Experimental Economics in Virtual Reality

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Experimental economics uses controlled and incentivized lab and field experiments to learn about economic behavior. By means of three examples, we illustrate how experiments conducted in *immersive virtual environments* emerge as a new methodological tool that can benefit behavioral economic research.

1 Introduction

Recent developments in virtual reality (VR) technology have the potential to revolutionize the way social scientists do experimental research. With light and affordable head mounted displays (HMD), such as Oculus' *Rift* or HTC's *Vive*, human subjects can be "immersed" into virtual environments. When combining this technology with tracking devices, subjects can literally move and use objects in virtual spaces, or – given multiple connected setups – interact with other subjects in virtual reality. This technology as well as surround-screen projection systems like CAVEs (Cruz-Neira, Sandin, & DeFanti, 1993) allow the experimenter to observe economically relevant behavior and social interaction in a natural, and at the same time tightly controlled virtual environment.

Jim Blascovich et al. suggested the use of *immersive virtual environments* as a methodological tool in social psychology, and conducted some of the very first experimental studies (Loomis, Blascovich, & Beall, 1999; Blascovich et al., 2002). Their

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research, together with other scholars' contributions, show that humans indeed perceive immersive virtual environments as natural. This phenomenon of feeling "being there" in the virtual environment is referred to as *presence* (Slater, Usoh, & Steed, 1994). While presence describes a subjective experience, *immersion* refers to the technological aspects of the virtual environment, such as the resolution and the "field of view" of the displays, the quality of the tracking system etc.

Due to high costs, however, until recently, social science research using virtual reality was limited to few labs and small sample sizes. Recently, affordable HMDs and other periphery devices, for example the *Microsoft kinect* for full body tracking or the *LEAP motion controller* for hand tracking, have become available and accelerated research. A study by Bombari et al.(2015) discusses the unique added value of VR technology for social interaction research and reviews the recent literature in this field.

Previous applications of virtual reality in experimental economics were mainly limited to research in desktop virtual worlds like *Second Life* (Chesney, Chuah, & Hoffmann, 2009; Atlas & Putterman, 2011; Fiedler, Haruvy, & Li, 2011; Füllbrunn, Richwien, & Sadrieh, 2011; Greiner, Caravella, & Roth, 2014). In virtual worlds, however, the degree of *immersion* is low, as visual information is mediated through 2D monitors, and the interaction with objects and other users is executed through mouse-controlled *avatars* (virtual representations of humans). While virtual worlds have some remarkable research potential (Bainbridge, 2007; Haruvy, 2011), they also have very important drawbacks for experimental research, as the loss of control over subjects' characteristics (Duffy, 2011). This led economists only recently to begin utilizing controlled virtual world experiments (Twieg & McCabe, 2014). A paper by (Harrison, Haruvy, & Rutström, 2011) discusses the key concepts behind the experiments in virtual worlds and virtual reality.

2 Experimental Economics in Immersive Virtual Environments

More than other disciplines, economics focuses on the evaluation of counterfactual scenarios which help to analyze strategic decisions and their efficiency effects. Counterfactuals, however, are not easily observable, not even in field experiments. On the other hand, counterfactual scenarios in the conventional lab settings are often perceived as "sterile environments" since they are not embedded in a natural frame (Harrison & List, 2004). Experiments in immersive virtual environments could fill a gap by enabling us to test counterfactuals using setups that are as controlled as in the conventional labs, but perhaps even more realistic. One could also test settings that would be very costly, or simply impossible to implement in the field, due to physical restrictions or ethical reasons.

In the next sections, by means of three examples, we illustrate the added value of experiments in immersive virtual environments and how they may benefit behavioral economic research.

2.1 Naturalistic representation: Eliciting (risk) preferences

Preferences expressed and economic decisions taken by human subjects can depend on perceptions of the external context and environment in which a decision problem is presented. A subject who experiences a strong presence in virtual reality may automatically suppress that she is participating in an experiment, and display a more natural behavior.

Glenn Harrison et al. conducted experiments in virtual reality, utilizing driving simulators to elicit subjects' risk preferences (Dixit, Harrison, & Rutström, 2013), or using flat monitors to show subjects 3D modeled wildfires, in order to evaluate their risk perception (Fiore, Harrison, Hughes, & Rutström, 2009). The latter study finds that subjects' beliefs about risks are closer to actual risks when they are exposed to 3D animated wildfires compared to when they see still pictures of the same 3D animation. By applying virtual reality to a context of evaluation choices, "the strengths of the artefactual controls of laboratory experiments with the naturalistic domain of field experiments or direct field studies" could be combined (Fiore et al., 2009).

2.2 Tracking & realistic interactive tasks: Breaking the limits of real effort experiments in the lab

In immersive virtual environments, subjects can perform more natural tasks than in traditional labs where this is confined to a 2D computer screen. Furthermore, *tracking* in virtual reality enables measuring a subject's position, orientation, and movements in space. In a novel real effort experiment conducted in the aixCAVE of the RWTH Aachen University, we capture exact measures of subject's effort not in only one but in several dimensions (Gürerk, Grund, Harbring, Kittsteiner, & Staffeldt, 2014).

In our setup, the subject is inside a virtual production hall. There, she physically works at a virtual conveyor belt, sorting out virtual cubes with a defect. To check for defects, the subject can literally grasp and rotate the cubes with the own hand. We are able to measure performance multidimensionally by taking the number of not rejected cubes with various types of defects, the number of rejected cubes without defects, the number of grasps and the duration of grasps into account. We can evaluate how subjects make the trade-off between quantity and quality as a function of the economic incentives

(a) aixCAVE (b) HMD

Figure 1: (a) Subject interacting with a virtual cube in the aixCAVE of the RWTH Aachen University. (b) A participant of the Econ. Science Assoc. Meeting trying our demo with a HMD, Dallas, October 2015.

provided. Other dimensions of tracking such as precision of grasps, body movement and eye tracking could also be included.

Using a variant of the immersive virtual environment introduced above, (DeHoratius, Gürerk, Honhon, & Hyndman, 2015) investigate whether and how product similarity affects execution failures in a retail setting when workers must identify and sort products based on their observable characteristics. Introducing a clear visual cue to distinguish the products improves execution when the products are dissimilar (by lowering sorting mistakes) and, even more so, when they are similar (both by reducing sorting mistakes and the number of products unsorted).

2.3 The magic of *co-presence*: Solving the reflection puzzle through human-avatar interaction

Using virtual humans in social interactions (Schroeder, 2010) creates the opportunity to analyze causal relationships between simultaneously observed individuals' (or groups') behavior, which in traditional experiments is severely hampered due to the well-known reflection problem (Manski, 1993). In the setup explained in the section before, we introduce a computer-controlled virtual human who works at a parallel conveyor belt and is observable by the human subject (Gürerk, Kittsteiner, Bönsch, & Staffeldt, 2015). The virtual co-worker exhibits different working behavior from slow to fast, respectively.

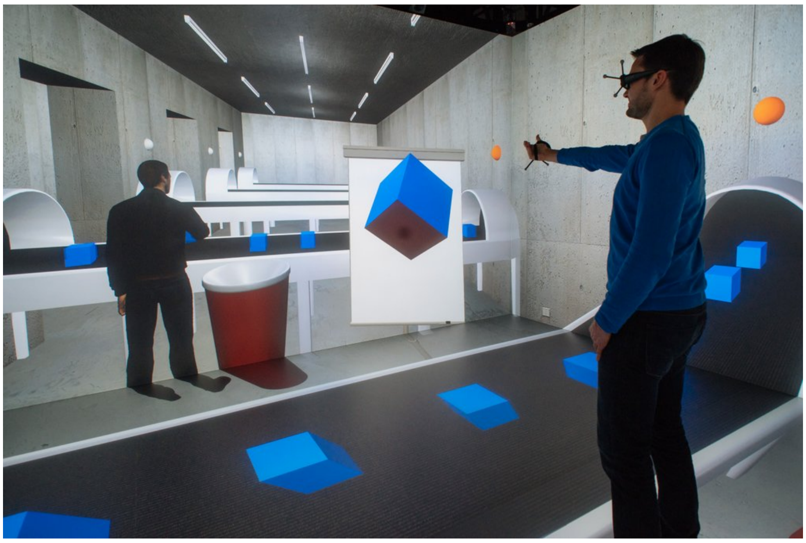

Figure 2: Subject working in the aixCAVE of the RWTH Aachen University in the presence of a virtual human.

Since the human subject cannot influence the virtual co-worker, we can rule out the identification problem. This enables us to observe non-confounded peer effects of the virtual human's work speed and work care on the human subject's performance.

As a further related idea, physically or behaviorally pre-programmed virtual humans may help overcome cultural barriers when conducting experiments with participants coming from different parts of the world.

3 Challenges

One of the challenges in conducting experimental research within immersive virtual environments is the trade-off between costs and internal as well as external validity. Using more costly virtual reality systems like a CAVE instead of a low-cost HMD usually increases the presence, as subjects can perceive their complete (physical) body, especially their interacting hands.

Furthermore, virtual humans' realistic visualization and movements crucially affect its acceptance by the subjects and how humans interact with them (Kasap & Magnenat-Thalmann, 2007). Modeling natural interaction patterns of virtual humans used to be a fundamental technological issue, but recent developments in optical tracking technology brought improvements with affordable prices.

As more and more research is conducted in immersive virtual environments, scholars must also investigate possible (lasting) effects of the VR technology on subject's behavior (in real life). A recent study covers this important topic (Madary & Metzinger, 2016), making recommendations for a good scientific practice for VR research with humans.

4 Conclusion

Currently, experts as Jaron Lanier who popularized the term "virtual reality", or entrepreneurs as Mark Zuckerberg expect a great future for virtual reality in entertainment as well as in transforming human communication and collaboration in shared virtual spaces. In a post dated 25 March 2014, Mark Zuckerberg announces the acquisition of HMD-maker Oculus VR by Facebook and states: "After games, we're going to make Oculus a platform for many other experiences. Imagine enjoying a court side seat at a game, studying in a classroom of students and teachers all over the world or consulting with a doctor face-to-face – just by putting on goggles in your home."[1]

We believe the new possibilities have also great potential to take experimenting in economics to the next level, by enabling us to elicit preferences more reliably, by leading to a better understanding of the relation between incentives and effort, and by the investigation of social interactions in a way never possible before.

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[1]Quote taken from the post on: `https://www.facebook.com/zuck/posts/10101319050523971`

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