **This task was achieved and reported in D21.3 (claim period 5)**
7. Qualitative investigation into the needs and requirements of the remote controller of 5G CAL to inform the design of level 4 automated vehicles	Qualitative investigation into the needs and requirements of the remote controller of 5G CAL to inform the design of 5G enabled level 4 automated vehicles (Qualitative)	**No change** **Experimental design – unchanged**
8. Public engagement - investigation into the public's requirements and perceptions towards the human-machine interaction of 5G CAL (optional)		*This task was optional, but some elements have been achieved through D21.3*

4. Evaluation of Tasks on the Live Route

Fig. 1 The Terberg electric autonomous tractor unit with trailer at the Vantec site

Quantitative Task - Investigation into the influence of mental disengagement on the takeover control performance of the remote driver and their interaction with 5G enabled level 4 automated vehicles

<u>Introduction</u>

The 5G CAL system designed by StreetDrone could potentially enable the evaluation of connected and automated vehicles (CAV) classified as SAE Level 4 automation (SAE J3016) thanks to the involvement of the Teleoperation system. A SAE Level 4 automation system refers to a system where an automated driving system responds to all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene. One important safety use case of the 5G CAL is the transition of the control process of CAVL during critical situations which the vehicle itself is not able to cope with. In such critical situations, the automated driving system will pull a stop and initiate a request to the safety driver on-board. In this situation, the human driver needs to re-engage themself into the vehicle control loop, to manually intervene by taking over the lateral and longitudinal control of the vehicle. However, if they are not able to do that appropriately, the automation system will initiate a 'fail-safe' mode where the control of the vehicle will be taken over by the Teleoperation system powered by the 5G network connection and controlled by a specially trained human remote controller. Therefore, the evolution of such use cases will mainly focus on the interaction between the three parties during a transition of control process:

- The automated driving system
- The teleoperation system controlled by the human operator
- The human on board safety driver

To date, there is limited knowledge regarding the remote driver's behaviour as well as their attention when interacting with 5G CAL. Whether the remote driver exhibits different behaviour when they are constantly monitoring the system compared to when they are distracted before being required to take over the control of the 5G CAL is under researched.

Aim

To add new knowledge and fill the knowledge gap above, the aim of this task is to explore the remote driver's attention and behaviour when interacting with 5G CAL, with a particular focus on investigating the effect of the mental disengagement on the remote driver's takeover performance and behaviour in 5G CAL.

Outline of the trial

Automated driving → Encountering system limitation → Pull to a stop → Inform the teleoperation system to take over control

Site: VanTec Road (Figure 3).

Experimental design

One-way repeated measure experimental design with Disengagement as the within subjective experimental variables.

The Disengagement variable contains two levels:

- Baseline condition - Monitoring driving (constantly monitoring the AV driving)
- Experimental condition - Disengaged (disengaged from monitoring the AV)

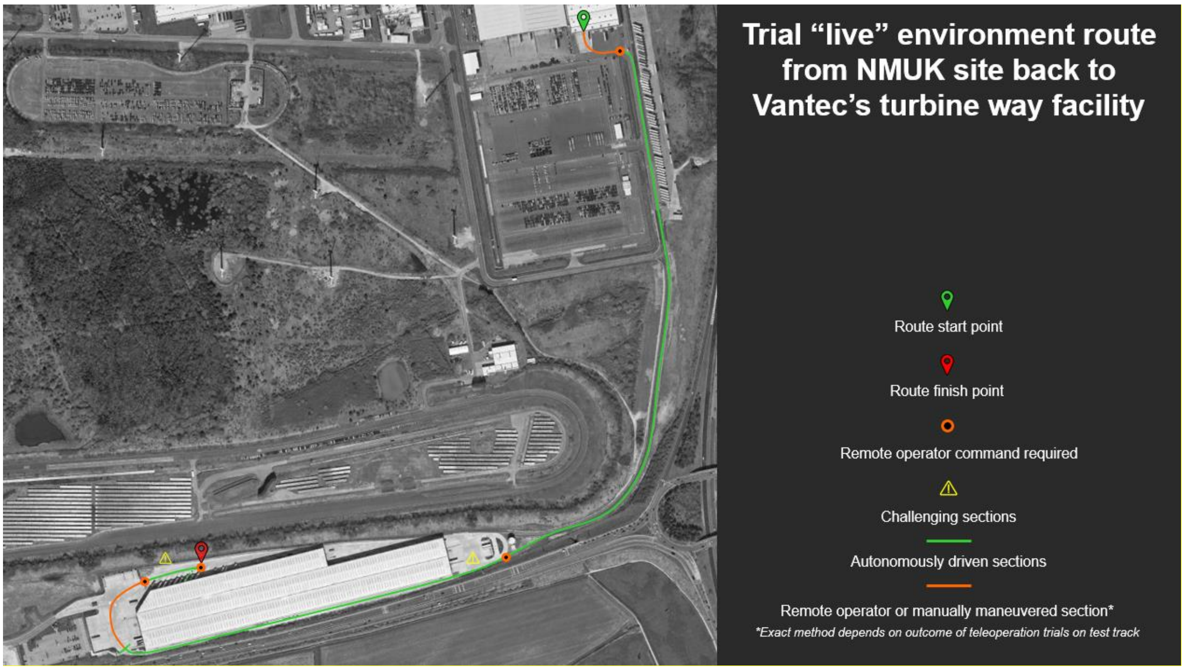

Fig. 3 Live Route between Vantec and NMUK

The baseline condition is 'Monitoring driving' when the remote driver is not operating the 5G CAL remotely. In this condition, the remote driver is physically disengaged from the control (their hands are off the steering wheel of the teleoperation unit). They wear a headphone to communicate with the 5G CAL on-board safety driver. They are constantly monitoring the 5G CAL driving and they are not distracted by any non-driving related activities. The following figure shows the 'Monitoring driving' condition.

Fig. 4 The remote driver is in the Monitoring driving condition

The experimental condition is 'Disengaged condition' when the remote driver is not operating the 5G CAL remotely. As with the baseline condition, in the 'Disengaged condition' the remote driver is physically disengaged from the control (their hands are off the steering wheel of the teleoperation unit). They wear a headphone to communicate with the 5G CAL on board safety driver. They are distracted by performing a non-driving related task (a reading task executed using a hand-held tablet). The following figure shows the 'Disengaged driving' condition.

Fig. 5. The remote driver is in the Disengaged driving condition in 5G CAL

Trial Design

Each remote controller experienced two trials:

- Monitoring
- Disengaged

Measurements

All the measures were collected using Tobii Pro Glasses 2.

Measurements	Data Type	Unit
Motor readiness time	Continuous	Seconds
Decision-making time	Continuous	Seconds
Gaze behavior	Nominal	N/A

Results

Motor readiness time

The motor readiness time is adopted to quantify how fast the remote driver reacts to a request (required to proceed or takeover requests). It is defined as the time duration between the point of receiving an 'authorisation required to proceed' request to the point that the remote driver makes a move (verbal response or moves hands) to initiate a 'GO' or 'NO GO' decision. The following figure illustrates the motor readiness time.

Fig. 6. Illustration of Motor readiness time

The results showed that when the remote driver is asked to intervene in the monitoring condition, a motor readiness time of 2.916s was generated. When he is in the disengaged condition, a motor readiness time of 8.225s was captured. A difference of 5.309s.

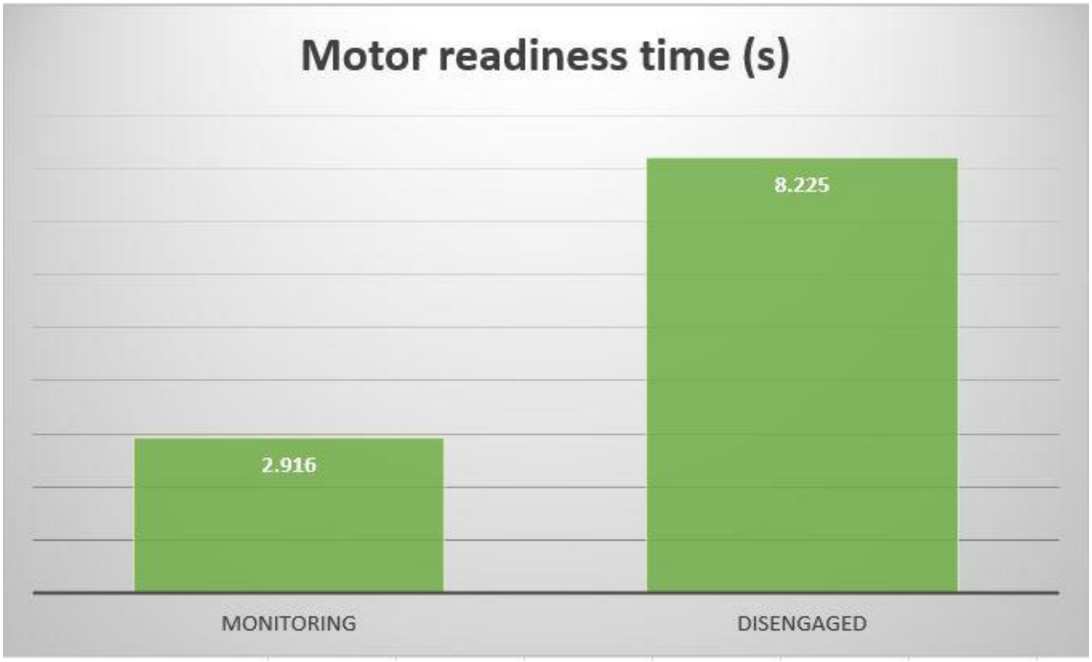

Fig. 7. The remote driver's motor readiness time in the monitoring (baseline) and disengaged (experimental) conditions

Decision Making time

The decision-making time is adopted to quantify the speed of the remote driver's decision-making when receiving a notification to step in. It is defined as the time duration between receiving the 'authorisation required to proceed' request/or a request to take over and the time point when the remote driver makes a decision of 'GO' or 'NO GO'/starts to operate the vehicle remotely. The following figure illustrates the decision-making time.

Fig. 8. Illustration of decision-making time

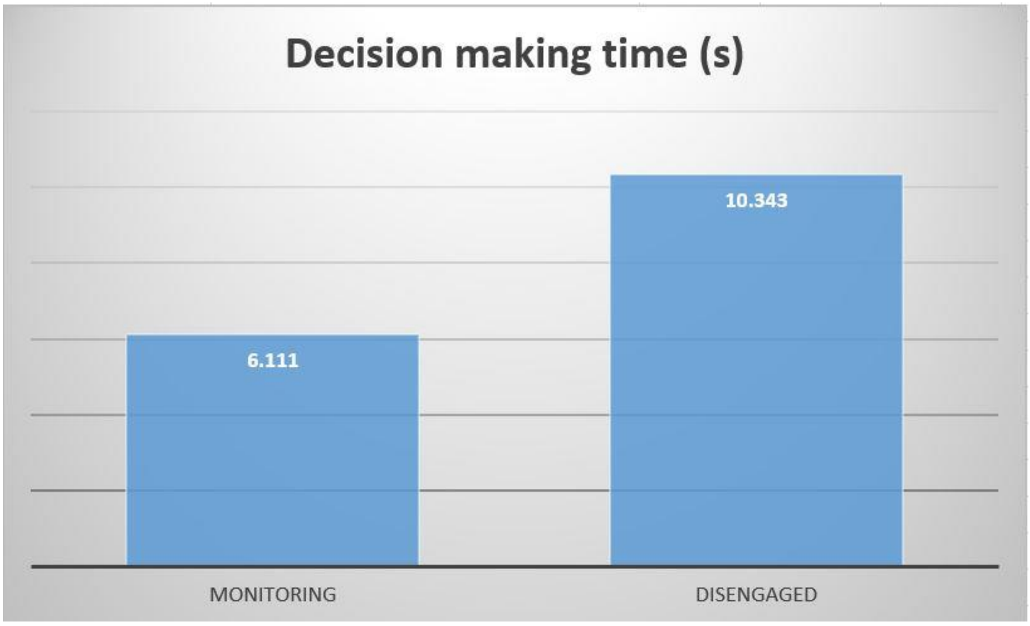

Fig. 9. The remote driver's decision-making time in the monitoring (baseline) and disengaged (experimental) conditions

The results showed that when the remote driver is asked to intervene in the monitoring condition, a decision-making time of 6.111s was generated. When he is in the disengaged condition, a motor readiness time of 10.343s was captured. A difference of 4.232s.

The above showed that the disengagement led to delay in both motor readiness time as well as the decision-making time. The possible explanation is that when the remote driver is distracted by the reading task while the 5G CAL system is performing automated driving, the divided attention and multitasking may lead to a slowed reaction time and slowed decision-making. In addition, the disengagement condition was achieved via the remote driver physically holding a tablet. So, when he was suddenly required to step in, he had to put down the tablet, which led to further delay in terms of reaction time and decision making.

The above sections explored the impact of disengagement on remote driver's interaction from a behaviour perspective using two time-based measures. The following sections will explore the influence of disengagement on the remote driver's interaction from a visual attention perspective.

<u>Remote driver's visual attention while interacting with the 5G CAL</u>

The remote driver's visual attention is illustrated using eye tracking heat maps. Eye tracking heat maps show how looking is distributed over the stimulus. Heat maps are a visualization that can effectively reveal the focus of visual attention for the participant. Since the experimental design involves a manipulation (disengagement achieved by distracting the remote driver using a reading task on a tablet) to affect a cognitive process, 'fixation duration' is the appropriate eye tracking measure. Fixation duration is a widely used measure and generally recognized to increase with additional mental task demands (Marquart *et al*, 2015). Previous research regarding driver hazard perception has found increased fixation durations during hazardous moments, indicating increased mental workload. Long fixation duration is associated with high processing load. In this study, duration-based heat maps for the monitoring condition and disengaged condition were generated.

The following heat maps show fixation behaviour of the remote driver in the monitoring condition and disengaged condition. They were generated on the basis of absolute fixation durations and both heat maps are scaled to 2.2 second maximum corresponding to deep red.

The following figure shows the remote driver's visual attention in the monitoring driving conditions. When the remote driver is monitoring the 5G CAL system driving, his visual attention was broadly distributed over the monitors with high fixation duration focused on the road ahead.

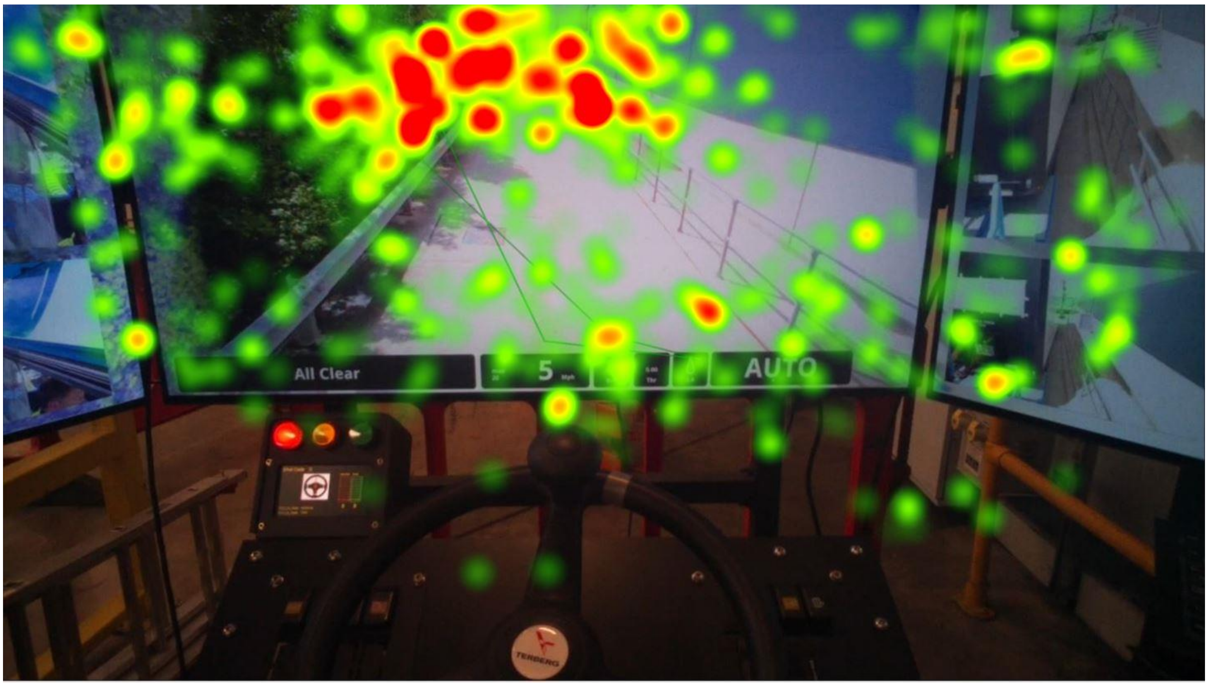

Fig. 10. Fixation durations heat map when remote driver is in the monitoring condition (Gaze filter-Tobii I-VT, Radius 30 px, Scale max value 2.20 s)

The following figure shows the remote driver's visual attention in the disengagement driving conditions. When the remote driver is distracted by the reading task while the 5G CAL system is driving autonomously, his visual attention was broadly distributed between the monitors as well as the tablet with high fixation duration spread between the monitors and the tablet. Compared to the monitoring condition, the remote driver exhibited increased heat in the disengagement condition, indicating slightly higher mental workload. In addition, their point of attention was also affected by the reading task. This is in accordance with the delayed motor readiness time and decision-making time due to the disengagement caused by the reading task. The possible explanations of this finding may be that the remote driver was distracted by the reading task, with their attention divided between the tablet and the monitors, which potentially increased the cognitive workload. In addition, the multitasking involved in this process also contributed to the increase in cognitive workload.

Fig. 11. Fixation durations heat map when remote driver is in the disengaged condition (Gaze filter-Tobii I-VT, Radius 30 px, Scale max value 2.20 s)

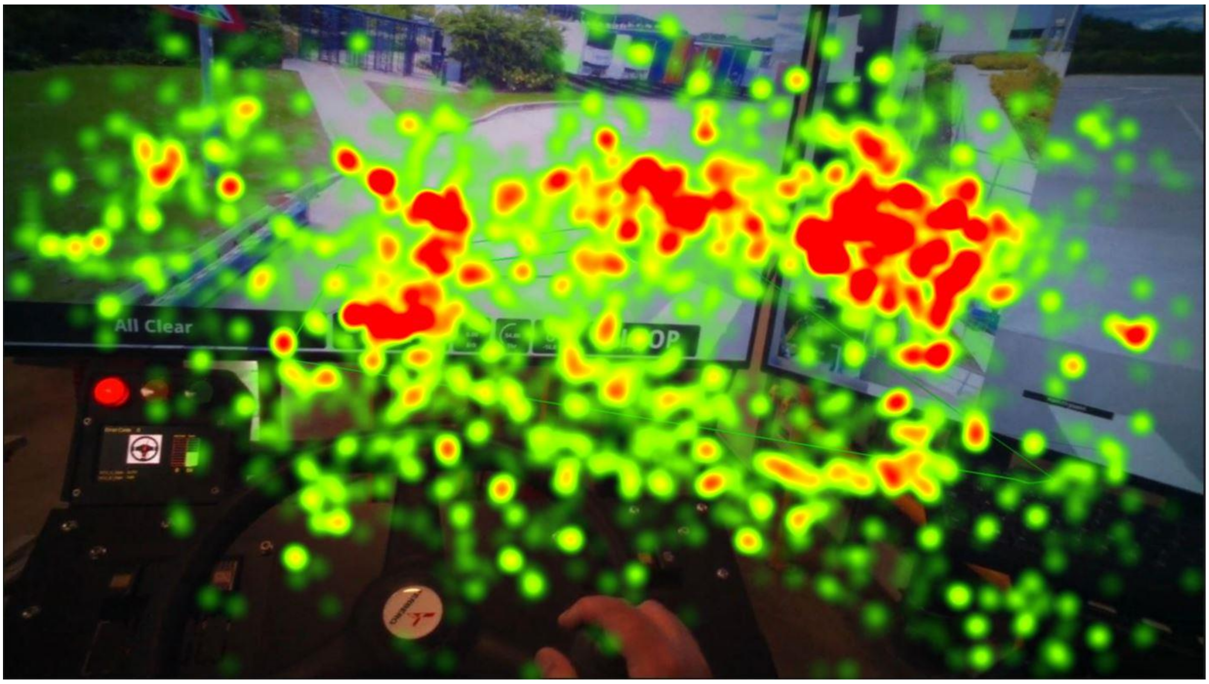

Fig. 12. Fixation durations heat map when remote driver is in the teleoperation mode (Gaze filter-Tobii I-VT, Radius 30 px, Scale max value 2.20 s)

Figure 12 shows the remote driver's visual attention in the teleoperation mode. It shows that when the remote driver is operating the vehicle remotely, there is significant increase of fixation duration compared to both monitoring and disengagement conditions, indicating increased cognitive workload when operating the vehicle remotely.

<u>Summary</u>

This task attempts to quantity the human-machine interaction between the remote driver of the teleoperation systems and the 5G CAL. The main purpose was to explore the remote driver's attention and behaviour when interacting with the 5G CAL. The main findings are as follows:

- Compared to constantly monitoring driving, the mental disengagement (achieved by distraction via a reading task on a tablet) led to slowed motor readiness time of the remote driver when required to step in, with a difference of 5.309s
- Compared to constantly monitoring driving, the mental disengagement leads to slowed decision-making time of the remote driver when required to step in and make a decision, with a difference of 4.232s
- Compared to constantly monitoring driving, the mental disengagement affects the remote driver's attention focus from the road
- Compared to constantly monitoring driving, the mental disengagement leads to increased cognitive workload for the remote driver
- When the remote driver is controlling the vehicle remotely, it resulted in higher cognitive workload compared to monitoring and disengagement conditions

<u>Future work</u>

This study has generated useful knowledge and findings. There are several directions that can be further explored in the future.

- A higher sample size. The current study collected data from one remote driver because the 5G CAL is still in the early stages. Future work could repeat the current experiments using a much larger sample size
- In the current study, the non-driving task adopted was reading from a tablet. There are still plenty of tasks that could be adopted to distract the remote drivers. Future research could test their impact on the remote driver's attention and behaviour. For example, eating, drinking, reading or using mobile phones
- In the current study, the remote driver was in an environment with some levels of noise. To control the impact of environment in order to precisely quantify the impact of disengagement on the remote driver's status, performance and interaction with the 5G CAL, future research could repeat the research in a relatively quiet environment
- The current design of the human-machine interfaces (HMIs) between the remote driver and the 5G CAL is visual and auditory. Future research could explore the HMI designs with different modalities, such as visual, auditory and vibration
- The findings found that the remote drivers' mental workload was higher when they were controlling the vehicle remotely compared to when they were in standby status.

Future research could explore potential measures that can reduce remote driver's mental workload when controlling the vehicle remotely. This would be especially significant in connection with experiments where the remote driver is responsible for controlling more than one vehicle

Qualitative Task - Investigation into the needs and requirements of the remote controller of 5G CAL to inform the design of 5G enabled level 4 automated vehicles

Introduction

In the 5G CAVL deployed in this project, SAE Level 4 automated driving is achieved via the 5G enabled teleoperation system operated by the remote controller. Understanding the needs and requirements of support from the remote operator's perspective is important to design safe and user-friendly 5G enabled automated vehicles.

Aim

To qualitatively investigate the remote operator's needs and requirements in 5G CAL.

Methods

Participants requirements (1. valid UK driving licence holder. 2. Active driver while participating in the research. 3. Having experience of / actively engaged with the teleoperation system). The sample recruitment resulted in 6 people (4 from StreetDrone and 2 from Vantec).

Topics of the semi-structured interview

- What is your general opinion of the Level 4 automated vehicle?
- If you are sitting in the remote-control centre and the vehicle is performing automated driving, what would you do?
- How would you prefer to be informed about a remote-control request of the automated vehicle?
- What are the differences and similarities between operating the vehicle on-board and remotely?
- When you are performing the remote control of the automated vehicle, what difficulties have you encountered?
- When you are performing the remote control of the automated vehicle, what support do you need?
- Any recommendations to the OEM (in terms of vehicle design and remote-control centre design).

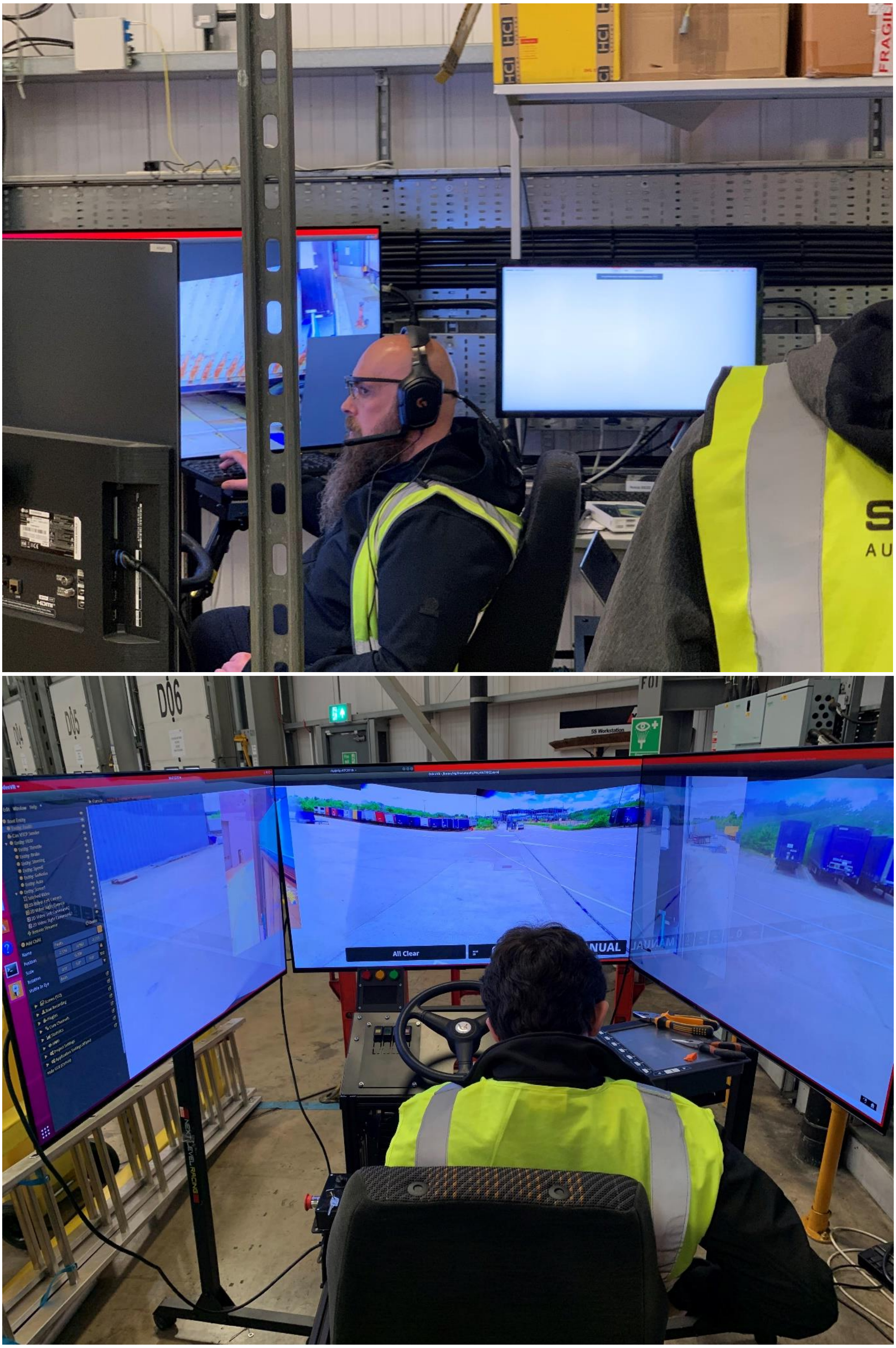

Fig. 13. Remote drivers in the teleoperation unit

Procedure

As illustrated in the following figure, the first step is experimental design, with the research proposal submitted to Newcastle University Ethical Committee for review. After the Ethical Approval was granted, the research team contacted the subjects eligible for this research from within the project. The data collection then started. The subjects' opinions and requirements were collected using semi-structured interviews. After that, the interviews were transcribed. The transcribed data was reviewed against the original interview by two researchers separately. Then, the data was analysed and the report was written.

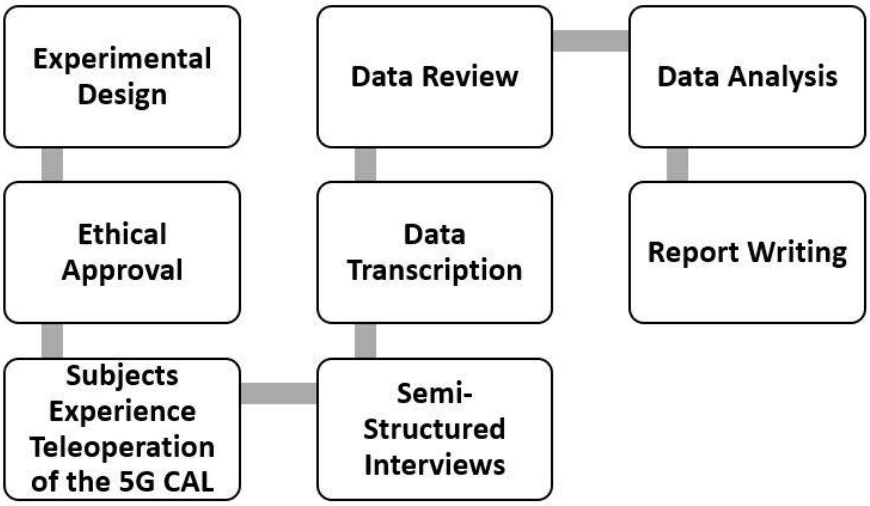

Fig. 14. Illustration of research procedure

Findings

Summary of Main findings:

- Remote drivers have positive attitudes towards the 5G CAL
- Remote drivers would be monitoring the road when the 5G CAL is performing automated driving. They expect to be informed if something happens
- In terms of the human-machine interfaces, the remote drivers would like to have verbal communication if there is a safety driver on-board. If there is no safety driver on board, a visual, audible and vibration HMI would be beneficial
- The main difference and difficulties remote drivers experienced when controlling the vehicle remotely is lack of depth vision as well as not being able to feel the feedback from the vehicle when executing a manoeuvre (e.g. bumps in the road)
- Remote drivers would like more support to augment their vision when driving
- Remote drivers' decision making (GO or NO GO) is consistent with the on-board safety driver's

General opinions Towards 5G CAL:

The following italicised statements are direct quotes from the interviewees.

- *I think obviously it's looking really good, you can get good feedback from the remote or teleoperation side by the end of the project. The visibility and visual aids that the person's got are really good in terms of mirrors and replicate what you would get if you're in the vehicle*
- *I think it has some very good use cases. I don't think it's applicable for the public, you know, the average consumer. I think it's got some good use cases for business in controlled environments*
- *All I do is keep an eye out for any problems*
- *It seems amazing to me*
- *At first I could never see it working – thought it was crazy. As time went on I was amazed. It's like nothing I'd ever seen before. Couldn't take my eyes off the screen.*

Things to do for the remote driver when the 5G CAL is in automated driving mode:

- *Obviously, the screens are displaying the same video data that they always are, so you can kind of keep an eye on what the vehicle is doing, but there's no role as it were*
- *I don't need to do anything until it tells you there's a problem. If it's level 4 I don't need to be constantly monitoring it, there should be enough time for me to take over rather than an immediate thing. I would do whatever I would, just sit and have a look at the cameras*
- *I'm observing it all the time. It can't check way points by itself. I'm checking the way ahead is clear.*

Human-machine Interfaces between the remote driver and the 5G CAL:

- *So, the moment there's obviously a message popping up bottom left hand corner of the screen. Probably would be beneficial if there's some kind of audible noise as well. So, I don't think we have that at the moment. In case you're looking at the way or looking at something different*
- *Audible is usually good, an audible alert as well as visual, some sort of buzzer maybe not a siren, what could potentially also be useful is like a pack tile. A frequency device that can vibrate the chassis, I feel that would be a very noticeable thing. Even if you're listening to music or watching a film or something*
- *Just a clear instruction would be nice, don't know how practical that is on a large scale*
- *If there's safety driver in the vehicle, I'll definitely want a verbal communication with them. Where there's no safety driver and of course it has to be like a digital like pad in front of you, tells you this is what's going on, on a screen. Visual prompt on the screen.*

Difference between operating a vehicle on-board and remotely:

- *The similarities are we got quite good views on what's around you. I think differences are, again, it's the feel of the vehicle, so acceleration, deceleration, you don't get any of that feel. And then also the audible kind of feedback of what's going on with the vehicle, you don't get any feel of that either*
- *'Cause obviously you don't get the size of the vehicle as easily, so it can be more difficult to tell distance, obviously you're looking at a 2D screen, so you can't get the 3D without VR or something like that, then you could have the depth vision. But at the moment the way it is currently, it's hard to have a perception of speed and the size of your vehicle*
- *The camera angles, obviously when you're in a car you've got 360 degrees view*
- *The main difference is you can't feel it. In normal driving you can, like you feel your foot on the pedal and you can steel the vehicle like rolling forward, you can hear it, you turn the wheel, you can hear it. In the remote driver seat, you don't get that at all*
- *Major difference is lack of feedback from steering wheel e.g. bumps in the road*
- *In a real truck you can turn your head and see behind you – in a tight reverse in remote control you lose the vision of where the rear of the trailer is. Wide angled mirrors can help. This maybe an area for more improvement*
- *I think the main difficulties are seeing those kind of blind spots and seeing right in front of you when it's really close around you, so kind of sometimes gauging the vehicles, if the road is quite narrow, gauging how close you are on either side is a little difficult because you haven't got that view right down in front of you. And also I kind of witnessed some of the guys when we done live loads with a heavier trailer, the difference between a light trailer versus a heavy trailer, you don't necessarily get the feel for that from the remote driver either*

Support needed for the remote driver:

- *Some extra camera views and then also extra feedback in terms of probably movement of the seat or the wheel and things like that would help. Also, potentially some feedback through the wheel of pedals and you've got a different load on*
- *VR could be one option, it could give you the depth perception then you could have your peripheral vision and be able to see things more clearly*
- *Visual cues on the monitors could be a good way to have markers for where your vehicle is*

GO or NO-GO Decision Making:

- *I don't see any occasions where, as a remote driver, we've been keen to proceed, but then the safety driver put their foot on the brake to stop it effectively. So, I think it's been really successful in terms of the decision that the remote driver is making*
- *Yeah, it's pretty much exactly the same*

- *Yes. my decisions correspond to the safety driver's. I can see the entire area, they can see like everything*
- *Yes, we are in constant communications. I wouldn't authorise without his authority first*

Conclusion and Future work

This study qualitatively investigated remote drivers' opinions and requirements towards the driver-vehicle interaction of 5G CAL. The remote drivers are positive towards the 5G CAL but perceived some limitations of the remote operation in terms of their vision as well as the perception of feedback from the vehicle. The strategic decision-making is consistent between the remote driver and the safety driver on-board.

The findings of this work have important implications for stakeholders including policymakers, OEMs, and research organisations, in terms of the development of safe and comfortable human-machine interactions between the remote driver and the 5G CAL.

The findings of this work could be developed in the following directions for future work:

- Future work could adopt a larger sample size of remote drivers
- Future work could explore potential measures of the remote driver's vision in terms of enhancing depth vision
- Future work could investigate potential measures for enhancing the remote driver's feeling and perception of feedback from the vehicle when a manoeuvre is executed
- Future work could investigate the remote driver's needs and requirements when a safety driver is not on board
- Future work could investigate the user requirements from the on-board safety driver's perspective

5. Conclusion

This deliverable contributes to the successful integration of 5G teleoperations with the Terberg trial vehicle on the live route at Nissan/ Vantec, which culminated on 15- 16th June with the autonomous Terberg delivering automotive components in a live manufacturing environment to Nissan Manufacturing UK (NMUK) from Vantec without on board human intervention. The vehicle performed autonomous reversing into the dock at Vantec and teleoperated (remote) reversing into the dock at NMUK.

The deliverable directly relates to D22.5 Evaluation Plan, which was submitted in claim period 4. That deliverable reported the testing schedule as it was envisaged at the time, proposing evaluation tasks covering both quantitative and qualitative data collection and analysis.

The evaluation as executed mainly focuses on the interactions between the three parties (on board safety driver, Level 4 automated driving system and the remote operator) during transition of control Th evaluation attempts to quantity the human-machine interaction between the remote driver of the teleoperation systems and the 5G CAL. The main purpose is to explore the remote driver's attention and behaviour when interacting with the 5G CAL. The main findings are as follows:

- Mental disengagement (achieved by distraction via a reading task on a tablet) led to slowed motor readiness time of the remote driver when required to step in
- Mental disengagement leads to slowed decision-making time of the remote driver when required to step in and make a decision
- Mental disengagement affects the remote driver's attention focus from the road
- Mental disengagement leads to increased cognitive workload for the remote driver
- Remote control of the vehicle results in higher cognitive workload compared to monitoring and disengagement conditions

Part of the evaluation gathered information from the remote drivers and safety driver through interview. The feedback was overwhelmingly positive:

- Remote drivers have highly positive attitudes towards the 5G CAL
- Remote drivers are monitoring the road when the 5G CAL is performing automated driving
- Remote drivers would like to have verbal communication if there is a safety driver on-board. If there is no safety drivers on board, a visual, audible and vibration HMI would be beneficial
- Remote drivers would like greater depth vision and physical feedback from the vehicle when executing a manoeuvre (e.g. bumps in the road)
- Remote drivers' decision making (GO or NO GO) is consistent with the on-board safety driver's