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Virtual reality experiments in economics

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ABSTRACT

The paper provides a review of research using virtual reality as a laboratory tool in economics. It addresses the question of whether behavior in virtual environments is a valuable source of empirical evidence for economists. A typology of virtual reality experiments based on the difference between low-immersive (LIVE) and high-immersive virtual environments (HIVE) is proposed. It is argued that virtual reality experiments are *framed* field experiments, which allow testing the effect of contextual cues on economic behavior under the strict control of the experimenter. This feature enhances replicability and attenuates the context-free illusion that represents an important limitation of the standard laboratory approach in economics.

1. Introduction

Laboratory experiments were first proposed as tools for economists nearly 70 years ago. Since then they have been increasingly used to investigate market efficiency and to improve our understanding of economic behavior. As a result, it is not controversial today that simulating and analyzing choices taken under artificial and controlled conditions is useful for economists to such an extent that experimental economics has become a reference for comparison and validation of disciplines like psychology, which originated as experimental sciences (Hertwig and Ortmann 2001).

Nevertheless, the evolution of the discipline has been anything but straightforward by giving rise to a vigorous debate that have put continually under scrutiny methods and principles of laboratory research in economics (Guala 2005). This history, which owes its inception to the laboratory tests of Neumann and Morgenstern (1947) models of strategic interaction, and its key turning points to Vernon Smith's (1962) representation of markets as experimental microeconomic systems and Kahneman and Tversky (1979) foundation of behavioral economics, challenged the basic tenets of economic theory by focusing on the validity of the rationality hypothesis. As a result, the main approach to experimentation in economics aimed at verifying the behavioral implications of abstract models in very stylized decision tasks rather than addressing the issue if laboratory behavior generalizes to the real world.

More recently, however, the debate on the use of laboratory methods in economics has progressively shifted from the content to the context of experiments. On one hand, it has been argued that context-free experiments are an elusive goal because laboratory is not a socially neutral framework but an institution per se with its own explicit and tacit rules (Loewenstein 1999). On the other hand, the behavioral and cognitive approaches to economics have contended that it is not appropriate to draw conclusions about the validity of theories from experiments without taking into account how context affects behavior (Harrison and List 2004; Levitt and List 2007). Indeed, a major tenet of cognitive psychology is that all forms of thinking and problem solving are context-dependent and that to test decision models it is necessary to remind and to evoke in the laboratory social and contextual cues, which may activate associations and emotions and trigger the use of field heuristics (Loewenstein 1999).

These arguments led Harrison and List (2004), which endorse field experiments to check the validity of laboratory findings when context matters, to propose a taxonomy that differentiates *natural* from *framed* field experiments, being the latter those in which "the field context is embodied in either the commodity, the task, or information set that the subjects can use" (Harrison and List 2007: 1014). A recent approach to embody the field in the lab is

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offered by virtual reality experiments, which can be considered proper *framed* field experiments, since they provide contexts in which users are immersed under the control of the experimenter.

The main question addressed by this paper is if, by providing controlled settings in which individuals decide and interact, virtual reality may contribute to offset the context-free illusion affecting the dominant approach to laboratory experimentation in economics. To investigate this question, the following pages discuss economic research using virtual reality in order to assess its usefulness for checking the empirical validity of economic theories and, by rephrasing Harrison and List (2007: 1013), for verifying if successful decision patterns that evolve in *certain* virtual reality environments *travel* to field and laboratory settings.

Section 2 provides some definitions and a classification of virtual reality experiments based on the difference between low-immersive virtual environments (LIVE) and high-immersive virtual environments (HIVE). Section 3 surveys experiments that apply virtual reality to tests of economic theories by addressing, first, the question if subjects' behavior differs between laboratory and virtual worlds and, then, if virtual environments can provide significant contexts for economic decision-making. The final section summarizes strengths and weaknesses of virtual reality experiments in economics and offers some suggestions for future research.

2. Defining virtual reality experiments

Virtual reality is a powerful method to simulate situations and tasks that allows an accurate control of the state experienced by users. Technically, virtual reality is a computer-generated setting in which individuals act in a real-time simulated environment creating artificial locations through an interface that stimulates one or more senses. The digitally generated space is such that users' movements are tracked and environs are displayed in synchrony with users' actions.

The virtual reality technology can be applied to two types of environments that are differentiated by the degree of users' immersion. The first types are low-immersive virtual environments (LIVE) that are computer screen-based renderings of real environments or virtual worlds, such as Second Life, World of Warcraft, EverQuest, The Sims, in which users interact each other through digital models called avatars embodying their virtual selves. The second types are high-immersive virtual environments (HIVE) that employ specialized displays as Cave Automatic Virtual Environment, which are enclosed boxes showing images projected on multiple interior screens, head-mounted displays, such as Oculus Rift, Samsung Gear VR or Google Cardboard, or augmented or mixed reality devices, like Microsoft Holographic and HoloLens headsets. In these settings, users' senses are dominated by the technical equipment to a degree related to the adoption of devices, such as headphones, body trackers, gloves or touch controller, the extent of view field, the quality of rendering, and the speed of the interaction with virtual domains.

The key element that differentiates virtual reality experiments from standard laboratory tests is the higher level of immersion, which can provide original empirical evidence for a variety of factors. The first factor is related to the theory of ecological rationality (Gigerenzer 1999; Smith 2003), according to which decision making is dependent on the cognitive constraints of decision makers. In order to predict, describe and explain choices, it is necessary to assess carefully the process of individual perception by taking into account the decision environment and the impact of naturally occurring cues, contextual features or pattern recognitions. Ecological rationality is defined as the adaptation to specific environments in order to enhance individual ecological fitness. In virtual reality settings, differently from standard laboratories, individuals can be shown naturalistic details such as "to generate cues that are sufficiently natural and familiar that decisions will be significantly more like those that would be generated in the field with sufficient expertise." (Fiore et al., 2009: 69). Secondly, immersive settings are useful to investigate the processes of information processing and decision-making adopted by individuals to reduce cognitive load and task complexity. By injecting in the lab frames and cues presents in real domains, virtual reality experiments can validly support the main purpose of behavioral economics, that is concerned with the effect of psychological and emotional factors on decision-making (Camerer and Loewenstein, 2004). By being immerse in the artificial setting, subjects react to the virtual environment as if they were real by adopting the behavior driven by the experimental stimuli (Slater et al., 1994; Biocca et al., 2003; Sanchez-Vives and Slater 2005; Gürerk et al., 2016). Thirdly, the immersion in virtual settings can enhance the feeling of copresence, which occurs when individuals treat other digital agents as if they were real human beings (Blascovich et al., 2002). Most virtual reality research on social interaction is conducted in virtual worlds as Second Life, in which users form communities and learn by experience how to interact each other. These features make Second Life a socio-economic environment per se, in which it is also possible to investigate if behavior in virtual reality mimics actual economic behavior (Castronova et al., 2009; Bloomfield and Choo 2011), to analyze social cognition (Bainbridge 2007) or to implement business education (Bloomfield 2009). Thus, it is not surprising that the pros and cons of Second Life as scenery for economic experiments have been carefully scrutinized (Bainbridge, 2007; Chesney et al., 2009; Duffy, 2011; Fiedler et al., 2011; Mildenberger, 2013; Greiner et al., 2014).

Second Life's main practical advantage is that it makes available graphic tools and software to build virtual laboratories, where subjects may be recruited, instructed and incentivized. This feature allows replicating standard laboratories with great flexibility, by achieving a tighter control and providing easier access to a great number and variety of subjects. Virtual worlds give access to subject pools that are far more diverse than standard lab populations. Design implementation can be also carried out easily and conveniently. Both pen-and-paper and computerized experiments can be reproduced accurately and economically, with verbal and nonverbal communication. If necessary, participants may be assembled in the same virtual location to read instructions and post-experimental surveys are easily collectable by checking data collection and comprehension failures. Incentives can be provided through virtual money (Linden dollars), that are convertible to real currency at Lindex, an official currency exchange, or by assigning virtual goods available in virtual markets. More importantly, the environment can include richer contexts than physical laboratory, by providing cues and hints mimicking those occurring in the real world.

On the other hand, anonymity, virtual identity and their entertaining nature present potential drawbacks of experiments conducted in virtual worlds. Firstly, the impossibility to physically observe experimental subjects may represent an invalidating factor. Users may falsify their identity and state, participate multiple times or act in groups by changing avatars, e-mail or IP address (Chesney et al., 2009; Duffy 2011). These behaviors may seriously affect the generalization from results obtained in virtual worlds that can involve selection biases difficult to remove (Harrison et al., 2011). Secondly, the use of avatars can be a direct source of biased behavior. Avatar-based communication has been criticized for being unnatural (Kock, 2004) and to induce artificial identities instrumental to users' interests or expectations. Significantly, Yee and Bailenson (2007) show how the change of the physical appearance of avatars can have a substantial and instantaneous effect on be-