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Conducting Stated Choice Experiments within an Immersive Virtual Reality Environment: an Application to the Discrete Choice of Automated versus Normal Taxi

Hao Yin, Elisabetta Cherchi*

Future Mobility Group - School of Engineering, Newcastle University, Cassie Building, Newcastle upon Tyne, NE1 7RU, UK

Abstract

This paper describes the methodology set up to measure consumers' preferences in a choice between a fully automated and normal taxi, using a Stated Choice (SC) experiment embedded in an immersive Virtual Reality (VR) environment. VR represents an important tool to allow respondents to "live" their choice with the potential to reduce the typical problem of lack of realism in SC experiments. This paper describes the work done to build the VR-based SC experiment, and discusses challenges and potentialities. The study is applied to the choice of taxi in the city centre of Newcastle upon Tyne in the UK.

Keywords: Immersive Virtual Reality; Stated Choice Experiment; Automated Taxis; Discrete Choice

1. Introduction

Stated Choice (SC) experiments have been extensively used in the last decades in many different fields to elicit users' preferences and recently to elicit preferences for innovations such as adoption of electric vehicles and autonomous vehicles. However, as summarized also in a workshop held at the 10th International Conference on Transport Survey Methods (see, Cherchi and Hensher, 2015) SC experiments suffer from lack of realism; a problem

* Corresponding author. Tel.: +44 (0)191 208 3501
E-mail address: Elisabetta.Cherchi@newcastle.ac.uk

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known for long time that still remains critical and unsolved. The issue with realism, linked to hypothetical bias, is even more serious when SC experiments are used to study innovations, because it is likely that preferences do not exist for products that are not currently available in the market and hence products that people do not know and have not experience with. In these contexts, preferences for hypothetical situations are based on users' mental imagination of the product.

Mitigation techniques have been adopted over the past years to alleviate this problem (see Ortúzar and Willumsen, 2011, page 114). In recent years, in particular, pictures and videos have been increasingly used with the goal to improve realism in SC experiments. Some recent works on Autonomous Vehicles (AVs) have attempted to offset the problem by showing participants videos of AVs before conducting the survey (e.g. Howard and Dai, 2014; Kolarova et al., 2018). Although using videos and images represents a clear intuitive way to improve realism, research is still needed to understand their behavioural relevance and the extent to which they are able to reduce hypothetical bias. Moreover, in these studies using videos or images the SC experiments are still presented in the traditional format, which is itself a non-realistic way in which choices are made in real life. Few studies have also used virtual reality (VR) but with the aim to control for the framing effect, i.e. to improve the preliminary information about the non-market goods respondents were going to evaluate (Bateman et al., 2009; Fiore et al., 2009; Matthews et al., 2017; Patterson et al., 2017). Some authors (Farooq et al., 2018; Arellana et al., 2020; Rossetti and Hurtubia, 2020; Bogacz, et al., 2021; Feng et al., 2022) have used virtual reality (VR) technology with SC experiment but applied to pedestrian experiments that involve a continuous movement, not a standard discrete choice. From a neurological point of view, the decision process is different (see discussion in Cherchi, 2020).

VR experiments represent a new area of research that promises to change fundamentally the way in which consumers' preferences for innovations are measured. According to the theory of 'ecological rationality' (Gigerenzer et al., 1999), the 'decision environment' plays a crucial role in the decision-making process due to cognitive constraints of the participants. Studies have shown that people can develop realistic spatial knowledge in the VR environment that is similar to actual physical environments (O'Neill 1992; Ruddle et al., 1997; Tlauka and Wilson 1996). VR can generate a sufficiently natural and familiar field, able to provide 'field cues' or 'field hints' that occurr in the real world (Fiore et al., 2009). VR allows the sensation of immersion in the activities on the screen and with the virtual elements (Animesh et al. 2011; Faiola et al. 2012; Nah et al., 2011), prompting individuals to act as if they were in the real world, which have crucial effects on conscious and non-conscious behaviours (Sanchez-Vives et al. 2005). For that to happen, the VR environment needs to be built with a high level of realism, and this paired with an embedded SC experiment, poses several challenges. In pursue of accurately presenting or describing complex alternatives or stimuli in experiments, VR techniques are gradually used as the survey technique in various disciplines to explore individual's perceptions or behavioural responses: tourism (Tussyadiah et al., 2018), marketing (Loureiro et al., 2019), environmental policy (Fiore et al., 2009) and economics (Innocenti 2017) etc. Recently, studies on VR techniques in autonomous driving has also been advanced (see literature review by Riegler et al., 2021). Nevertheless, most of them focused on the improvement in the human-machine interface for autonomous vehicles and entities affected by drivers, passengers, pedestrians and other road users, such as testing passengers' in-vehicles experiences- entertainment and games (Wang et al., 2016), backseat productivity work (Li et al., 2020), etc.

Motivated by the ability of VR to prompt individuals to act as if they were in the real world, in this paper we propose a SC experiment fully embedded in the immersive VR environment to test a standard discrete choice, that is a binary choice between a normal taxi and a fully automated taxi at the city centre of Newcastle upon Tyne, in the northeast of England. In our VR experiment, respondents do not simply watch a video but take decisions (as proposed in a standard stated choice experiment) while moving in the VR controlled environment and "living" the choice experience. The research focuses on fully automated taxis (level 5), because this is the closest alternative to a current taxi where passengers cannot intervene in the driving. To the best of our knowledge, this is the first experiment of its kind.

Automated Taxis (ATs), as on-demand services are considered a key commercial application of the driverless full automation, key in particular to facilitate a sustainable transport system. Previous studies on automated vehicles adoption have used traditional SC surveys, where the attributes used to characterize 'alternative' or 'stimuli' generally are 'level of service' variables (Stoiber et al. 2019; Yap et al, 2016; Krueger et al. 2016; Bansal and Daziano 2018), or specific features for the automated taxi, like the option 'to talk with an operator' or 'to change destination' (Yin and Cherchi, 2022). These are not so-called complex 'visual' attributes.

The remainder of the paper is organised as follows: Section 2 reports a description of the context of reference for the experiment. Section 3 describes the methodology followed to build the immersive VR environment and the VR-base SC experiment for the specific context of reference. Section 4 describes the rigorous experimental protocol that we used for data collection while Section 5 discusses the main results. Section 6 concludes the paper.

2. Context of reference

Identifying a realistic context of reference is a relevant task also in paper-based SC experiments. To ensure realism, it is always recommended to ask participants to describe a recent trip, in our case a trip made by taxi, and then the SC experiment is customised around this trip. In a paper-based SC experiment, any trip by taxi can be considered. Even if pictures or videos of automated taxis are presented to respondents, these do not have to refer to specific locations. Indeed images or videos often refer to imaginary cities. In the case of VR-based SC experiments, it is instead critical to define the precise context of the experiment, because respondents will make their choices within the virtually real environment.

In our experiment, respondents were asked to make a choice between a conventional taxi (with driver) and a fully automated taxi (no driver and no steering wheel). The first step then consisted in identifying a realistic context where passengers have the possibility to see the taxis operating while they are making their choice. This was a first challenge and the only solution was to locate the experiment at a taxi rank. Despite the diffusion of car-hailing and private hire services, traditional taxi services are still extensively used in Newcastle and there are numerous taxi ranks in the city centre.

3. Constructing an immersive VR-based SC experiment

Constructing the VR scene (or environment) and constructing the standard SC experiment within the VR environment are two main components of the VR-based SC experiment.

3.1. Constructing the VR scene

The design of the VR scene mainly includes two parts: the selection of the location where to run the experiment (i.e. in which part of the city to locate the taxi rank), and the definition of how to modify the current urban structure to make the inclusion of automated taxis in the taxi rank realistic.

First of all, for obvious reasons, it was decided that the location should be a street where there is currently a taxi rank. Out of the six possible locations identified within Newcastle, Northumberland Road was chosen as context for the VR environment. A couple of reasons are behind this choice. First, in order to enhance the realism of the experiment, the context needs to be located in an area familiar to the respondents. Northumberland Road is adjacent to a major pedestrian shopping street in Newcastle and it is very well known by the locals. Second, from a technical point of view, it fulfils the requirements needed to maximise the quality/cost ratio of the VR experiment[†], namely:

- Simple buildings
- No trees, straight road
- No long-distance horizons
- The walking distance compatible with the space available in the room where the experiment is performed

Fig. 1 reports some pictures of the possible taxi ranks locations analysed, while Fig. 2 reports two pictures of Northumberland Road, which as we see fulfils almost all the above criteria. There is a long-distance horizon, but this is far from the point where the actual experiment takes place, which allowed us to use a low definition for the buildings

[†] These requirements were identified as part of this research.

far in the horizon. The street is not very wide but there is enough space to include the taxi rank and to allow the movement of the taxis.

Fig 1. Location of some of the taxi ranks considered in Newcastle upon Tyne

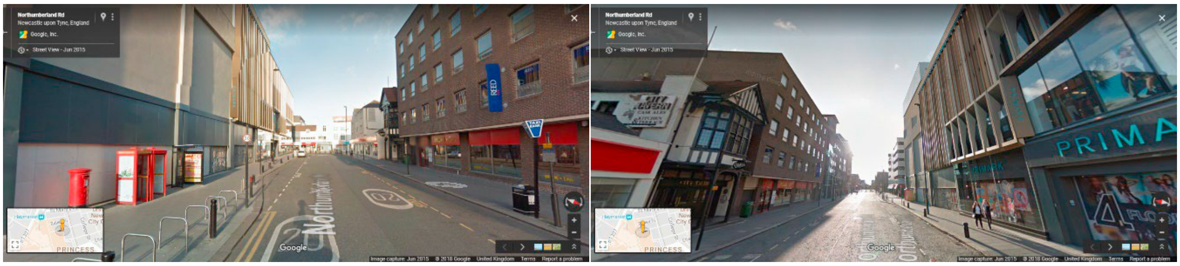

Fig 2. Street view of Northumberland Road in Google Maps

The blue sign in the left picture in Fig. 2 is the sign of the current taxi rank. In our experiment, we need to offer respondents the choice of two types of taxis (NT and AT), the layout of the street was then modified to accommodate both taxis. Several alternative designs were evaluated. Fig. 3 shows the geometrical design selected (on the left) and its implementation in the VR environment (on the right). As it can be seen:

- The taxi rank was organised with two separated lines of taxis, as this facilitates the experiment where respondents have to appreciate the characteristics of each taxi to make their choice.
- The black line in the drawing is a small island, where a *Ticket Board* is located as well as the space to queue for the taxis. The creation of this island has the main purpose to allow participants to walk from the ticket board to the queues, without the problem of crossing the street in front of the cars, as this could add safety concerns that needed to be controlled in the experiment.
- People waiting for the taxi will be standing in the small island. This allows passengers to be equally distant from both NTs and ATs, and to see the front of both types of taxis.
- The island needs to be wide enough to allow two clearly distinct lines of passengers. Careful considerations were required to ensure this was feasible given the real dimension of the area.

- The left side of the waiting area is for NTs and the right side for ATs. Ideally, the position should be randomised among the tasks presented to the respondents. However, changing the position of the cars in the VR environment is costly, and we decided not to implement this feature.

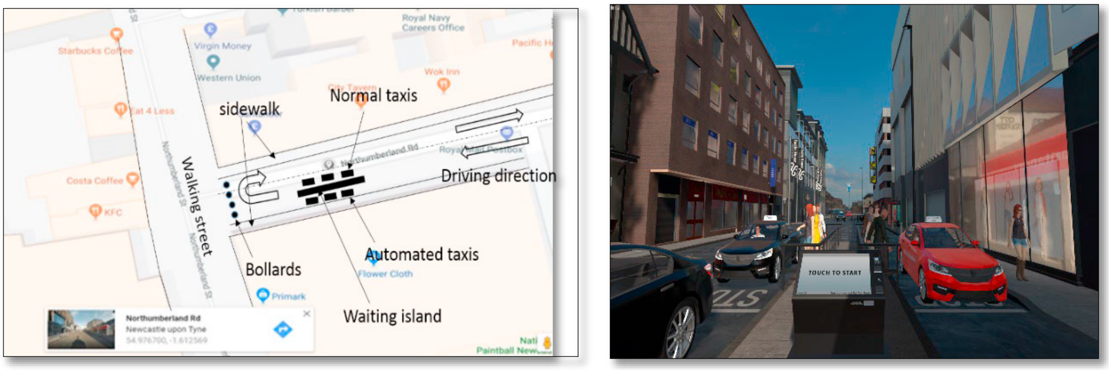

Fig 3. Re-design of the taxi rank area: drawing and VR environment built

The VR platform was built using Unity 3D Engine for gaming and virtual reality, which allowed pushing the realism to very high standard. As it can be appreciated comparing the right sides of Fig. 2 and Fig. 3, it features an extremely detailed reproduction of the buildings. Respondents using the VR have then the possibility to see how the taxi system (and in particular the AT) works and is used: passengers queue waiting for the taxi, the taxis (normal and the automated) arrive, pick up passengers and leave the taxi rank. Since respondents are immersed in this environment, they can really live in the environment: they can get close to the taxi, queue with the other passengers, cross the street and see the automated taxis passing by.

A potential problem with realistic environments is that unintended information might affect the respondent choices since VR environments include richer contexts (Patterson et al., 2017). The real-life contexts seldom allow the experimental control while in the VR context the effects of stimuli are fully controlled. Our VR environment represents the real environment with high fidelity. With this, we ensure that the VR does not introduce additional distractions compared to the real environment. The only new element, compared to the real environment is the AT that, however, has the same shape of a normal car. This was analysed in a series of Focus Groups (FGs) ran as preparatory analysis. Respondents showed a preference for cars of normal size and normal shape (i.e. similar to the current vehicles). This result guided the choice of the type of cars that appears in Fig. 3. For the NT, we used a black standard car that reproduces the shape of the taxis operating at the taxi ranks in Newcastle. For the AT, we used a red car. There was no particular reason behind the choice of the colour red for the AT. As we will discuss later respondents did not pay attention to the colour.

Another discussions that were held during the FGs were whether AT passengers should sit in the front seat or in the back seat and whether ATs should have a steering wheel (though without having the driver) or not. As for the sitting position, there was not a clear preference. We chose to show passengers sitting in the front, as this makes it even more evident the absence of the driver. In the VR experiment, it is possible to show passengers sitting both in the front or the back seats, but it is more costly. Interestingly, instead participants in the FGs showed a clear preference for an AT without steering wheel, mainly because it looked like what participants expected an automated taxi to be.

Another non-trivial decision referred to how the information about the taxis was presented (which is the core of the SC experiment) and how respondents would make their choice. An option considered was to present the information in a cell phone, but this is not easy to implement within the VR environment due to the difficulty to guarantee sufficient quality for the images in such a small dimension. It was then decided to design a ticket board that simulates a touch-screen, which respondents can activate using the trigger in the VR handle. To enhance realism, the ticket board was carefully designed to resemble existing ticket boards, both in the external appearance and in the format of the contents presented. Several formats were tested. The final version (reported in Fig. 4) includes a wide screen designed to present the characteristics of both the AT and NT available to the customer for that specific trip (i.e. the choice tasks) and on its right it includes the features to insert banknote and coins, to tap the bank cards and to receive tickets and change, which reproduces real-life ticket boards.

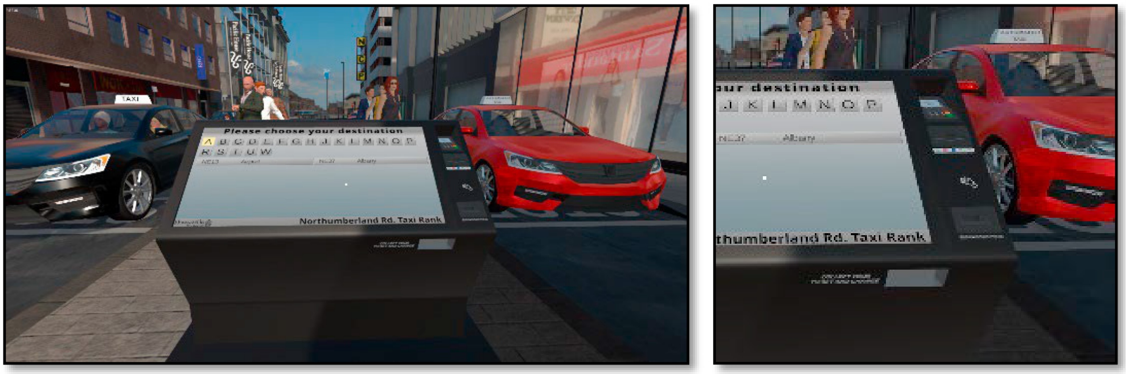

Fig 4. Ticket Board in the immersive VR-based SC experiment

The ticket board was positioned facing the taxis in order to give respondents the possibility to see the vehicles and the other passengers queuing while reading the information about the taxis available and making their choices.

Aspects that need to be carefully considered when designing the ticket board in the VR environment are:

- Size of text and images. Despite the very high quality of the VR environment, the resolution is not comparable with that of a computer or smart phone. This poses a constraint in the amount of information that could be presented in the ticket board. A significant amount of work was needed to identify how the information was presented (i.e. the attributes of the SC experiment and the text to include) without altering the SC experiment designed.
- Colour of text and images. The vision with the VR is slightly different from the one we have in the real world. For this reason, also a simple task like the colour of the text and that of the background requires several tests, in order to identify the best combination to ease to read.
- Height of the ticket board. This has to be high ~~tall~~ enough to allow respondents to read easily the information provided (given the resolution of the text in the VR environment) but not too high, otherwise respondents are not able to see the taxis and the other passengers queuing, which is an important part of the immersive VR experiment. In the VR, the height of the board can be adjusted based on the height of each respondent, but this option is relatively costly. Therefore, we opted for a fixed height. The appropriate height was identified after several tests, in accordance with feedbacks collected from respondents.

As discussed previously, since automated taxis do not exist in reality, it is necessary to provide respondents with background information. The VR environment was built in a way that respondents can see how the system operates and walk around the vehicles ~~moving~~ without the need to describe it. However, still some preliminary information is needed. From the FGs it appeared clear that safety issues are relevant and can affect the users' preferences elicited in the SC experiment. To control for this effect, we built an *Information Board*, where we included three pieces of information: (1) general information about AT safety; (2) general information about AT privacy and routing and (3) specific information about how the AT operates once on board the AT. Fig. 5 shows an example of the information board in the VR experiment. As shown in the right part of Fig. 5, at the top of the information board screen there is a menu, and respondents can select the information to display using the trigger in the VR handle. A discussion of the results of the FGs and the information provided before the SC experiment (and in the VR in the *Information Board*) is reported in Yin and Cherchi (2022).

Analogously to the ticket board, also for the information board several tests were run to identify the optimal height as well as the appropriate size of the text and images.

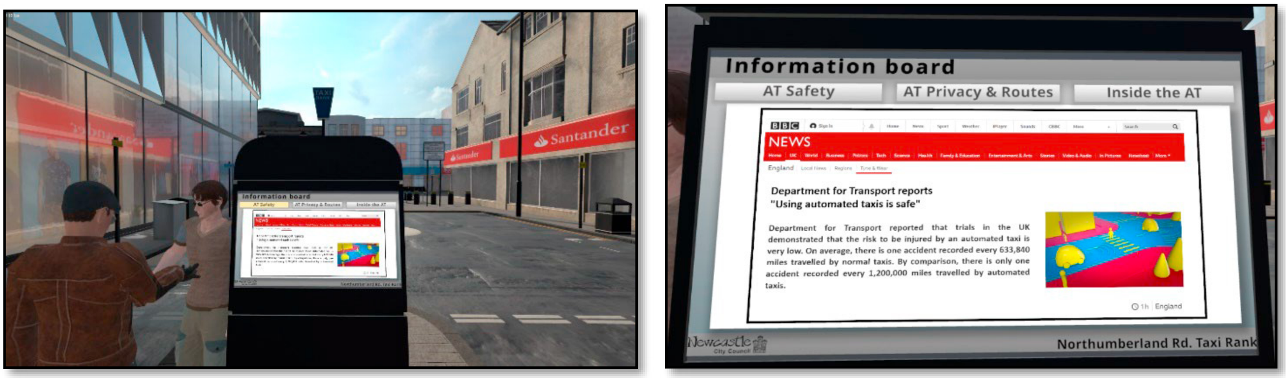

Fig 5. Information board in the immersive VR-based SC experiment

3.2. Constructing SC experiment

The process to build the actual VR-based SC experiment is not different from a standard screen-based SC. The SC experiment built includes seven attributes: three level of service attributes (waiting time, travel time and fixed journey fare, with three levels each), two attributes to measure specific features available inside the AT (talking with an operator and changing destination, with two levels each) and two attributes to measure the impact of social influence (number of customers with three levels and customer rating with two levels). Details about the definition of these attributes can be found in Yin and Cherchi (2022). Table 1 reports the values used for this UK application. A heterogeneous Bayesian efficient design was generated in Ngene (ChoiceMetrics 2012). Priors were taken from models estimated in several pilot tests based on orthogonal designs. Three SC experiments were optimised based on three travel distances of 5 km, 10 km and 15 km (the only differences are the attribute level values of 'travel cost' and 'travel time' among three SC designs). 12 choice scenarios were generated and randomly divided in two blocks. Each respondent was presented with six scenarios.

Table 1 Attributes and attributes levels

Attributes [Unit] (*description*)	Attribute levels		
	Short (5km)	Medium (10km)	Long (15km)
Waiting Time [minutes]		1/6/11	
In-vehicle Travel Time [minutes]	6/10/14	11/16/21	16/22/28
Fixed Journey Fare [GBP] *(does not depend on the travel time once on board)*	4/7/10	10/14/18	16/21/26
Number of Customers in the last hour *(customers who have chosen each type of taxi)*		17/80/143	
Change the Destination (*possibility to change destination*)		0:No / 1:Yes	
Chat with an operator (AT) (*possibility to chat with an operator)*		0: No / 1:Yes	
Customer Reviews Yesterday		0: Bad Reviews (2 Stars) 1: Good Reviews (4.5 Stars)	

Although the experimental design in itself is standard, some aspects need to be considered when implementing this SC into the VR environment. First, as in the standard SC experiments, before presenting the tasks, respondents were asked to choose the destination for their trip, and based on the distance of their destination, one of the three SC experiments was presented. To make it realistic, the list of destinations in the VR was presented in the ticket board. The first information asked of respondents was "select your destination". In standard SC experiments, this information is asked once at the beginning of the SC and before each scenarios respondents are asked to assume that they have to do a trip always with the same destination. Interestingly, this standard procedure, that sounds perfectly reasonable in the screen-based SC, but it appears extremely unrealistic in the VR environment. This is because each scenario in the VR starts at the ticket board, where the first information is "select your destination". Differently from the standard practice, we allowed respondents to choose different destinations in each scenario, and hence the 6 scenarios presented to each respondent can belong to any of the 3 designs (5km, 10km or 15km).

The second aspect that is worth mentioning refer to the information about payment types for the trip. Results from the FGs suggested that some people do still pay cash and prefer to do so. However, paying cash in the ATs is challenging, if not impossible. It was then decided to include the form of payment as an attribute in the SC experiment, to test its impact in the users' choice. While in the screen-based SC experiment the inclusion of this attributes in the task sounds perfectly fine, in the VR environment it appears unrealistic. When we choose a transport option in reality, we are only presented with the characteristics of the options, and after we make the choice the ticket machine asks us how we would like to pay. The realism of the SC experiment embedded in the VR experiment makes this problem evident. For this reason, after several tests, it was decided to remove this attribute from the SC experiment, and the question was asked after each scenario, i.e. after the respondent has chosen the type of taxi, in the ticket machine it appears the question "how do you want to pay?" with a list of options. After that, a screen appears with information about how passengers make a payment, like "insert or tap your credit card" etc. (see Fig. 6).

a) Customised VR-based choice task b) payment method and instruction

Fig 6. Example of SC choice task in the immersive VR environment

Finally, it is important to mention that all information presented in the ticket board where respondents needed to take an action (such as "select your destination", or "select your payment method") was provided with both texts and voices. Additionally, a short 'break' section was provided between scenarios. In the several preliminary tests conducted, it was discovered that presenting the choice tasks in sequence, as is always done in online surveys, was extremely unrealistic in the VR, and could jeopardise the entire experiment.

3.3. Practical aspects

Practical aspects to be considered are:

- A 2mx2m room, with 2 sensors is the minimum requirement of the VR program. However, there might be interference between the sensors (unexpected signals are captured or reflected when respondents move). We tested it and respondents experienced problems, such as 'sudden vibration' and 'instantaneous movement from one point to another'. A minimum 4mx4m room is recommended.

- Respondents can wear glasses in the VR experiment. However, the vision with glasses can appear blurry and small text is not clearly readable. Resolution of the written texts needs to be checked carefully.
- To auditorily isolate respondents from real world and increase realism, a background noise as coming from the street and the sound of taxis driving were added into the VR program.

4. Data collection methodology

A rigorous protocol was identified to carry out the VR-based SC experiment, which consists of the following four steps:

Step 1 Introduction

a. Participants were welcomed and asked to sign a consent form explaining the purpose of the study and some covid safety measures implemented to mitigate risks of the infection during the experiment;
b. Participants were shown the basic components of the VR and given a brief explanation of the entire experiment.

Section 2 Tutorials

Respondents wore the VR headset and went through two short tutorials about VR:

c. A general tutorial, a video about how an immersive VR environment works;
d. A specific tutorial, respondents found themselves in the virtual Northumberland Road and were asked to walk and move around to familiarise with the environment of the final experiment.

These tutorials are particularly important and aim to ensure that all respondents have enough capabilities to complete choice tasks in the VR environment and to avoid distractions during the experiment. During the several pilot tests, respondents, particularly those with no previous VR experience, expressed a high level of excitement when they first found themselves in the virtual street of Northumberland Road and they were clearly distracted by what they were seeing, including the products displayed in the windows, though these are the same they could see in reality. This time to familiarise with the environment is then critical to avoid participants to be distracted by unintended information (Patterson et al., 2017; Birenboim et al., 2019).

Short break

Participants were asked to remove the headset and to have a short break (2 minutes-5 minutes). It is important to mention that, during the experiment and at the end of each tutorial, respondents were asked how they felt. The experiment would have been immediately stopped if respondents suffered from adverse symptoms (e.g. motion sickness the most likely, but it could also be dizziness or nausea, or a sense of claustrophobia, etc.)

Section 3 Formal VR-based SC experiment

e. Respondents were asked to wear again the immersive VR headset to perform the final VR experiment, where respondents were informed that they have now to imagine that they are in Northumberland Road to take a taxi as they do in reality. No further instructions were provided at this point regarding the SC experiment in itself. Respondents were given only some information about how to use the controllers to make their choices in the VR experiment.

Section 4 Post survey

f. At the end of the VR experiment, respondents were asked to fill in a short online questionnaire, including socio-demographic questions and some relevant questions about their experience with the VR-based SC experiment, such as:

- Can you tell what was the colour of the autonomous taxi in the VR experiment?
- Can you tell what was the colour of the normal taxi in the VR experiment?
- Did you notice the passengers' queueing when you were doing the VR experiment?
- Can you tell how many people approximately were queueing for the AT and how many for the NT in the last exercise?
- How realistic was the VR experiment?

During the several tests of the VR environment, the following additional questions were added to the post-survey to evaluate in detail several aspects of the VR environment:

- Did you feel motion sickness (e.g. dizziness)?
- How clear do you think are the following types of content in the virtual reality experiment? (measured by Likert scale)
  - Overall virtual reality environment quality (e.g. surrounding buildings etc.)
  - Destination list
  - What you can do when travelling with an AT
  - Waiting time
  - Travel cost
  - Travel time
  - Number of customers in the last hour
  - Customer rating yesterday
  - Payment methods & payment instructions
  - The content in the virtual environment was helpful in informing me of my current task
  - The user interface to be helpful in informing me of my current task
- How easy was it for you to choose the taxi in the virtual reality experiment?
- To which extent the virtual reality experiment made you feel as if you were making a choice in reality?
- Did you feel scared when you walked to the info board or turned around (locomotion issue)?
- Did you have any problems in using the controller to make the choices?
- What improvement in the virtual reality do you think will have the greatest impact on generating a more immersive experience?
  - Better visual displays
  - Better audio/sounds
  - Adding a sense of touch, feeling and force (Haptics)
  - Other, please specify

5. Results and Discussion

Setting up an immersive VR-based SC experiment requires a quite intense work. We estimated that testing the immersive VR environment described in this paper, it required approximately 900 hours, this includes the layout of the SC experiment, but not the actual experimental design. The post-survey conducted during the tests was very useful to understand which parts of the VR environment needed improvement and how to improve them.

It is important to mention that during these tests no respondents experienced motion sickness. Only in the final experiment, one respondent suffered from claustrophobia and could not continue the experiment. The vast majority found it very easy to perform the choice task and felt the VR was highly realistic, though this does not necessarily mean that everybody felt as if they were making a choice in reality. The layout of the SC experiment was evaluated to be very clear in all the tests, while we had to work on improving the information about the tasks that respondents had to perform, as the majority of the respondents felt this was unclear. The protocol described in Section 4 is the result of this work.

The question about the colour of the taxis was added to test the concern that there could be a colour effect in the experiment and this could affect the preferences elicited. Interestingly in the pre-tests only 50% of the participants correctly answered this question. In the final test, the percentage was the same (50%) for the normal taxi, while it was a bit higher (67%) for the automated taxi. Finally, all participants noticed the people waiting in the queues, confirming the importance of the proposed scenario setup (i.e. the position of the ticket board, as described in Section 3).

The final immersive VR-based SC experiment was conducted in the premises of Newcastle University on December 2021. The sample was recruited using online panel and advertising the experiment also in the university. After removing 2 participants who never used taxis before, a final sample of 40 responses was obtained. Each VR experiment lasted between 40 and 60 minutes. This is much longer than the traditional online SC experiments (around 15 minutes). Nonetheless, none of the respondents complained about the prolonged duration as they seemed to lose the perception of time during VR experiment, implying the subjective perception of time accelerated when engaging in or focusing on VR experiments. This effect was reported also in Arellana et al. (2020). Because of Covid-19, an additional 5-10 minutes was added between participants to sanitise and disinfect the equipment. In addition, to mitigate covid-19 risk, strict safety measures were taken during the experiments: all participants and researchers must wear facemasks and disposable gloves; participants were required to wear a shower cap to isolate contact with VR headset. 50% of the participants had never tried a VR before, 25% had tried once, the remaining 25 % more than once. Of these respondents, 62.5% were male. Participants ranged in age from 21 years old to 80 years old, and 47.5% were students.

The focus of this paper is to present the novel methodology to embed SC experiments into the VR environment; however, we would like to mention that the data collected in the SC experiment are used to estimate Mixed Logit (ML) models, and compared with the results from an identical online survey. This work is in progress and it will be the object of another paper. It is very difficult to anticipate which variables could be perceived differently by respondents in a VR versus an online setting. From a theoretical point of view, all variables tested could be perceived differently when respondents are living the choice as in the VR environment. Our expectation is that waiting time and the social influence variables could be perceived differently due to the presence of the avatars (that can work as cues) and the fact that in the VR respondents can see customers queuing for the taxis. Based on the preliminary results the most interesting result is that the effect of the descriptive norm attribute 'number of customers in the last hour' that, differently from the AT-related online surveys in Yin and Cherchi (2022) as well as several EV-related online surveys, was positive and significant at 94%. This probably reflects the importance of realism in its ability to capture the impact of normative conformity.

6. Conclusions

This paper presents a methodology to build the SC experiment within an immersive VR environment in the domain of innovative transport choices (i.e. automated taxis versus normal taxis) along with a rigorous protocol for data collection. Immersive tools are useful to present a 'decision environment' or to give respondents a feeling of 'being there' when participants made mode choices. One of the major benefits of using immersive VR-based SC experiments is the level of realism that can be achieved, but the process to build the experiment is more complex. Our VR experiment exposed the limit (in terms of realism) of assumptions typically made in the screen-based SC. In particular we found that, assuming that the trip destination does not change among scenarios, the inclusion of the payment method simultaneously along with other attributes such as travel time, presenting the choice tasks continuously without a break, seem jeopardise the level of realism in VR experiments. Additional tests were requested to adjust text and images presented (which are even same as web-based counterpart), which result in the situation where building the SC into a VR environment is relatively demanding. The preliminary estimation results added to the evidence that the using VR might have advantages in measuring the effects of attributes related to social influences. To answer the question whether using the VR allows estimating more precisely preferences for the innovative travel mode (i.e. automated taxis in this case), a comparison with the results from a screen-based survey is needed. This will be the objective of another paper.

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