Peers at Work:
Economic Real-Effort Experiments in the Presence of Virtual Co-workers

Andrea Bönsch[1,*] Jonathan Wendt[1,*] Heiko Overath[1,*] Özgür Gürerk[2,†] Christine Harbring[2,†]
Christian Grund[2,†] Thomas Kittsteiner[2,†] Torsten W. Kuhlen[1,*]

[1]Visual Computing Institute, RWTH Aachen University, Germany [1]JARA-HPC, Aachen, Germany
[2] RWTH School of Business & Economics, RWTH Aachen University, Germany

Abstract

Traditionally, experimental economics uses controlled and incentivized field and lab experiments to analyze economic behavior. However, investigating peer effects in the classic settings is challenging due to the reflection problem: Who is influencing whom?

To overcome this, we enlarge the methodological toolbox of these experiments by means of Virtual Reality. After introducing and validating a real-effort sorting task, we embed a virtual agent as peer of a human subject, who independently performs an identical sorting task. We conducted two experiments investigating (a) the subject's productivity adjustment due to peer effects and (b) the incentive effects on competition. Our results indicate a great potential for Virtual-Reality-based economic experiments.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality; J.4 [Computer Applications]: Social And Behavioral Sciences—Economics

1 Introduction

Besides evaluating happenstance field data, behavioral economic research uses two kinds of experiments to gain insight into human behavior: field experiments in a natural context and well-controllable lab experiments. Although both ways are reliable, they come with certain drawbacks. Field experiments often lack a significant amount of experimental control. By this, the results may be influenced by unknown effects. In contrast, conducted lab experiments are often perceived as sterile and abstract as, e.g., physical work is realized by artificial and sometimes even purely cognitive tasks as proxies.

To overcome the aforementioned drawbacks, the methodological toolbox of experimental economics can be enlarged by means of Virtual Reality (VR). As stated for instance by Fiore et al., conducting experiments in immersive virtual environments (IVEs) combines the advantages of both classic experimental settings [1]. By using display systems like Head-Mounted Displays or CAVEs, the subjects are completely immersed, resulting in a strong feeling of presence in the visualized scenes. Furthermore, a natural behavior of the subjects in terms of interacting with and navigating through the scenes can easily be achieved. Thus, VR-experiments have an almost natural frame while researchers retain maximum control over the experiment.

To this end, we introduce a VR-based real-effort experiment, in which subjects perform sorting tasks by actual physical work. Moreover, we propose to collect additional data on the subjects by means of tracking their positions, orientations and movements in space. Using this data, a better insight into the human behavior can be provided.

*e-mail:{boensch|wendt|overath|kuhlen}@vr.rwth-aachen.de
†e-mail:{ozgur.gurerk|christine.harbring|christian.grund|thomas.kittsteiner}@rwth-aachen.de

Figure 1: Experimental setup: A subject performs a real-effort sorting task at a virtual conveyor belt. In her field of view, a computer-controlled virtual co-worker independently works on the same task.

One of the important research topics in the experimental economics is based on investigating peer effects in the workplace. Understanding the occurring effects is of utmost importance for the composition of teams or incentive provisions for employees in order to, e.g., increase the productivity of firms. However, conducting experiments in the classic settings to observe peer effects is challenging: Due to the reflection problem, there is no way to unequivocally establish who is influencing whom [2]. Thus, researchers often reduce the information flow in lab settings by, e.g., excluding channels for social influence that may be present in the fields. For instance, subjects only obtain numerical information about their peers' effort choices. As a result, the experiment becomes more artificial.

By using VR techniques, the reflection problem can be prevented in order to observe non-confounded peer effects. To this end, we represent peers by computer-controlled virtual agents who work independently on identical tasks in the subject's field of view. By this, only one channel for social influence is available, which is the virtual peers' influence on the subject. Furthermore, the subject is able to constantly observe her virtual peers' performances.

To summarize, our contribution is two-folded: First, we introduce and apply VR techniques to conduct economic real-effort experiments. Second, we use this experimental methodology to examine two types of non-confounded peer effects.

2 Real-Effort Sorting Tasks

Figure 1 shows our scenario for conducting economic, real-effort sorting tasks: A human subject is positioned at a virtual conveyor belt inside a virtual production hall. A specified number of virtual cubes appears one by one out of a hole in a side wall and are transported by the conveyor belt to a hole in the opposite wall, passing the subject. Her task is to sort out those cubes with a defect. To detect a defect, the subject has to physically grasp a cube with her dominant hand and inspect it from all sides. If the cube is colored uniformly, it has no defect and has to be returned to the conveyor belt. In case one face has a different color, the cube has a defect and has to be rejected by being thrown into a bin located next to the subject. To avoid an immediate detection of a defect during the cubes' approaching, only faces averted from the subject may be colored differently. Furthermore, the subject's handedness determine the IVEs design: For right-handed, the cubes approach from right and the bin is located on the subject's right side. For left-handed, the complete scenario is reversed.

We used a five-sided CAVE (no ceiling) with the dimensions $5.25m \times 5.25m \times 3.30m$ ($w \times d \times h$) providing a 360° horizontal field of regard. The subjects wore active stereo glasses and a hand target on their dominant hand for interaction, both tracked at 60 Hz. This setup allows us to log several parameters: We logged several parameters: how often and how long a cube was grabbed, the amount of correctly and falsely rejected cubes, and the subject's head and hand motions. By this, we can state which faces of a cube have been inspected before the subject decided on keeping or rejecting the cube.

2.1 Study: Incentive Schemes as Proof-of-Concept

After designing our IVE, we conducted a proof-of-concept study. We tested four treatments with two different economic incentive schemes that were frequently studied in classic settings: two fixed wage schemes, and two piece rate schemes, with a pay per correctly sorted cube, added to the basic wage. We investigated whether the additional monetary incentives induce a higher work effort in our subjects.

We conducted our study with 120 volunteers. All subjects were naïve to the purpose of the study. After a familiarization phase in which the subjects trained the interaction with the cubes, the sorting ability of each subject was measured as base line. Afterwards, each subject experienced one of four treatments, resulting in 30 subjects per treatment. In our results, the subjects' respond to the financial incentives were in line with the well-known pattern of behavioral response. Furthermore, the results show that subjects could perfectly deal with the environment as well as with the basic task. Thus, we proved the feasibility of VR-based economic studies. Furthermore, we did not find any indicators that the fun and excitement aspects of the VR setting distorted the results.

2.2 Study: Productivity Adjustment by Peer Effects

After validating our VR-based sorting task, we next gained insight into peer effects. To this end, we extended our basic setup by introducing a computer-controlled, male, virtual agent as peer. As shown in Figure 1, the peer is located at another virtual conveyor belt, independently performing the same sorting task. The peer is in the subject's field of view, enabling her to constantly observe his performance.

Understanding, e.g., whether a low performer has a negative impact on a fellow worker's performance or whether a high-productivity performer induce fellow workers to high effort levels, is of utmost importance for the design of work organizations. Thus, we designed two peers with identical appearance, but with two distinct and pre-defined behaviors: One peer performed the sorting task with low effort, indicated by several short rests during the sorting, and one with high effort, indicated by grasping and sorting every single cube. Both behaviors were realized by scanning a student's movements via a Kinect 360 and by manually mapping this data on a SmartBody character [3].

With this extension, we conducted a second study with 108 volunteers to investigate whether we can observe non-confounded peer effects, i.e., whether subjects react accordingly to their peer's performance. Again, all subjects were naïve to the purpose of the study. We set up three successive phases, in which the peer was only present in the last phase. Furthermore, the cube orders during the study, i.e., which cube has a defect on which face, were identical in-between the subjects. In phase one, subjects were trained in performing the sorting task. Phase two was used to characterize subjects as low or high performers. To this end, their individual ability was measured by sorting 168 cubes, from which 34 were defect. If subjects rejected less than 20 cubes correctly, they were characterized as low performers, high performers otherwise. In phase three we introduced the peer as a computer-controlled co-worker and asked the subjects to do a second sorting task. This time we doubled the total amount of cubes, ending up with 68 defect cubes out of 336. While the subjects sorted their cubes, the peer individually performed the same task. 54 subject experienced the peer with low effort, 54 with high effort.

Our results indicate that low performing subjects have a significant performance increase when they are working in the presence of the low productive agent. Additionally, we could show that these subjects had a significantly weaker corresponding reaction towards a high productive agent. These results are in line with the predictions of the social comparison theory: Stronger peer effects can be observed when perceived similarities between peers and a fellow worker are high.

2.3 Study: Incentive Effect of Competition

Next, we focus on the effect of competition against an agent. A variety of incentive schemes are used to elicit an individual's higher performance. One important mechanism is based on relative performance evaluation, i.e., the individual with the higher output receives a higher bonus. To this end, we extended our peer's behavior to be able to provide an intense competition: Instead of two predefined behaviors, we now dynamically adjust the peer's productivity to the one of the subject. This is realized by using the grabbing feature of SmartBody [3].

In order to raise pressure on the subjects, they cannot only see their peer's performance, but are able to continuously track their peers as well as their own productivity on two virtual monitors during the experiment. Our research design is aimed at understanding the incentive effects of competing against an agent compared to a simple individual performance pay (piece rate). By being able to predefine the agents ability we may analyze the subjects behavior towards slightly better agents, less able agents or agents with the same productivity.

We conducted a third study with 75 volunteers to investigate the incentive effect on competition. Again, all subjects were naïve to the purpose of the study. We chose a comparable setup to the one of our second study, only the amount of cubes and their ordering changed (180 defects out of 360 cubes) and the peer's behavior was dynamically. Furthermore, subjects were informed that they will receive a higher payment in form of a bonus, if they perform better than their opponent, the peer. We are not yet finished evaluating our data. However, initial results indicate that being exposed to competition induces stronger incentives to perform compared to an individual piece-rate scheme.

3 Summary and Future Work

We have presented a novel approach of using VR for economic real-effort sorting tasks and peer effect investigations. Our studies indicate the benefit of VR-based experiments complementing the classic field and lab experiment for behavioral economic research.

In future work, we plan to extend our peer effect settings: by adding room acoustics and auditory feedback for rejected cubes we want to increase the immersion and raise more pressure on the subjects.

Acknowledgements

The depicted research was funded by RWTH Aachen University as Exploratory Research Space Seed Fund Project (2014/15), as PathFinder Project in the Research Area Managerial & Organization Economics (2015/16), and by the project house ICT Foundations of a Digitized Industry, Economy, and Society (2016/2017).

References

[1] S. M. Fiore et al. Virtual Experiments and Environmental Policy. *Journal of Environmental Economics and Management*, 57(1):65 – 86, 2009.

[2] C. F. Manski. Identification of Endogenous Social Effects: The Reflection Problem. *The Review of Economic Studies*, 60(3):531–542, 1993.

[3] A. Shapiro. Building a Character Animation System. In J. Allbeck and P. Faloutsos, editors, *Motion in Games*, pp. 98–109, 2011.