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UNDERSTANDING HUMAN FACTORS IN THE METAVERSE – AN AUTONOMOUS DRIVING EXPERIMENT

Research in Progress

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Abstract

Research often draws on established research methods such as lab or field experiments to investigate urgent questions about human factors in future autonomous mobility. However, conducting experiments in such a context is either expensive and complex to implement and operate, when the researchers aim for realism, or otherwise entails limitations with regard to the external validity of the experiments. In this work, we propose the use of immersive virtual experiments in emerging game-based 'metaverse' platforms as a cost-efficient approach with the potential for high realism. Next to a prototype, we present the setup of an experiment for investigating user behavior in an autonomous driving scenario we want to realize. Finally, we provide an outlook on how we plan to gain novel insights for designing realistic experiments in the metaverse.

Keywords: Social Experiments, Brinkmanship Game, Autonomous Driving, Metaverse.

1 Introduction

In traditional economic and behavioral science, laboratory and field experiments are standard methods for investigating scientific questions. However, these methodologies have limitations when it comes to new forms of human-robot interaction, which becomes easily clear in the example of autonomous driving (e.g. Hussain and Zeadally 2019). The role of human factors, and in particular aspects such as (over-) trust and human behavior in critical situations in which manual inputs are required, needs to be investigated more comprehensively to design more effective and safe autonomous cars (Parasuraman 2000, Payre et al. 2016, Awad et al. 2018). Since autonomous driving is complex and expensive to test in the field and comes with safety issues for the participants, researchers mainly draw on laboratory and online experiments with an abstract and simplified setup. However, due to their setup, the results of such experiments have limitations when it comes to their 'ecological' validity. One crucial aspect is the generalizability of these experiments, which is limited as user behavior is likely to differ in real-world scenarios (Sportillo et al. 2019). Furthermore, experiments that involve humans that interact with intelligent machines, such as autonomous vehicles, are often limited by the fact that such experiments could potentially harm participants. For instance, investigating the overtrust of humans in autonomous cars could physically harm people if such an experiment is conducted in a scenario with a car accident as a potential outcome. While such limitations of traditional lab and field experiments become evident in the case of autonomous driving (e.g. Camara et al. 2018), these shortcomings are not only relevant for studies in the context of modern forms of human-machine interaction. Several traditional economic, psychological, and behavioral experiments have been criticized for their lack of realism, often owing to the fact that a realistic setup would be too expensive to implement for the research team or too unsafe for the participants. One solution to increase realism and safety of experiemnts are experiments in virtual environments (Mol 2019). The latest developments in the field of virtual and mixed-reality technologies, such as virtual reality glasses, have enabled researchers to conduct immersive and thus realistic simulations. Conducting experiments in such environments has been found to provide high external and, in particular, ecological validity (Innocenti 2017). However, setting up such virtual simulations for conducting experiments is often cost-intensive and complex to realize. Therefore, in this work, we propose using emerging game-based 'metaverse' platforms such as Roblox, Meta horizon, VRChat, or Fortnite Creative to conduct realistic and immersive experiments that could be realized with low efforts and costs. These platforms are growing in popularity and offer free tools to easily, and thus cost-efficiently, implement immersive 3D worlds, which could be used for conducting virtual simulations and experiments. In order to investigate whether virtual experiments can be realized in current metaverse platforms more efficiently than in traditional virtual environments and with a higher external validity than traditional lab experiments, we use an autonomous driving scenario and implement a virtual experiment on the Roblox platform. Our approach draws on the 'chicken game', a traditional game-theoretical concept that assumes two cars on a collision course and investigates whether participants swerve to avoid a potential crash, for studying whether people are willing to forego autonomous driving in order to gain a slight advantage over others. Thus, by performing this research, we want to answer the following research questions:

RQ1: How can virtual 'metaverse' environments support scientists in conducting experiments with high external validity?

RQ2: Are people willing to forego autonomous driving and thus accept an accident in order to gain a slight advantage over others?

In this work, we will realize the autonomous driving experiment according to the game-theoretic chicken game. Previously performed experiments on this game are mainly of theoretical nature and have been mainly conducted in abstract and very simplified representations of reality. In these scenarios, participants have to decide on a strategy before the actual experiment. As a result, the behavior of participants might be purely driven by strategic thinking without potential effects of the situation. We also want to allow spontaneous reactions, which is why we plan to use a virtual experiment. Thus, we plan to use a scenario where two drivers aim to reach an empty spot at an electric charging station at the same time. The worst outcome for the participants hereby can be a virtual car body damage at low speed. We believe and want to empirically test whether such experiments provide higher external validity in terms of providing a simulated version of the real-world experiment. In our setup, the decisions are made during the experiment and are not made before the actual experiment. In particular, we want to investigate if user behavior and decisions in experiments in the metaverse differ from traditional approaches in lab experiments with more abstract designs. We argue that virtual experiments in metaverse platforms can be implemented more efficiently and might be perceived more realistic by participants compared to traditional approaches of previous research in this field. This research could also give novel insights into how experiments should be replicated in virtual worlds.

As an experimental environment, we will build custom 3D worlds within the metaverse platform 'Roblox'. With more than 29 million registered developers and 24 million virtual worlds, Roblox is one of the largest and most popular metaverse platforms. Further, the Roblox developer tools allow implementing immersive 3D environments easily and fast, even without comprehensive programming knowledge.

In the following, we will present related work and the fundamentals of this planned study. Next, we will demonstrate how we will set up the experiment and evaluate the results. We will then introduce the planned experiment and demonstrate how we will run the experiment. Further, we present an insight of the actual ongoing implementation of the experiment in Roblox. We then conclude with limitations and an overview of the work as well as an outlook on our following steps.

2 Related Work

2.1 Game-Theoretic Experiments

Game-theoretic experiments and the related field of game theory have a long tradition in social science, economics, and politics (Myerson 2013). The roots of modern game theory lay in the early 20th century, starting with the work of Zermelo and Borel (1913) and Neumann in 1928 (Leonard 1995). During the World War II, the research field became popular and widely accepted (Von Neumann and Morgenstern 2007). Game theory focuses on explaining individuals' decision-making by taking into account the specific goals and preferences of individuals. Commonly, game theory deals with the study of mathematical models between two or more individual decision-makers. Cooperation and conflict situations are mathematically analyzed, as the individual decisions will always provide a measurable outcome expressed through the welfare of the other participants (Myerson 2013). In the past years, economic experiments used experiments both to test theories but also to motivate and develop new theories. The latter requires a high external validity of experiments (Mol 2019). Previous research has implemented such experiments with tremendous efforts or simply could not ensure required realism. One example of an experiment that is hard to implement and test in reality is the popular Chicken Game.

2.2 Brinkmanship Game / Chicken Game

In the classical Brinkmanship game, better known as “Chicken Game”, two participants compete against each other on a narrow route. Each participant drives a vehicle and has the choice to swerve or to stay on the course. Staying on the course causes a head-on collision, if no one swerves. However, if at least one driver is swerving, the collision can be avoided (Allison 1971; Snidal 1991). Although this experiment looks very simple, it has gained much interest for the investigation of intergroup relations (Bornstein et al. 1997) and even in international relations (Allison 1971). For example, Allison explained the Cuban missile crisis through this game-theoretic approach. Also in economics, intergroup conflicts such as disputes between workers and their management are regarded through this approach (Snidal 1991). What they have in common is, that a failure of both sides lead to an outcome with great disadvantages for both sides such as bankruptcy or war (Bornstein et al. 1997). This can be represented in a related payoff matrix as shown below. In this matrix, a participant has a small benefit from not swerving when the other participant does (combination (a12,a21) or (a11,a22)). However, a great disadvantage gains the combination (a11,a22), where both drivers force the strategy 2 and do not swerve. The notation in the matrix hereby is: (Payoff Driver 1, Payoff Driver 2).

Driver 1\ 2	a_{21}=swerve	a_{22}=straight
a_{11}=swerve	(0,0)	(-1,+1)
a_{12}=straight	(+1,-1)	(-100,-100)

Table 1. Payoff Matrix ot the Chicken Game (adapted from Bornstein et al. 1997)

In the chicken game, each participant can only decide between two options. However, in reality, commonly more options are existing. Further, if someone would realizing this game in a real-world experiment, participants would have more than two options, for example swerving at different points of time or throwing the steering wheel out of the window as a self-binding strategy. Such experiments can hardly be realized (e.g. prohibition through laws or ethics) and could influence the safety of the participants. Virtual experiments can help hereby to realize such experiments in a safe and at the same time immersive, and thus realistic environment (Mol 2019).

2.3 Virtual experiments

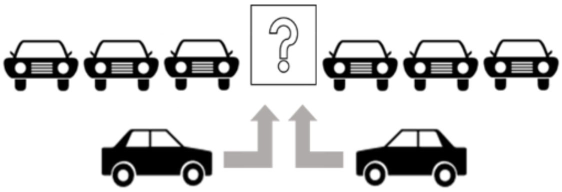
In disciplines like psychotherapy, engineering, spatial planning, or social psychology, the use of virtual realities for conducting research is already well established (Bombari et al. 2015). However, economic research have largely neglected the use virtual research tools so far and only few virtual experiments have been found in previous research (Mol 2019), although experts highlight that such using virtual realities could "add crucial realism to lab experiments and more control to field experiments" (Mol 2019, p. 156). Escaping the real world by entering virtual worlds has captured people's imaginations for many years. The idea of creating virtual worlds was introduced in science in the mid of the 1990s. In the last years, experimental economists started to discover the unique advantages of virtual realities for their research, but the number is still small (Mol 2019). This is astonishing as advantages in the field of experimental control and increased realism (e.g. through immersion in the virtual reality) are obvious (e.g. Biocca and Levy 1995). Innocenti (2017) investigates, how virtual experiments allow for a proof of external validity of an economic theory. In this work, Innocenti (2017) focused on virtual environments like virtual worlds on Roblox or Fortnite. For the researcher, virtual "experiments are framed field experiments, which allow testing the effect of contextual cues on economic decision-making under the strict control of the experimenter" (Innocenti 2017, p. 71). He furthermore points out "to construct and test models of behavior in virtual reality to check if behavioral implications of these models fit what might be found in the real world" (Innocenti 2017, p. 86). However, designing virtual worlds is traditionally cost intense. Further, entering these worlds requires specific hardware. However, the video game industry has worked intensively to make the creation and use of virtual worlds accessible to the mass market in recent years. The developments have resulted in so-called 'metaverse' platforms on which users can create connected virtual worlds and make them accessible to other users on the platform. Previous research has largely overlooked this emerging area for conducting experiments.

3 Method

In order to realize the experiment in a virtual environment, we use the basic version of the chicken game with two players. Thereby, we are focusing on autonomous driving in our experiment. As mentioned, such a chicken game can be conducted very complex. However, we want to keep it simple to enable an easy understanding of the realization and to encourage scholars to realize such experiments virtually.

3.1 Experimental Scenario

Due to recent technological developments, autonomous driving is gaining increasing relevance and use in everyday mobility and transportation. In autonomous driving, various situations can be found in which a user may need to take over the system and make a manual decision suddenly. In such situations, users who can react immediately can have advantages over users who relax or focus on other things than the traffic during autonomous driving. We investigate such a scenario with two autonomous driving cars in a specific setup. Both drivers arrive at an electric charging station simultaneously with just one spot left. In order to avoid an accident, each car stops immediately next to the charging station and requires the driver to take over. The drivers can switch to manual drive, drive in charging station spot and benefit from saving time being the first who has repowered the car. In the worst case, they will cause a virtual car body damage at low speed if both use the manual drive, with a negative outcome for both drivers.



Driver 1\ 2	a_{21}=stop	a_{22}=drive
a_{11}=stop	(P_{1A},P_{2A})	(P_{1B},P_{2B})
a_{12}=drive	(P_{1C},P_{2C})	(P_{1D},P_{2D})

Figure 1. Empty spot scenario and related Payoff matrix with Payoff P_X for Driver x

The figure above reflects the scenario, where two cars arrive at the charging station spot at the same time. On the right side, the different strategy combinations of two drivers and the choices between stopping and driving are given. In order to keep the fundamentals of the chicken game, the individual payoff relations of the drivers have to be:

Driver 1: $P_{1C} > P_{1A} > P_{1B} >> P_{1D}$ and **Driver 2**: $P_{2B} > P_{2A} > P_{2C} >> P_{2D}$

The payoff of situation A,B and C has to differ only little, while the payoff for both drivers in situation D has to differ noticeable (Snidal 1992). Both drivers that immediately drive cause an accident with a much higher negative payoff in amount than they would gain from being first to recharge.

3.2 Subjects and Design

As shown above, the experiment is a two player experiment in which the players compete against each other. One advantage of this scenario is that it would be expensive to realize in reality but not very complex t oexcecute in a virtual environment. Further, it is possible to include more than two players in order to investigate different effects (Bornstein et al. 1997).

Participants can be heterogeneous and form a cross-section of society. They just need a computer and need to follow a link, sent via mail or shared in a social platform like Instagram or Facebook. As incentive, they will get a monetary reward after taking place in the experiment, which can be transferred on the bank account. Each participant is assigned as player one or two and plays one round in order to eliminate “tit for tat” or personal strategies in repeated games.

3.3 Platform Roblox

The experiment is realized in the metaverse ‘Roblox’, a game-based platform that allows to easily create immersive 3D worlds with low requirements on programming skills. We decided for Roblox because it is easy to use and well-known as for example half of the children under 16 in the US use the platform (Browning 2020). The Roblox Corporation, founder of Roblox, sees its mission in bringing people together from all over the world and provide immersive 3D experiences (Bronstein 2021). Next to traditional games, also labs or scientific content can be shared in virtual Roblox worlds. We use Roblox to gain a realization of the chicken game according to the foundations and principles.

3.4 Procedure

The virtual setting allows to measure precise and realistic user behavior and at the same time ensures the physical safety of the participants. A link will bring users to the experiment’s page on Roblox. After starting the game, we will provide the users with an instruction, including the rules of the game and the payoff. The individual payoffs are implemented as a function of the player’s own decision and the decision of the other player. Subjects are not instructed to maximize their payoff or to cooperate with the other player. Before starting, subjects have to answer questions, proofing their understanding of the instructions and the payoff matrix. Each participant takes part in exactly one round. At the beginning of the experiment, the participant finds himself inside of a car in front of an empty spot of a charging station and gets some time to get used to the environment. Next to this virtual avatar, the user can see another car with the same distance to the parking spot. Each participant has to decide between keeping the autonomous driving button or change to manual drive. The car will drive to the spot and gets recharged by the charging station attendant. However, if both press the manual drive button an accident will happen. If both press the autonomous drive button, an algorithm will randomly select who will be recharged first. The process of recharging a car has a duration of 5 minutes, which means, that the participant of the second car has to wait 5 minutes before he can drive in the spot and has to wait another 5 minutes. After recharging, each participant gets to the debriefing page and has to fill in his bank details.

3.5 Payoff

Each participant gets an individual payoff, which is a combination of money and time. If no accident happens, each participant gets 10 $ at the end of the experiment. In case of an accident, they only get 1 $ after 10 minutes. In a pre-test, we will investigate, if the waiting time is sufficient or has to be enlarged. Being recharged first means a time advantage and therefore an increased benefit in contrast to be recharged second. Each individual payoff matrix looks the same for each participant:

Individual Payoff		Decision other Participant	
		Autonomous Drive	Manual Drive
Own Decision	Autonomous Drive	A: 10 $ in 7,5 minutes	C: 10 $ in 10 minutes
	Manual Drive	B: 10 $ in 5 minutes	D: 1 $ in 10 minutes

Table 2. Individual payoff matrix for the experiment

One has to note, that if both drive autonomously, 7,5 minutes are the expected value for each participant, as there is a fifty percent chance to be selected being recharged first and fifty percent to be selected second. Additionally, we expect the time differences as a small benefit for each participant, while there is a huge benefit regarding 1$ and 10$. This implies the payoff relation for each participant as PC > PA > PB >> PD. Causing no accident will result in a much higher benefit and only small advantages can be gained through driving manual while the other is keeping the autonomous driving.

4 Prototype

In the following, we will show the prototype and screenshots of the experiment. As mentioned, each participant plays one round. Following the procedure, described above, the participants first get information about the experiment and about the general setting. This can be done in the system itself (left side of the figure) or even another system can be used, linking to Roblox for the experiment. As it can be seen in the following figure, the participant can click through the information and has the possibility to jump forward and back in the information phase whenever he wants. With clicking on “Start Game”, the experiment starts and the user does not have the chance to get back. In the right side of the following figure, the experimental decisions are given. The participant can decide between the autonomous and the manual drive with the related outcomes. As mentioned, the experiment is played only one round but can be easily extended to more rounds. We can thereby log for the users actions and can exclude results, where participants did not follow the rules. The result of the experiment is shown in the screen: If no accident was caused, the player have to wait the specific time (5, 7.5 or 10 minutes) and gets 10$. If an accident happened, the both players have to wait 10 minutes and get a payment of 1$ each. The time for refuling and for waiting is also shown to the player. Furthermore, one has extensive modelling possibilities like a charging station attendant (in the right part of the figure):

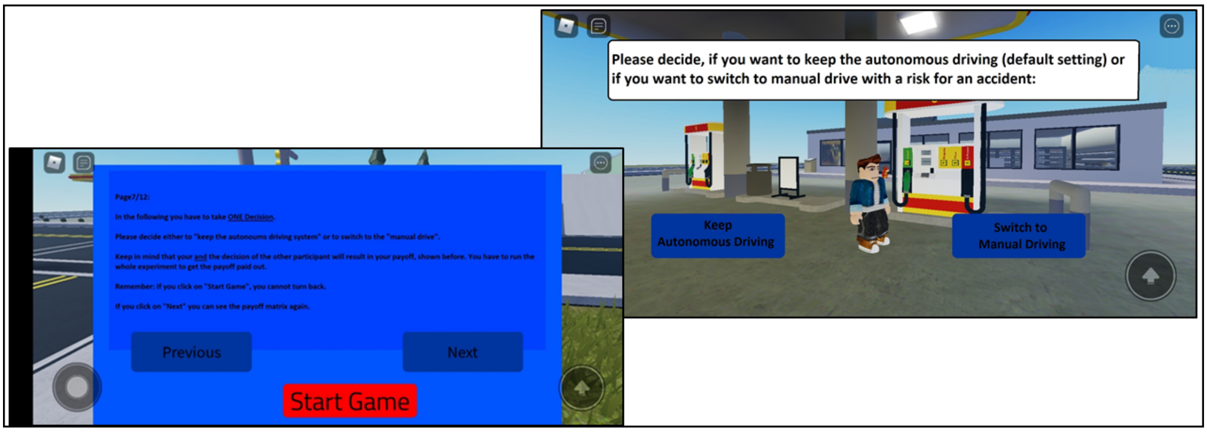


Figure 2. Exemplary information (left) and experimental decision (right) in the Roblox System

5 Limitations and Conclusion

As shown, metaverse platforms such as Roblox provide huge and yet untapped possibilities for experiments. Laboratory experiments can be transferred easily into a virtual environment. Further, researchers could control the whole experimental environment and can isolate variables to investigate cause-and-effect relationships. Virtual experiments enlarge the possibilities of scholars that aim to study social and behavioral outcomes, as nearly any situation can be simulated virtually. Another advantage of experiments in the metaverse compared to real world experiments and previous conducted virtual experiments is, that virtual metaverse experiments can be designed and implemented fast and with low effort. Next to lower time and costs, even complex experiments can be implemented even with low knowledge in programming. However, also virtual experiments come with some limitations. Virtual experiments, in particular in playful environments like Roblox, might be not as immersive as real-world experiments and thus might have variations in the psychological outcomes. Further, designers of virtual experiments should check, if the participants are realy into the setting. The metaverse we selected for this study, Roblox, provides an artificial “comic”-like environment, where users have simplified avatars with little expressions. As a result, it needs to be ensured, that ones’ natural behavior is investigated and not an artificial behavior caused by the virtual setting.

The simplified representation of avatars and objects makes it easy for designers to implement an experiment. On the other hand, the missing details can counteract the immersion and limit the design space. For example, experiments that would require the use of facial expressions might not be feasible on such metaverse platforms. Future research should investigate, for example, how the appearance of avatars in virtual experiments may influence decisions.

Nevertheless, based on our first experiences of using metaverse platforms like Roblox to conduct experiments, we could state that such platforms offer a helpful and efficient environment for designing and performing virtual experiments. We have developed a world in which we can test a setting, where participants have to decide whether to get a slight advantage by taking the risk of a potential accident or waiting to be on the safe side but risking to be served second. Our approach shows that even setups, which would be hard to realize in reality, can be implemented virtually on metaverse platforms. Further, we believe that such experiments can support scholars in attracting large groups of participants, as such game-based platforms could be accessed from mobile and desktop devices independent of their physical location. This work presents the development of a virtual experiment in the platform Roblox, ready for collecting insights on decision-making and human factors in autonomous driving. As a next step, we will run this experiment to investigate whether people prefer to get a slight advantage under the cost of a potential accident with an autonomous car. Further, we will investigate whether our results differ from previous, more abstract studies. We believe that metaverse experiments offer an innovative and efficient way for performing experiments next to laboratory experiments and other types of virtual experiments.

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