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Virtual reality for stakeholder engagement on autonomous vehicles

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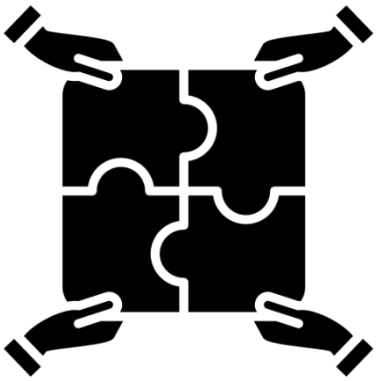
1. What is stakeholder engagement?

Stakeholder engagement is the organisation of activities to understand the concerns of citizens or organisations that might be affected by a problem or a change.



- For policy-makers, engagement ensures that public policies address the problems felt by the community and that all voices are heard. This can increase transparency and contributes to public support of the policies.
- For researchers, engagement ensures that research projects address the right questions, produce useful results, and use appropriate methods. This can increase the social impact of the project

2. Why is engagement needed in research and policy about autonomous vehicles?

Autonomous vehicles will change the transport system, which will affect many things: how we get around, traffic safety, land use, the economy, social justice, public health, the environment, and even crime. Our work in the EU-funded Move2CCAM showed what citizens and organisations think about these effects. See our full report here and a short version here.

Public policies and research projects about autonomous vehicles need to engage with citizens and organisations because it is crucial to know how they will use these vehicles, what are their needs, and how the vehicles could affect their lives. Knowing information can be useful to:

- create strategies to build trust and acceptance of autonomous vehicles among the population
- design policies that ensure that the benefits of autonomous vehicles are realised, and the unintended costs are mitigated
- understand the changes that will be needed to adapt the transport infrastructure and regulations to autonomous vehicles
- guide the development of software for autonomous vehicles

3. How can virtual reality be useful for engagement on autonomous vehicles?

Virtual reality can be used to provide stakeholders experiences of trips in different types of autonomous vehicles, using different infrastructure designs and in different contexts. The experience can be passive or interactive (as a game).

Virtual reality can be more effective than surveys or workshops, as virtual reality can represent future scenarios (some of them with radical changes in the transport system and urban landscape), which individuals may find difficult to imagine.

Virtual reality experiments also have some advantages comparing with organising a trial or demonstration of real autonomous vehicles, because:

- It is cheaper and easier to organise
- It can present participants with a variety of conditions that may not occur in the real world (especially because trials and demonstrations are confined to a small area)
- Experiences are not affected by all the distractions of the real world, allowing to isolate the specific causes of participant reactions

4. How different is the experience of a virtual vs real autonomous vehicle?

The experience of a virtual vehicle differs from an experience of a real one. On the positive side:

- Participants may feel more engaged in virtual reality because the trip can have more changes than those experienced in the real world.
- They can experience two innovations (autonomous vehicle and the virtual reality itself)
- Virtual vehicles can be represented as moving fast and encountering challenging situations (e.g. involving pedestrians), while real vehicles used in demonstrations need to move slowly and in controlled and reasonably standard conditions, to reassure participants that the vehicle is safe.
- Virtual reality can test different traffic conditions and different external and internal designs of the vehicle (for example, changing the space available, seat configuration, level of comfort, and crowding levels in public transport).

On the negative side:

- Participants may miss the human interaction aspect of travelling in real vehicles with other passengers.
- Virtual reality cannot account as well as real vehicles for vehicle movement and manoeuvres (turns, acceleration, and braking).

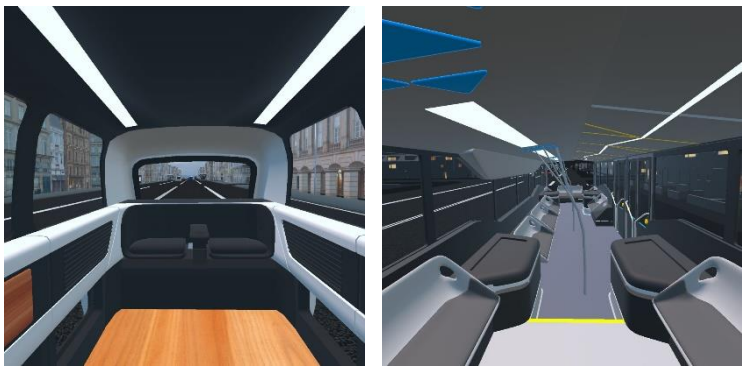
Regardless of the differences between the two experiences, virtual reality can contribute to changes in opinions about autonomous vehicles among people who have already tried real autonomous vehicles. For example, in the Move2CCAM project (move2ccam.eu), we found that participants tend to thing more positively about autonomous vehicles after having the two experiences (real and virtual), compared with just the experience of a real autonomous vehicle.

5. How can virtual reality be useful for organisers and pleasant for participants?

The experiment requires the design of a virtual reality scenario or the reuse of an existing one. Designing a new scenario requires specialist skills and is usually costly (upwards from €50,000 for 10 minutes) but it ensures that the scenario is suitable for the purposes of the experiment.

Ideally, the experience should provide participants with the opportunity to use an autonomous car and a public transport vehicle (such as a bus), so that participants have a balanced view of the type of autonomous vehicles that will exist in the future (Figure 1). Careful consideration needs to be put in the selection of the elements to include in the car and bus scenarios, possibly with the aid of preliminary focus groups, balancing this with cost and ethical considerations which we will mention later.

Figure 1. Example of virtual reality representations of an autonomous car and bus



The road traffic shown in the scenarios does not have to be 100% autonomous vehicles. It can feature some human-driven vehicles, as both types of vehicles will coexist for some time in the future. However, autonomous vehicles should be shown without a steering wheel or other features associated with human drivers. To reduce costs, human figures (e.g., pedestrians, bus passengers) can be portrayed as simplified silhouettes rather than human-like characters. However, these silhouettes should be identifiable as humans due to their shape, gestures, and sounds. The experience should include sounds such as general city noises, bus doors opening and close, and bus passengers chatting.

The scenario should show aspects that could be relevant in trips in autonomous vehicles, to gather data about participant perceptions and reactions to those aspects. These aspects include:

- the landscape seen outside of the window (this is important because when driving will no longer required, all passengers can enjoy the scenery)
- different vehicle speeds and driving styles
- different types of road and traffic conditions
- trips in different times of day
- interactions with other road users
- the exterior and interior design of the vehicles
- vehicle notifications to the traveller

- the presence/absence of a human assistant (in autonomous buses)
- different bus passenger numbers (both overcrowding and no other passengers in the bus)

Apart from generating data for researchers, the experience should also be enjoyable for participants. They should feel engaged, not bored or disappointed. This means that the speed of the virtual vehicle should not be too slow, and the scenario should change during the experiment.

A short experiment (5-10 minutes) keeps costs down. However, short experiments can be disappointing for participants. They also cannot capture all the aspects of the experience of long trips and the emotions they generate. However, longer experiments may induce boredom or motion sickness. They also imply either reducing the number of participants or increase the number of hours or days to complete the experience, with extra costs.

The scenarios should be realistic and changes in scenarios should be noticeable, to ensure participants remain engaged and react to the changes. However, virtual reality can never fully represent aspects such as speed, vibration, smells, weather conditions, activities while travelling (e.g. using phone), and distractions. Other aspects where achieving realism is difficult are:

- movement – it should include braking, lane changes and overtaking
- roads – it should not be too straight, and it should have intersections and faults (e.g. potholes)
- traffic – it should not be too harmonious or having too many or too few vehicles. It should also have unexpected situations and instances where traffic signals are red
- buildings – their design should vary
- human figures – it should include bus passengers, pedestrians, and cyclists, who should be realistic in terms of appearance and behaviour (e.g. not static or repetitive).
- representation of the participant – it should be clear where they are within the scenario and if they are standing or seating

Increasing realism will also increase cost and may deteriorate the experience of some participants who may feel uncomfortable with over-realistic scenarios or feel motion sickness.

6. Which type of data can be collected from virtual reality experiments?

Virtual reality can be used simply as a demonstration tool, to give participants the experience of using an autonomous vehicle. But it can also be used to understand their perceptions of autonomous vehicles. To gather data about these perceptions, participants can be asked to fill a questionnaire after the experiment. The answers can be compared with those given to similar questions before the experiment. Possible questions include:

- opinion about autonomous vehicles and how they compare with human-driven ones, especially regarding uncertainty areas such as safety and personal security, but also speed, stress, and comfort
- intention to use one.

Participants can also be asked questions about the experiment itself, such as

- feelings during the experience (e.g., safety, security, engagement, boredom)
- opinion about the virtual reality scenario (how realistic it was, what they noticed)

Participants can also be asked to discuss in small groups about their experiences. For example, the organisers can show them images of the scenarios they experienced and ask them what they felt at that time, and the implications for their lives, if trips in autonomous vehicles were made in the conditions shown in those scenarios.

Virtual reality can also be used to test participant reactions to various aspects of travelling on an autonomous vehicle. These reactions can be measured through:

- Responses and choices made (when the experienced is designed as a game)
- Physiological measurements (heart rates, skin conductance, and brain activity), which can infer emotional states such as stress, anxiety, arousal, and discomfort. This requires participants to wear additional equipment.
- Head or eye movement tracking

The last two options increase the complexity and the cost of the experiment.

7. What are the technical and organisational requirements and challenges?

Besides the virtual reality scenarios, the experiments also require virtual reality headsets. These can be standard commercial products of the type used to play games. Several headsets are needed, to be used simultaneously, if the experiment aims at engaging a suitable number of participants within a reasonable period (e.g. one day). If participants join the experiment in groups of three or four, it should be possible to have a reasonable number of participants within an 8-hour day.

The experiment also requires ample space, with participants sitting in separate tables, to keep equipment separate, provide participants with more comfort, and minimise mixing of sound from different devices (Figure 2). There should also be space for the movement of staff between tables, to monitor possible issues. Equipment should be moved to a separate area for charging in the intervals between sessions.

Figure 2. Aspects of the experiments

Technical issues are bound to arise. The scenarios may not display correctly. Participants may also be using the hand-held commands in an incorrect way (e.g. pressing buttons they should not press). A solution is to cast the experience of each participant onto a tablet computer, through an app linked with the virtual reality headset. This allows staff to monitor what the participant is seeing at each moment, and to address any problem or answer any question the participant may have. This solution only works for some types of virtual reality headsets. It also increases the cost, as it requires the use of tablet computers. The casting also may not always work due to poor wi-fi connectivity. This can cause the interruption of the experience of the participant as staff will not be able to identify the problem without looking at the casting.

The repetition of the experiment several times during each day also requires attention to battery charge and possible faults in the equipment occurring during the day. The experiment can become even more complex, in terms of organisation, if physiological data is collected, as it requires using extra equipment (headsets, earbuds, or wrist bands). In this case, several devices will be used simultaneously including, for each participant, one virtual reality dataset, one tablet computer to cast the experience, and equipment to collect physiological data.

8. How to recruit participants?

Participant recruitment can be done by market research companies, but this has a cost. An often-used solution is to recruit through announcements in social media. However, this does not guarantee that the participants will be representative of the population as some groups are more likely to engage in social media.

Having a large number of participants increases the potential to engage with various population groups, while also producing more data. However, it increases the cost and complexity of the experiment, especially if it cannot be conducted in a single day. Engaging with 100 participants can generate enough data to derive robust results and compare them across gender, age, or other groups. While there is interest in implementing the experiment in several sites representing different geographic and socio-economic contexts, an overall sample of 100 participants across all sites would not allow for the analysis of gender or age differences within each site.

The group of participants need to be balanced in terms of age, gender, and socio-economic background it should include groups that are usually underrepresented in citizen engagement activities, especially those using virtual reality, such as residents in villages, ethnic or national minorities, individuals without a university degree, with disabilities affecting mobility, and those not able to drive. The sample should also have individuals who are less (or not) aware of autonomous vehicles and those who are not early technology adopters.

The use of a balanced sample can uncover differences in reactions to autonomous vehicles. It also allows for the generalisation of results and reduces self-selection (the overrepresentation of groups who are more likely to have a positive opinion of autonomous vehicles). On the negative side, a it requires more time and effort to monitor and complete quotas, and a close engagement with recruitment companies. Recruitment also becomes more expensive.

9. How to address ethical issues of virtual reality experiments?

Addressing ethical concerns requires more than simply seeking informed consent from participants. Ethics should be embedded in the design and implementation of the experiment. Organisers should identify potential ethical issues and devise strategies to address them.

This requires time and effort, but it can contribute to the effectiveness of the experiment and the quality of the collected data, as it ensures a better experience for participants and reduces the chance of some of them dropping out before or during the experiment.

The following table show ethical issues that may arise, and possible solutions.

Ethical issues related to the experience as a whole

Problem	Solution
General concerns about what will happen	• Provide participants with information in advance explaining the objective of the study, funder, organisers, and nature and duration of the experiment • Assure participants of the possibility of withdrawing at any time • Participants should not start the experience if they have not given consent in writing, confirming that they understood what the experiment involves and what is expected of them. • Participants should be briefed before each step of the experience.
Use of participants' time and risk of fatigue	• Participants should be offered a small monetary compensation. • The schedule of the experiment should have frequent breaks (e.g. between the experiment and questionnaires) • Participants should be provided with food and drinks • Preliminary questionnaires can be answered in advance
Experience not accessible due to disabilities, long hair, glasses	• Preliminary checks to ensure that equipment is fully accessible

Ethical issues related to equipment

Problem	Solution
Participants may feel intimidated or embarrassed using the headset	• Use standard commercial headsets • Test headsets thoroughly before the experiment • Participants should be informed in advance about the headsets (including photos and links to the manufacturers' web pages) and reassured that they are easy to use • Participants should join the experiment in small groups • Provide participants with instructions to wear and calibrate the headset (staff only intervening when asked) • Male and female staff both present to guide participants on how to wear the equipment
Motion sickness, headache, skin irritation, marks on forehead and other discomforts during or after using the headset	• Design a short and simple experience • Design procedures to address any cases occurring during the experiment • Inform participants in advance about these discomforts, what to do if they do happen, and reassure them they can withdraw at any moment, before or after started wearing the headset.
Risks of transmittable diseases through wearing headsets used by others	• Disinfect headsets after each use
Effects on individuals with certain conditions and implanted medical devices	• Advise participants with epilepsy, heart disease, visual impairments, psychiatric disorders, or implanted medical devices (heart pacemakers, defibrillators, hearing aids) should not take part in the research

Ethical issues related to the virtual reality scenarios

Problem	Solution
Participants may feel uneasy with some scenes	• Human figures should not be too realistic. • The scenarios should end on a positive note, with all situations resolved and the vehicle arriving safely at the destination. • Scenarios should be tested and refined several times to remove any possible problems • Participants should be informed about scenarios in advance (and provided with screenshots) and reassured that they could withdraw at any moment
Negative associations of behaviours of human figures with gender, age, or other groups	• Figures designed as generic silhouettes, identifiable as human beings but not as particular groups.

Ethical issues related to data collection and treatment

Problem	Solution
Concerns about how data is collected and treated	• Treat data in a secure manner • If possible, separate institution collecting experiment data and the one collecting participant names and contact details. • Inform participants in advance about the type of data collected (including photos/videos of the experiment) and its use and seek informed consent. • Questionnaire answers about sensitive characteristics (e.g. disability and ethnic background) should be optional

10. Acknowledgements

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