Trial 3: Interactions Between Autonomous Vehicles and Pedestrians and Cyclists
What is VENTURER?

VENTURER is a £5m research and development project funded by government and industry and delivered by Innovate UK. Throughout the project’s three-year lifecycle, the potential future of Connected and Autonomous Vehicles (CAV) is being explored through a series of road and simulation trials, research into public acceptance, investigation of technical challenges, and studies of the insurance and legal implications.

The trials and the data collected will together provide a greater understanding of how the technology performs, how people interact with the technology and will aid in informing the development of future insurance models and legal frameworks. This will help in enabling the deployment of autonomous vehicles on UK roads.

Authors and contributors

The University of the West of England - Bristol (UWE) Centre for Transport and Society were the primary collators of the human factors elements of this summary report.

Discussion on the technology was co-ordinated by the Bristol Robotics Laboratory (BRL). The VENTURER Simulator was developed by Williams Advanced Engineering. BAE Systems provided the Wildcat vehicle and implemented the Wildcat experiments in partnership with UWE. Atkins co-ordinated the experiments and the production of this summary report.

Definitions

Autonomous Vehicle (AV) is a vehicle which uses a range of advanced vehicle systems, enabling it to operate with no driver intervention in some or all driving situations.

Connected and Autonomous Vehicles (CAV) are autonomous vehicles that communicate with each other and other objects or infrastructure.

The Wildcat used in VENTURER’s third trial is classed as an AV and is referred to accordingly throughout this report.
**Trial 3: Participant Experiments**

The Trial 3 participant experiments investigated road user behaviour and participant trust when AVs (Autonomous Vehicles) form part of traffic in urban environments. The ability of AVs to interact safely with a range of road users, particularly in urban settings where interactions are most common, is a crucial step towards enabling their integration into the wider transport network and safe deployment onto UK roads.

The objective of the Trial 3 participant experiments was to test the responses of observing cyclist, driver and pedestrian participants by asking them to rate their trust in an autonomous vehicle as they observed it interacting with pedestrian and cyclist actors. This took place while the AV manoeuvred around seven typical highway scenarios at T-junctions and on road links.

The main objective of the technology in Trial 3 was to facilitate the experiments by replicating and building on the autonomous system used for Trial 2 (Interactions Between Autonomous Vehicles and Other Vehicles on Links and at Junctions).

The human factors research questions that Trial 3 sought to address are outlined below:

<table>
<thead>
<tr>
<th>Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the trust in the AV vary depending on the manoeuvre the AV is undertaking?</td>
</tr>
<tr>
<td>How does trust in the AV vary depending on whether the observer is a pedestrian, cyclist or driver-passenger in the AV?</td>
</tr>
<tr>
<td>How does trust in the AV vary depending on whether the AV is the real-world Wildcat or the VENTURER Simulator?</td>
</tr>
<tr>
<td>In the simulator environment, how do the observing pedestrian and cyclist rate the scenarios when the vehicle is being driven by a human as compared with when the vehicle is in autonomous mode?</td>
</tr>
<tr>
<td>Does trust in the AV correlate with age, driving experience or trust in automation?</td>
</tr>
</tbody>
</table>

**How did we do it?**

A total of 133 participants took part in the Trial 3 participant experiments. Based on their most frequently used mode of transportation these participants were designated roles during the experiments:

- Cyclists;
- Drivers; and
- Pedestrians.

Participants were asked, thinking of themselves in their designated role, whether they trusted the behaviour of the AV after having observed a range of driving scenarios undertaken by the Wildcat road vehicle and in the VENTURER Simulator.

The scenarios were replicated in the VENTURER simulator, also housed at BRL. The simulator was set up to provide the same environment as that experienced in the real world in the Wildcat in terms of layout of the road and certain distinctive landmarks (e.g., the Exhibition Centre building).
**Experiment Design**

Trial 3 replicated seven complex scenarios typical of those encountered on the UK road network every day. These are depicted and described below:

<table>
<thead>
<tr>
<th>Scenario Description</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proceeding along a road with a zebra crossing, but no-one crossing.</td>
<td><img src="image1.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Turning right into an empty road.</td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Turning right with pedestrian crossing side road.</td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Turning right into side road with on-coming cyclist.</td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Overtaking a parked car with an on-coming cyclist.</td>
<td><img src="image5.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Overtaking a parked car with no on-coming traffic.</td>
<td><img src="image6.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Proceeding along a road with pedestrian crossing zebra crossing.</td>
<td><img src="image7.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**What did we find out?**

The findings in Trial 3 are consistent with those of Trial 2, which gives further confidence in the experimental design used within VENTURER’s trials. The reliability and consistency of the trust measures obtained in Trial 3 are also supported by the correlation between participants’ trust in automation and their trust ratings, with people who reported high levels of trust in general automation providing high trust scores.

<table>
<thead>
<tr>
<th>Human Factors Research Questions</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does the trust in the AV vary depending on the manoeuvre the AV is undertaking?</td>
<td>Trust ratings varied between participants and between manoeuvres. However, the differences were often small and patterns were not consistent across the Wildcat and simulator experiments.</td>
</tr>
<tr>
<td>How does trust in the AV vary depending on whether the observer is a pedestrian, cyclist or driver-passenger in the AV?</td>
<td>There was no statistically significant difference in the trust ratings given by cyclist, driver or pedestrian participants. This was the case for all scenarios in both the Wildcat and the simulator.</td>
</tr>
<tr>
<td>How does trust in the AV vary depending on whether the AV is the real world Wildcat or the VENTURER Simulator?</td>
<td>For all scenarios combined, trust ratings in the Wildcat were slightly higher than the trust ratings in the VENTURER Simulator. However, the difference in trust scores between the platforms was only statistically significant for two of the seven scenarios.</td>
</tr>
<tr>
<td>In the simulator environment, how do the observing pedestrian and cyclist rate the scenarios when the vehicle is being driven by a human as compared with when the vehicle is in autonomous mode?</td>
<td>Trust ratings were slightly higher when the simulator was being manually driven as opposed to driving in autonomous mode. The differences in trust ratings were statistically significant for four out of the seven scenarios. It should be noted, however, that the trust scores are likely to have been influenced by the fact that the manually driven circuit was always performed last, when participants were most comfortable with the testing environment.</td>
</tr>
<tr>
<td>Does trust in the AV correlate with age, driving experience or trust in automation?</td>
<td>There were no statistically significant correlations between trust ratings in any of the scenarios and either age or driving experience indicating that groups such as older drivers, do not demonstrate a statistically lower or higher feeling of trust towards AV decisions. However, there were statistically significant correlations between the results from the “trust in automation” survey and the trust scores for all scenarios in the simulator and six of the seven events in the Wildcat.</td>
</tr>
</tbody>
</table>
What does this mean?

Rating of trust

Under all autonomous scenarios, average trust ratings across all participants were at least 7.3 out of ten, with ten representing the maximum possible trust rating. This is consistent with VENTURER’s Trial 2 experiments in which almost all scenarios received trust ratings of at least seven out of ten. This shows that exposure to AVs in safe environments yields generally high trust ratings.

There was also some evidence that the presence of another road user, in this case a cyclist, resulted in higher trust ratings. This suggests that a barrier to achieving the highest trust ratings is not knowing how an AV would have behaved in a manoeuvre they were asked to rate where another road user could have been present, but was not.

During Trial 3, participants’ trust scores appeared to be more sensitive to the movement and noise of the AV rather than the perceived risk of the scenario. Therefore, during the early stages of AV development, it is important to understand that aspects such as the smoothness of manoeuvres has an impact on the public’s perception of safety and trust. Undertaking the experiments with further refinements to automated control of the AV might result in even higher ratings.

Application of findings

A possible implication of the high levels of trust given to AVs operating in test environments is that members of the public might be too trusting of AVs in their early stages of development. This becomes particularly problematic when considered against the backdrop of ongoing debates around liability at different Society of Automotive Engineers (SAE) levels of autonomy. The distinctions between the SAE levels can be small and the potential for confusion in terms of a vehicle’s capabilities will be more acute during the early stages of AV development and deployment.

AXA and Burges Salmon’s third VENTURER insurance and legal report acknowledges that more work needs to be done to explore ways in which the risk of consumer confusion could be mitigated or prevented by design and to ensure that drivers are educated as to the capabilities and terms of use of the specific CAVs they may drive. Beyond this, as indicated by Trial 3 findings, CAVs may also need to be clearly identifiable in the real world to other road users, such as pedestrians and cyclists, particularly in their early stages of deployment.

Platform comparability

Although overall trust was higher for the Wildcat than for the VENTURER Simulator, only two of the scenarios exhibited a statistically significant difference between the two platforms. Where statistical differences were identified they are likely to be explained by specific aspects of the execution of the scenarios or experimental design.

Variability between participant category

There were no statistically significant differences in trust ratings between cyclist, driver or pedestrian participants reported for any of the scenarios in either the Wildcat or the simulator. This could indicate that there is no particular need to differentiate messaging around AVs for different audiences.

According to these results, no matter if members of the public can drive cars, or are users of a range of transport modes in everyday life, cars-in-motion are highly familiar objects in the environment, and provided they operate in ways similar to human-driven vehicles, they are accepted as ‘normal’ cars.

Application of findings

A possible implication of the high levels of trust given to AVs operating in test environments is that members of the public might be too trusting of AVs in their early stages of development. This becomes particularly problematic when considered against the backdrop of ongoing debates around liability at different Society of Automotive Engineers (SAE) levels of autonomy. The distinctions between the SAE levels can be small and the potential for confusion in terms of a vehicle’s capabilities will be more acute during the early stages of AV development and deployment.

AXA and Burges Salmon’s third VENTURER insurance and legal report acknowledges that more work needs to be done to explore ways in which the risk of consumer confusion could be mitigated or prevented by design and to ensure that drivers are educated as to the capabilities and terms of use of the specific CAVs they may drive. Beyond this, as indicated by Trial 3 findings, CAVs may also need to be clearly identifiable in the real world to other road users, such as pedestrians and cyclists, particularly in their early stages of deployment.

Variability between participant category

Ahead of the deployment of fully automated AVs onto UK roads, it is crucial that they continue to be thoroughly tested in safe and controlled environments. Future research should consider how the use of incrementally complex trials akin to real world situations can be used to increase understanding of road users’ trust in AVs. More complex trials should involve combining scenarios, for example introducing multiple pedestrians, cyclists and motorised vehicles, and allowing for scenarios involving closer proximity between AVs and participants. It is also crucial that trust ratings generated when participants are interacting with the AVs themselves are gathered and analysed, including in scenarios where participants may not be aware of the AV’s presence.

It is possible that the appearance of a very ‘safe’ environment is having an impact on trust scores and therefore future research should examine how trials can appear to be less closely-managed, whilst retaining the high levels of safety. This could involve marshals wearing more discrete clothing or being more physically removed towards the boundary of the testing area.

1 Automated Driving (SAE International)
The trialling of AV and CAV technology in the UK is being undertaken following a structured approach under the DfT’s Code of Practice² for testing, which is substantially different to the regime in the USA and other countries. The safe and successful completion of the complex VENTURER trials is testament to the CAV research and development regime adopted in the UK and will ultimately contribute to the UK government’s vision of bringing ‘market-ready’ CAVs to public roads in a safe manner that realises all possible safety benefits.

Further details on Trial 3 can be found in the Trial 3: Interactions between Autonomous Vehicles and Pedestrians and Cyclists Technical Report, which is available on the VENTURER website: www.venturer-cars.com

These results will be explored further in several academic papers produced by the University of the West of England and will also help further inform insurance and legal debates supported by AXA and Burges Salmon, as part of their ongoing work in helping shape the regulatory landscape for the CAV sector.

The findings of Trial 3 will be promoted through the VENTURER Alliance, which has been formed to progress the learnings of the VENTURER project by using its acquired expertise and capabilities to support the deployment of CAVs onto the UK’s roads.

Further information on future trials, public demonstrations and blogs are also available on the VENTURER website, and you can follow us for updates on Twitter: @Venturer_cars.

Carolyn Mitchell - VENTURER Project Manager
carolyn.mitchell@atkinsglobal.com
