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Virtual Reality Experiments in Economics

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Abstract. The paper provides a critical review of research using virtual reality as a tool in experimental economics. It addresses the question of whether behavior in virtual environments is a valuable source of evidence for economists. It is argued that virtual reality experiments are proper *framed* field experiments, which allow testing the effect of contextual cues on economic decision-making 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.

Keywords: virtual reality, experimental economics, laboratory methods, virtual worlds.

JEL classification: B41, C90, C93

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1. Introduction

Laboratory experiments were first proposed as tools for economists nearly 70 years ago. Over this span of time they have been increasingly used to improve our understanding of economic behavior and investigate market efficiency. 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 methods in economics have 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 Von Neumann and Morgenstern’s (1944) stylized 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’s (1979) foundation of behavioral economics, challenged and modified the fundamentals of economics by focusing on the validity of the economic rationality hypothesis. As a result, the main approach to experimentation in economics aimed at verifying the behavioral implications of abstract models within very stylized decision tasks rather than addressing the issue if behavior observed in the laboratory generalizes to the real world.

More recently, however, the debate on the application of laboratory methods to 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 formal and informal, 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 conclusion about the validity of theories from experiments without taking into account how context affects behavior (Levitt and List 2007, Harrison and List 2004). Indeed, a major tenet of cognitive psychology is that all forms of thinking

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1 “Many experimental economists seem to view their enterprise as akin to silicon chip production. Subjects are removed from all familiar contextual cues. Like the characters ‘thing one’ and ‘thing two’ in Dr. Suess’s Cat in the Hat, buyers and sellers become ‘persons A and B, and all other information that might make the situation familiar and provide a clue about how to behave is removed. The desire to expunge context is reminiscent of a movement among behaviourist psychologists in the middle of this century, at the peak of which some researchers conducted experiments in ‘context free’ temperature and sound-regulated white egg-shaped enclosures. The context-free experiment is, of course, an elusive goal. An egg-shaped cage provides the same amount of context, albeit somewhat more alien, as any other environment” (Loewenstein 1999: F30).

2 “This approach omits the context in which the stressor is normally considered by the subject. In the ‘real world’ the individual is paying attention not only to the stressor, but also to the environment around him and various other influences. In this sense, individuals have natural tools to help cope with several influences, whereas these natural tools...”
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 environmental cues, which may activate emotions and associations and trigger the use of field heuristics (Loewenstein 1999).

These arguments led Harrison and List (2004), that 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 offered by virtual reality experiments, which can be considered proper framed field experiments since they provide computer-controlled sensory contexts in which users are immersed and that are under the full control of the experimenter.

The main argument of this paper is that, by creating controlled environments in which individuals decide and interact, virtual reality may contribute to offset the context-free illusion affecting the main approach to laboratory experimentation in economics. To support this point, the following pages present the research using virtual reality in order to assess if it can be useful to check the empirical validity of economic theories or, by rephrasing Harrison and List (2007: 1013), if successful heuristics that evolve in certain virtual reality environments travel to field and lab settings.

The next section defines the types of virtual reality experiment by introducing the concepts of immersion, presence and co-presence. Section 3 surveys economic experimental literature that applies virtual reality. Section 4 concludes by summarizing strengths and weaknesses of virtual reality experiments in economics and offering some suggestions for future research.

2. Defining Virtual Reality Experiments

Virtual reality is a powerful technique to simulate situations and tasks that allows an accurate control of the state experienced by the user. Technically, virtual reality is a computer-generated real-time setting where users act in a simulated environment. It is a system composed by hardware and software that creates artificial locations through an interface which 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.

are not available to individuals in the lab, and thus the full effect of the stressor is not being observed.” (Harrison and List 2007: 1033)
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), which are computer screen-based renderings of real environments or virtual worlds, such as Second Life, World of Warcraft, Kaneva, The Sims, in which users interact each other through digital models (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 in which the user is shown images projected on multiple interior screens or panels, head-mounted displays, such as Oculus Rift, Samsung Gear VR or Google Cardboard, or augmented or mixed reality devices, like Microsoft Holographic and HoloLens headset. In these settings, users’ senses are dominated by the technical equipment to a degree depending on the adoption of devices as headphones, body trackers, gloves or touch controllers or on the extent of view field, the quality of rendering, and the speed of the interaction between users and virtual domains.

The key element that differentiates virtual reality experiments from standard laboratory tests is the higher degree of immersion that can provide original evidence for a variety of purposes.

The first 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, such as contextual features, pattern recognitions, or template decision rules. Ecological rationality is defined as the adaptation to specific decision environments in order to enhance individual ecological fitness. Thus, cognitive processes are efficient only in relation to specific conditions, while they may be inappropriate in other situations. 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).

The second distinctive feature of virtual reality is to investigate the heuristics adopted by individuals to reduce task complexity and cognitive load. By injecting in artificial environments 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 bounded rationality and psychological and emotional factors on decision-making (Camerer and Loewensteine 2004). By being immerse in artificial environments, individuals responds to the virtual stimuli as if they were
real and can adopt the heuristically driven behavior induced by the messages (Slater et al. 1994, Biocca et al. 2003, Sanchez-Vives and Slater 2005).

Thirdly, the immersion in virtual worlds can enhance the feeling of co-presence, 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 was conducted in Second Life, whose content is created by the users themselves that learn by experience how to behave in naturally evolving communities. These characteristics make Second Life a socio-economic environment per se, in which it is 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).

The pros and cons of Second Life as scenery for economic experiments have been carefully scrutinized with respect to different dimensions (Bainbridge 2007, Chesney et al. 2009, Duffy 2011, and Fiedler et al. 2011).

Its main practical advantage is that it makes available graphic tools and software to build virtual laboratories, where subjects may be recruited, instructed and incentivized. Second Life allows replicating standard laboratories with convenience and flexibility, by achieving a tighter control and providing easier access to a great number of subjects. Design implementation can be carried out without technical constraints. Both pen-and-paper and computerized experiments can be reproduced accurately and economically. More importantly, the environment offer greater realism and may include richer contexts than physical laboratory, by providing strictly controlled cues and hints mimicking those occurring in the real world. In virtual worlds nothing prevents from repeating experiments over long periods with the same set of individuals or to allow or not allow interaction among subjects. Verbal and nonverbal communication between experimenters and subjects and among subjects can rely on a variety of channels (chat, voice, message boards, and screen boxes) that can also be activated simultaneously, privately or publicly. If necessary, participants may be assembled in the same virtual location to read instructions, as it normally happens in standard laboratories (Greiner et al. 2014). Questionnaires or surveys are easily collectable by checking in real time the correctness of data collection and screenshots can be used to provide exhaustive visual and temporal information on the experimental process and to detect mistakes or comprehension failures.

Incentives can be provided through virtual money (Linden dollars), that are convertible to real currency at Lindex, an official currency exchange, or at third party exchanges, or by assigning virtual goods, which are available in virtual markets and shopping malls. Virtual worlds give access to a subject pool that is far more diverse than student populations in many aspects, i.e., education,
age, background, ethnicity, and nationality, but they also allow submitting tests to the standard lab population composed by students or to specific classes of individuals or experts in some field domain (Chesney et al. 2009).

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 be 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). They may unexpectedly disappear attracted by other activities offering greater rewards (Duffy 2011). These issues may seriously affect the generalization from results obtained in virtual worlds that can depend on selection biases very difficult to remove (Harrison et al. 2011).

Secondly, the use of avatars can be a source of biased behavior. Avatar-based communication has been criticized for being unnatural (Koch 2004) and the creation of an artificial identity can be instrumental to users’ interests or expectations. Significant, Yee and Bailenson (2007) show how the change of the physical appearance of avatars can have a substantial and instantaneous effect on behavior in virtual environments. In general, avatars are cast in roles and users may act in accordance with his misperceptions of these roles.

Thirdly, it may be difficult to convince participants that they are part of a scientific experiment. Virtual worlds project a game-like atmosphere in which users may see himself “matching wits” against other subjects or the experimenter. The same incentive effect may be biased by the fact that Linden dollars are not measured by any price index and Second Life residents show a drastic overvaluation of virtual money. (Greiner et al. 2014)

All these criticisms seem more appropriate for the low immersive condition and, particularly, for virtual worlds while they appear less pertinent for high immersive virtual environments, in which technical equipment assures a full control on users’ experience and subjects are physically present in the laboratory. The key question for HIVE settings is whether they are also useful as experimental tools. Do subjects isolated in artificial environments by helmets or caves behave similarly to how they do in standard laboratories and are their decisions responsive to the design created by the experimenter?

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3 “An important purpose for virtual worlds is to create an alternate life, so that differences from one's own life and characteristics, projected and self-reported in virtual worlds, might be expected to be false” (Harrison et al. 2011: 92).
4 “The set of studies presented in this paper makes clear that our self-representations have a significant and instantaneous impact on our behavior. The appearances of our avatars shape how we interact with others. As we choose our self-representations in virtual environments, our self-representations shape our behaviors in turn.” (Yee and Bailenson 2007: 287).
This issue has been dealt in reference to the difference between the concepts of presence and immersion. The isolation experienced in HIVE settings allows people focusing solely on the experimental stimuli, not differently to how monetary incentives provide a necessary requisite for the validity of findings in standard economic laboratories. The immersion of subjects in artificial environments that dominate their perception does not prevent them from being active and cognitively engaged during exposure (Fox and Bailenson 2009, Lee et al. 2009). This condition enhances the sense of presence to the point such that “responses should be considered at every level, from unconscious physiological behaviours through automatic reactions, and from conscious volitional behaviours through to cognitive processing - including the reporting of the sense of ‘being there’” (Sanchez-Vives and Slater 2005: 338).

The feeling of presence allows shedding light on cognitive processes that are typically neglected in experiments in which subjects decide to play a strategic game or assess probabilistic outcomes as the result of conscious and deliberate reasoning. Appropriately modulated, LIVE and HIVE settings can be analyzed like field experiments in which the context is entirely embodied, and consequently controlled, in the experimental design. It is this feature that represents the main difference between virtual reality and field or laboratory experiments and that explains most research work that will be discussed in the following section.

3. Virtual Reality Economic Experiments

It is not surprising that most economic experiments in virtual reality are conducted in LIVE settings and particularly in Second Life virtual world, which provides a set of ready-to-use tools. It is also expected that most research directly addresses the question if behavior “maps” from the lab to the virtual by replicating experiments conducted in standard laboratories. If this may not be necessarily the best approach to appraise the value of a new technology, the emphasis on methodology is a consequence of the many facets of innovation that characterizes virtual reality. However, it should be stressed that an assessment of its usefulness for economic experiments depends on the implementation of HIVE experiments, whose introduction is still in its infancy.

To provide a review of the state of the art, it is useful to divide research works focused on methodological issues (section 3.1) from those introducing explicitly contextual elements in the experimental design (section 3.2). The papers surveyed below are selected on the basis of two features. Firstly, they concern economic experiments conducted in virtual reality environments and, secondly, tests in which participants are rewarded with monetary incentives. These criteria exclude
online experiments, in which subjects are recruited on the Internet to participate in standard economic experiments (Anderhub et al. 2001, Eckel and Wilson 2006, Charness et al. 2007) and researches using virtual world as a venue for conventional field experiments (Nicklish and Salz 2008, Bloomfield 2009, Castronova et al. 2009, Fiedler 2011, De Sousa and Munro 2012).

3.1 Does virtual world behavior map to the laboratory?

The first question addressed by economists in virtual worlds was whether virtual reality experiments replicate the results of standard laboratories rather than how behavior differs between real and virtual environments.

Chesney et al. (2009) are the first to investigate if “virtual behaviour conforms to established results generated in conventional experimentation” (p. 621). They submit to Second Life residents a set of strategic games to analyze how their choices replicate previous laboratory findings. Subjects are casually recruited in various Second Life locations and gathered in a virtual building with restricted access, equipped with virtual objects and tools very similar to computerized laboratories. Instructions and post-experiment surveys are delivered in written form and payments are made in Linden dollars just after the experiment.

In four out of five games, Chesney et al. (2009) find close similarity between virtual and laboratory settings. The only exception is given by the dictator game, in which Second Life users exhibit a slightly greater degree of altruistic giving than laboratory tests, which the authors attribute to the experimenter demand effect, possibly triggered by two-way communication via private instant messaging. The overall results allow authors to conclude that “virtual world economic phenomena are based on similar behavioural regularities observed in standard economic settings and can be tested experimentally within the virtual environment”, although it may be limited by the absence of physical presence that in virtual experiments may preclude “involuntary non-verbal communication, that reveals emotional states” (Chesney et al. 2009: 632).

Similar results are provided in a within-subject experiment by Spann et al. (2007), which test dictator game in the virtual World of Warcraft and compare it to an online experiment. The virtual treatment confirms the statistically significant greater degree of altruism, which is found to be inversely correlated with the self-reported feeling of being present assessed by post-experiment questionnaires. On the basis of these results, Spann et al. (2007) claim that a higher degree of immersion may enhance the external validity of virtual reality experiments.
In contrast, Füllbrunn et al (2011) provide divergent evidence in a trust game,\(^5\) which is submitted in Second Life to users’ avatars and in a physical laboratory to students. Results show that sent amounts are lower, returned amounts are higher and trustees’ choices are more erratic in virtual reality than in the laboratory. These findings are attributed by the authors to the social structure of Second Life that would be an informal, “still evolving” or even “capricious” society, though also a cooperative and trustworthy environment. However, it seems plausible that a sort of experimenter demand effect is at work in Füllbrunn et al.’s virtual setting. Although the procedure is strictly double-blind, the difference between the experimental locations, an entertainment arena in Second Life and a university cafeteria in the lab, and between the monitors recruiting participants, a fancy avatar and a student assistant respectively, could better justify the divergence between the two treatments.

The comparison between virtual and laboratory experiments is extended to the ultimatum game\(^6\) by Greiner et al. (2014), whose design analyzes the effect of communication with or without face-to-face interaction in Second Life and in the lab. They find that more face-to-face communication increases offers and acceptances in the laboratory but not in the virtual world, where subjects-avatars behave more cooperatively across all different treatments. Although Greiner and colleagues argue that differences may be due to the mere effect of belonging to a virtual world, they conclude that “Had Werner Güth conducted his seminal 1982 study of the Ultimatum Game in the virtual world Second Life, his conclusions about deviations of behavior from subgame-perfect *homo oeconomicus* play would not have been different.” (Greiner et al. 2014: 381) They also notices that comparability across experimental methods may be affected by discrepancies in the subjective values attached to virtual Linden and real US dollars and by potentially uncontrollable selection biases in the virtual subject pool.

An original contribution is offered by Duffy (2011), who provides the report of his own experience as participant in a virtual reality experiment.\(^7\) He points out how individual perception of virtual laboratories can be negatively affected by the anonymity of avatars, which may generate a credibility problem that affects the comparison with laboratory findings.\(^8\) This issue, which also concerns online experiments, can be even worsened by the game-like atmosphere characterizing

\(^5\) In the trust game, a first mover (trustor) sends an amount out of an initial endowment to a second mover (trustee). Any amount not sent to the trustee is kept by the trustor. The amount sent is multiplied by 3 by the experimenter and the trustee then chooses to return any part of the received money back to the trustor.

\(^6\) In the ultimatum game, the proposer makes an offer how to split a received endowment with the responder, who then decides if to accept or to reject the offer. In case of acceptance, the endowment is distributed as proposed, in case of reject both players get nothing.

\(^7\) The experiment is described in Atlas (2008).

\(^8\) “The absence of other experimental subjects does lead me to question whether the other player is real, whether those other participants have been given the same instructions (public information), and whether the environment is completely controlled by the experimenters who are playing the role of the other player.” (Duffy 2011: 60)
virtual worlds. It may also explain the propensity to lie on personal traits (age, gender, and education), generally affecting web communities. It does, however, not apply when the virtual environment is specifically designed for the experiment.

Apart these concerns on subjects’ identity, this early research provides support for a close parallelism between virtual world and laboratory experimentation. The key difference seems to be caused by the intrinsic social nature of Second Life, which has a direct impact on subjects’ behavior and may be biased by being located in suggestive environments like fancy islands where users are “teleported”, factors difficult to disentangle by other environmental parameters. In this light, Second Life assumes more the characteristics of a setting for a particular kind of framed field experiments (Harrison and List 2004: 1014), in which the field context is embodied in its rules and norms of social interaction. This implies that the effects of interpersonal relations and communication on economic behavior can represent a direct object of experimentation in virtual worlds, but also that to full appraise the validity of virtual reality experiments is necessary to provide dedicated and tailored settings totally under the control of the experimenter.

### 3.2 Can virtual environments provide context?

The other path to apply virtual reality to economic experiments is the introduction of specifically provided environmental cues in virtual worlds or in stylized virtual simulations of economic settings.

A set of papers testing the one-shot trust game follows this approach. Atlas and Putterman (2011) investigate the effect of visual cues, Fiedler and Haruvy (2009), Fiedler (2009) and Fiedler et al. (2011) the influence of communication and social distance.

Atlas and Putterman (2011) host subjects recruited on Second Life in a specifically designed virtual laboratory, which simulates a physical one with individual rooms where avatars sat in front of screens. Their design replicates the field experiment of Bateson, Nettle and Roberts (2006) on the relations between contributions to an honesty box and the feeling of being watched by pics of staring eyes. They project similar pics and instructions on the virtual lab room’s and introduce two additional textual cues, respectively suggesting cooperative and competitive behavior. In the visual treatments Atlas and Putterman (2011) find that the amounts sent by trustors is significantly

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9 It is interesting to note that subjects’ visual field is under the strict control of the experimenter; “One could vary what pictures hang on the wall of a brick-and-mortar lab room also. However, the virtual environment makes it easier to experiment with different placements, sizes, and lighting, to rule out the possibility of prospective subjects noticing changes being made, and to assign subjects to rooms having one or another photo or none with no possibility of seeing the other rooms (thanks to travel by “teleportation”). More importantly, perhaps, the specific visual manipulations we tried only scratch the surface of what is possible in this medium, so that our treatments might be compared to taking a new vehicle for a quite modest test drive.” (Atlas and Putterman 2011: 60)
increased by the cue of being watched to a degree similar to Bateson et al. (2006), while trustees are significantly more trustworthy, although their decision appears more affected by received amounts than cues. Interestingly, visual hints result more effective than textual ones in enhancing cooperation while the reverse is true for the competition-enhancing cues by confirming the in virtual reality the psychological condition of immersion create a sense of presence eliciting not only context-aware responses but also individually unconscious reactions.

Nonetheless, virtual worlds are structured social networks where the effect of group identity and explicit social cues can be analyzed to assess, for example, the difference between individual and group choice (Charness and Sutter 2012) or the patterns of group decision making (Kugler et al. 2012) without compromising real-world anonymity. This is the object of the experiments conducted by Fiedler (2009), Fiedler and Haruvy (2009) and Fiedler et al. (2011) on the effect of communication on trust game behavior. Fiedler (2009) compares computer mediated communication in Second Life (audio) and on Skype (text chat) by finding that cheap talk increases significantly trust propensity (the amount sent by trustors) but not trustworthy propensity (the amount returned by trustees). Fiedler and Haruvy (2009) show that avatar-based communication among students increases significantly only the amount sent by trustors but non the amount returned with respect to the treatments with no communication and communication among Second Life residents. Finally, Fiedler et al. (2011) try to elicit the embodied social presence characterizing virtual worlds (Mennecke et al. 2011). They submit trust game on the web to Second Life residents and in a conventional laboratory to university students using Second Life as a platform. The treatment with partner selection is played by groups composed by one trustor and two trustees. Before playing the game, the trustor is allowed to chat on various topics with one of the two trustees, who is located in the same room. Then, the trustor has to choose if to play the trust game with this trustee or with the other anonymous trustee located in a different room. In the first case, the amount sent by the trustor to the trustee is multiplied by 2, while in the second case by 3 or 4. The control treatment replicates the standard trust game played anonymously by pairs without communication. Unsurprisingly, findings show that social distance, measured by avatars’ room location and communication, dominates the effect of monetary incentives by causing a loss of efficiency, but Second Life residents exhibit greater dependence on social distance, lower trust propensity and higher trustworthiness than university students by confirming how an endogenously generated institution like Second Life affects subjects’ behavior.

It is exactly this feature that induces Al-Ubaidly et al. (2014) to consider Second Life as a proxy for social institutions in which to conduct a typical framed field experiment on the natural resource curse. The authors claim that “the visceral, visual elements inherent in Second Life™ are
“desirable because they reduce the social distance between subjects relative to traditional laboratory designs.” (Al-Ubaidly et al. 2014: 46) In their experiment, subjects have to decide how to allocate the initial endowment of natural resource income between rent-seeking pursuit, characterized by negative externality, and production, associated to positive externality. The virtual environment reproduces a spatial layout mimicking physical neighborhoods in which subjects’ avatars can move around to chat with and to monitor other avatars’ behavior. As postulated, in the treatment with communication and monitoring, assumed to be representative of high quality institutions, subjects play cooperatively by reducing rent-seeking and increasing production in response to a resource boom. In another experiment, Twieg and McCabe (2014) test the same condition - a virtual environment with chat and spatial monitoring - to investigate the conditions for efficient property rights systems in a common-pool renewable resources system. They use an open-source server platform (Open Sim) to create a customized virtual world and a commons spatial environment in which heterogeneous natural resources (berries of different colors in virtual berry fields) can be harvested to analyze which kind of territorial property rights emerge. The design also includes the possibility of costly specialization in harvesting a specific color of berry that maximizes income. Their key finding is that communication, monitoring and specialization enhance the probability of creating efficient private property rights. Twieg and McCabe’s design replicates Jansse and Ostrom’s (2008) test in which that which subjects communicated face-to-face in a desktop simulation of a renewable resource environment. In both cases, participants use avatars, but in Twieg and McCabe’s customized virtual world the introduction of virtual places and meeting areas enhances participants’ immersion and sense of presence.

How effectual spatial and temporal cues can be provided in virtual reality experiments is shown by Fiore et al. (2009), whose simulation of forest fires is aimed at investigating how subjects change their propensity to pay for fire prevention policies. With respect to previous experiments (Jude et al. 2006), their rendering enables subjects to change perspective on the visual environment by traveling across space and by moving back and forth in time within fire scenarios, which are made to develop according to a formal model. The comparison between the virtual reality treatment and the static treatment with 2-D time-shot images of the same fires allows estimating subjective parameters of risk and loss aversion and probability weights. Fiore et al. (2009) also submit a questionnaire on the sense of presence (Witmer et al. 2005) showing that subjects perceive high levels of involvement and immersion. A similar approach is followed by Bateman et al. (2009), who implement a virtual reality experiment to elicit preferences for changes in coastal land use. As in Fiore et al. (2009), subjects can fly around and explore rendered areas built on the basis of actual geographic and topographic data, while in the control treatment the same identical lands are
presented in numeric form (i.e., use types and hectares). In the virtual treatment participants exhibit a lower difference between willingness to pay for gains and willingness to accept the corresponding loss. The conclusion is that the provision of virtual cues can temper the impact of judgment errors in assessing the attributes defining the good to be valued.

This evidence provides a robust argument to criticize one of the basic tenets of laboratory methodology is that the use of non-professional subjects and monetary incentives allows making subjects’ innate characteristics largely irrelevant (Smith 1994). In many experiments, it is as if subjects take into the lab the preferences applied to real choices and stick to them with high probability. These biases or inclinations may override the incentive effect. Visual information and, more generally, labels provided in virtual reality can offer clues to make subjects more rational and to increase external validity of experiments with a minimal sacrifice of internal validity.

This effect can be amplified by boosting the sense of presence in HIVE settings, where context and subjects’ attention is totally under the control of the experimenter. A first attempt in this direction is provided by De Horatius et al. (2015), which design an experiment in which subjects perform a sorting tasks on a virtual conveyor belt. They use a cave automatic virtual environment (CAVE), in which projectors are directed to five of the surrounding walls of a room-sized cube, users wear special glasses to perceive the three-dimensional graphics and interface software synchronizes projected images with users’ positions and movements. The result is that subjects experience full immersion while performing experimental tasks. This apparatus allows providing images of the products (virtual cubes of different colors to sort in virtual bins) to be sorted on the conveyor belt and visual cues helpful to improve sorting accuracy and productivity.

4. Conclusion

The question that this paper has addressed is whether virtual reality can be a suitable tool for conducting economic experiments. The literature surveyed above points out a number of pros and cons, but it makes evident that the process of introduction of virtual reality in experimental economics is still in its early days. A full assessment of its effectiveness clearly depends on the development and availability of content for experiment in high-immersive virtual environments. Until today, it should be said that the technology allowing to reproduce high immersive environments in the laboratory is too recent to be effectively implemented.

The most evident advantages of virtual reality experiments are the practical ones. Today researchers can easily perform experiments in virtual sceneries perfectly tailored to their scientific
purposes and to keep them under strict control. Subjects’ perception of the experimental setting can be manipulated and tested almost without limits in a way that is not possible either in the field or in the lab. Today this can be made with low budget and it can reasonably be expected that the cost of generating experimental data in virtual reality will be constantly decreasing in the near future. Recruitment is easier and, if appropriately made, it allows avoiding sample selection effects. Finally, the design implemented in virtual reality can be replicate accurately both on the web and in the lab.

But the main argument supported by this literature is that the importance of environmental cues in cognition that makes virtual reality a more appropriate experimental tool than the field or the lab. On one hand, it ensures the ability to implement the full control on experimental conditions that is lacking in the field, on the other hand it has the capacity to submit tasks and stimuli providing cues less stylized and artefactual than laboratory experiments.

This result is closely related to the sense of presence, that is a consequence of immersion but it is a cognitive state that it is usually tested in psychological and cognitive studies by means of post-experimental questionnaires assessing the degree to which the virtual environment engages participant’s senses such as they are actively involved in the experimental task.

Research work conducted in virtual worlds has tried to prove that what subjects do in virtual reality match that which is found in standard laboratory experiments. Most evidence reported in the survey confirms that virtual reality experiments replicate the results of standard laboratories. The notable exceptions are related to the social nature of virtual worlds, which naturally affects subjects’ behavior. In these settings it is possible to test social behavior because it is the sense of co-presence, rather than presence, to be activated and this represents an asset rather than a limitation of virtual reality experiments, which allows duplicating mechanisms and environments in which social exchange occurs. From a purely methodological point of view, the correct approach to develop the new tool should not be different from that on which experimental economics has been founded since its inception. That is to construct models of behavior in virtual reality and then tested them in virtual reality experiments in order to examine how well these models fit what might be found in real world. Finally, the introduction of avatars acting as monitor or experimenter can make subjects less affected by experimenter bias.
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