Universität Tübingen
- Mathematisch-Naturwissenschaftliche Fakultät -

Externes Laborpraktikum

Affordance Judgements in Virtual Reality

im Studiengang Kognitionswissenschaft

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1 Introduction

The goal of the internship is to learn how to implement and run Virtual Reality experiments. An existing experiment (Reaching Study) will be used to learn how to set up and run participants. Depending on how much time will be left two more follow-up experiments can be implemented and run during the internship.

In the virtual environment of the Reaching Study the participants find themselves sitting at a round table. Their task is to judge if they can reach for an object that appears on that table at different distances. Besides from their own perspective at the table most of the trials demand the participant to imagine to sit at a different location around the table. The question being addressed here is if the participants show different reaction times for different locations around the table which would argue for some kind of "mental rotation of the self in 3D". Furthermore the data of these trials will provide the participants estimated maximum reaching distance. In the second part of the experiment the participant can actually reach for several objects on the table with a virtual arm controlled by the participant's actual arm which is tracked by a controller. The virtual arm for one half of the participants is (20In the third part of the experiment the participants do the same task as in the first part. The question being addressed now is if the experience of a shorter/longer arm has the effect that the estimated maximum reaching distance is decreased/increased. This would support the idea that temporarily changing one's body (and therefore one's action capabilities) also changes perception. After having experienced a shorter (longer) arm, we argue the participants scale the object distance based on the new so called perceptual ruler which makes them perceive objects further away (closer). And as a result the estimated maximum reaching distance decreases (increases).

2 Methods

2.1 Participants

37 participants(21 female, 16 male; all right-handed) from the local university community participated in the experiment. Their age ranged from 21 to 41 years. All participants were naive to the purpose of the experiment and had normal or corrected-to-normal vision. The experiment was approved by the ethics committee of the University of Tübingen, and was performed in accordance with the Declaration of Helsinki. Participants gave written informed consent prior to the experiment and were compensated with 8 Euro per hour for their participation.

2.2 Apparatus

The virtual environment was displayed in stereo using an HTC Vive head-mounted-display (HMD) with a resolution of 1080 x 1200 pixels per eye (2160 x 1200 pixels combined). Inter-pupillary distance was measured with a pupilometer and set accordingly on the HTC Vive for each participant. Before the experiment two HTC Vive controllers were used to calibrate the experiment according to the participant's arm span. During the experiment one HTC Vive controller was attached to the participant's wrist to track hand and arm movements. The tracked controller movement data was used to display a virtual arm that moves according to the participants real movements. Participants were sitting during the whole experiment and viewed their virtual task in front of them. An XBox controller was used in order to allow participants to make decisions and proceed to the next trial.

In one part of the experiment (trial phase) the virtual environment consists of a round table and an empty chair which is located at the table and a small blue ball is located on top of the table. In the other part of the experiment (adaptation phase) the virtual environment consists of a square table an there a three different blue objects (a ball, a square and a capsule) located on top of the table.

In the trial phase participants make a decision if they can reach the blue ball by pressing the shoulder buttons of the XBox Controller. The left shoulder button is used to decide they can not reach the ball and the right shoulder button is used to decide they can reach it. Participants can start each trial by pressing the 'A' button of the XBox controller. In the adaptation phase participants only use their own hand movements to control their virtual arm which is tracked by the HTC Vive controller.

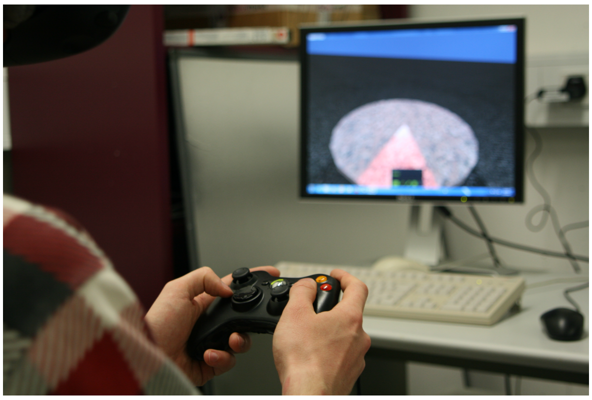

Figure 1: XBox controller used to make decisions in the trial phase.

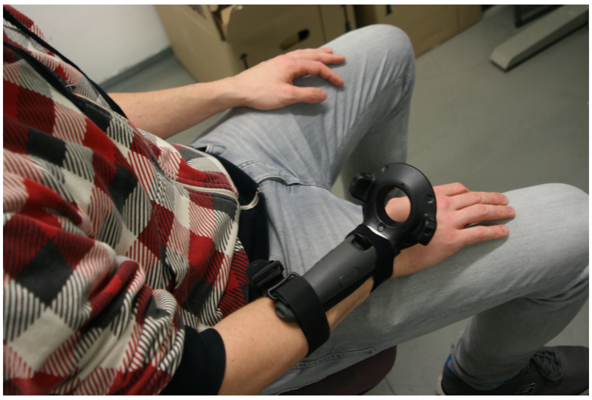

Figure 2: HTC Vive controller attached to the participant's arm to track hand and arm movements.

2.3 Procedure

Participants were invited as a group of two people and did not know each other. In one group session the two participants solved the task on their own in a separate virtual environment and together in the same virtual environment. The sequence of single and collaborative condition was counter balanced among all groups. In both the single and collaborative condition participants solved 20 tasks of which all had the same design as described above and differed only in color. In the single condition participants viewed the task always from the same perspective, which means that the starting cube was always placed at the same position in the solution space. In the collaborative condition we rotated the solution space after 10 trials, which means the starting cube is on one participant's side for the first 10 trials and on the other participant's side for the remaining 10 trials.

The detailed procedure for the single condition will be explained in the following: After having read the instructions of the task participants also received a verbal instruction by the experimenter. Before the actual 20 trials began participants had to solve 4 training trials in order to verify that the participant understood the task and the way it has to be solved. It was emphasized that it is important to always stick

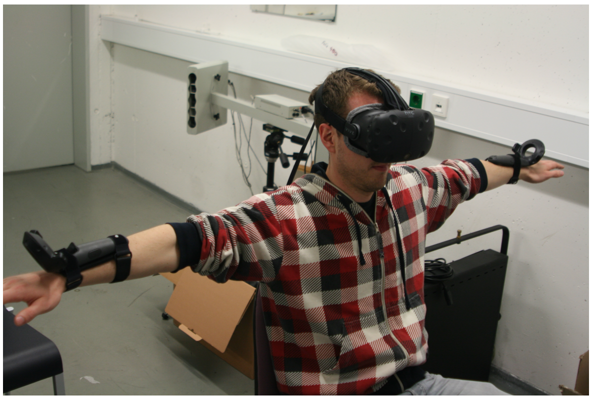

Figure 3: Two HTC Vive controller attached to the participant's arms to measure and calibrate the virtual arm.

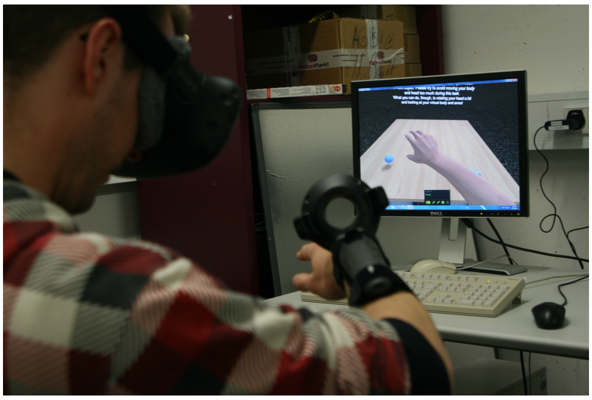

Figure 4: HTC Vive controller in use during the adaptation phase. Participants can control the virtual arm with their own hand and arm movements.

to the sequence of putting in and removing cubes as described above. Furthermore participants could experience that the starting cube can not be removed and is the only cube in the experiment that collides with the other cubes (that was important to prevent other cubes from overlapping with the starting cube). Participants could also get used to the fact that the top color is always white and the bottom color is always black and that gray always faces to the inside of the solution space. The training trials could be started by the participant by holding a controller button for 2 seconds. When they started the training they saw the solution space surrounded by the 9 cubes which are all in reaching distance. They also saw the starting cube already being placed into the solution space. Above the task participants could see in which trial they currently are. In this case they would see "Training 1/4". Once they have finished a trial they can proceed with the next trial by pressing the controller button again for 2 seconds.

Before the actual 20 trials started the experimenter repeated the most important instructions. Participants should try to solve the task as quickly and as accurately as possible. Furthermore they were not allowed to move around the problem space and should stay mostly stationary in their position with only a few steps to the sides allowed. After the 4 training trials participants could start the actual trials as soon as they were ready by clicking a controller button again for 2 seconds. For the actual trial the experimenter would emphasize that participants should always make sure their solution is correct before proceeding with the next task. In case participants did not correctly solve a task and still proceed with the next task the experimenter took notes in order to exclude the trial from the analysis.

The procedure for the collaborative solving of the task was mostly the same. The only difference was that just one participant was able to skip to the next trial and therefore the instructions were that participants had to agree on when to proceed with the next task.

3 Results

Data analysis was done by applying linear mixed models with the Kenward-Rodger degrees of freedom approximation. The random factors were the group number (= an individual number assigned to each group in the group condition), participant number (= an individual number assigned to each individual participant in the single condition) and the number of players(= either one or two). The only fixed factor was the number of players.

Although much more data has been recorded during the experiment this section will only cover the most relevant results that suit best to compare the performances of the single vs the group condition.

All data was automatically recorded from the time participants pressed the controller button to start the task to when they pressed the button again in order to skip to the next task. The data was based on the controller trajectories, rotations and user input. In the following the term "task duration" will be used to describe the duration in which data was recorded for an individual task.

3.1 Time to complete

The time to complete is the average of all task durations. Figure 5 shows that the groups were much faster with an average of around 50 seconds compared to single participants with an average of around 80 seconds. The output of the linear mixed model was F:(1,18.99) = 52.049, $p < 0.001$.

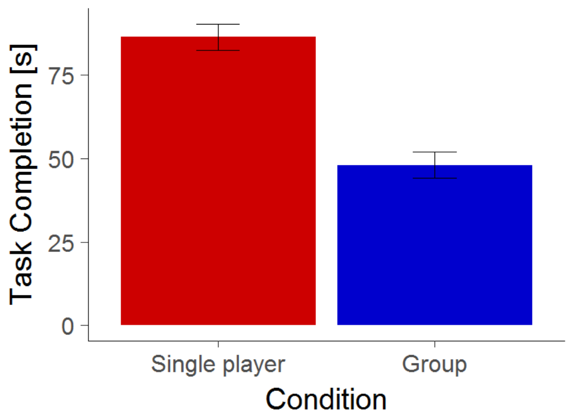

Figure 5: Average time to complete in single and group condition.

3.2 Rotation sum of cubes

The rotation sum of cubes is the sum of rotations made by one participant during the task duration. In the group condition we summed up the rotations of both group members first and calculated the averages over the group sums. Figure 6 shows that the average rotation sum for groups with an average of 5000 degrees was significantly lower compared to single participants with an average of 8000 degrees. For the rotation sum a the smaller value indicates the better performance because the less a participant rotates a cube the more confident and efficient the participant is expected to be at solving the task. The output of the linear mixed model was F:(1,18.99) = 12.164, $p < 0.01$.

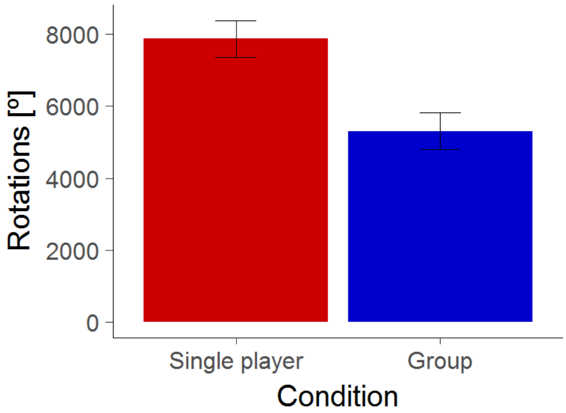

Figure 6: Average sum of rotations in degrees in single and group condition.

3.3 Number of cube snap-outs

The number of cube snap-outs is the number of how many times a participant took a cube back out from the problem space during the task duration. Figure 7 shows that groups needed much less snap-outs with an average of 2.1 snap-outs compared to single participants with an average of 4.5 snap-outs. Snap-outs can be categorized in two classes: "necessary" and "unnecessary" snap-outs. Necessary snap-outs are the ones which are part of the task design which means participants are supposed to try certain solution paths and if a path was not successful they need to snap-out some cubes and snap-in new ones until they successfully finish the task. It is possible though that participants try the same solution path more than one time and therefore have to do unnecessary snap-outs. For the number of cube snap-outs a smaller value indicates the better performance, because it means that less unnecessary snap-out were made. The average of necessary snap-outs is expected to be equally distributed with an expectancy value of 2.0. In other words scoring an average of 2.0 snap-outs is an indicator of almost "perfect" performance. In the group condition the performance is very close to perfect with an average od 2.1 snap-outs. The output of the linear mixed model was F:(1,18.99)=22.112, $p < 0.001$.

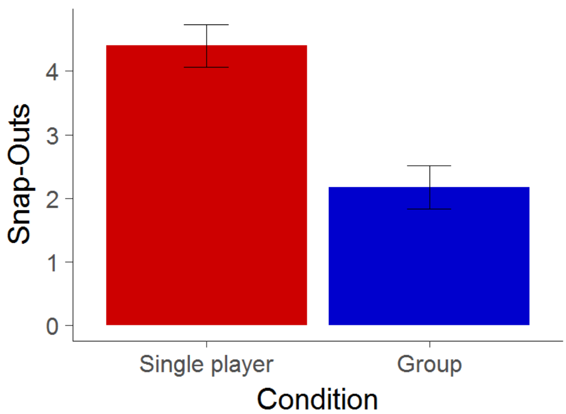

Figure 7: Average number of cube snap-outs in single and group condition.

4 Discussion

2. Follow-up: affordance judgments for others

The first follow-up experiment will be changed only in the way that participants will be asked to not imagine themselves sitting at a different location, but to judge for an avatar appearing at different locations around the table if it would be possible for him/her to reach the object. The main question then is if participants - after having experienced a shorter/longer virtual arm – also show an increase/decrease in estimated maximum reaching distance for the avatar. If so we would argue that temporary changes to our body not only influence how we perceive our own action capabilities but also how we perceive action capabilities of others.

3. Follow up: 3rd person adaptation

The second follow-up experiment will only change the participant's perspective in the second part of the experiment from 1st to 3rd person perspective. This means that the participant's own arm movements now control the arm of an avatar in the scene instead of the participant's own virtual arm (the participant's own arm will not be rendered at all). With this manipulation we want to address the question if the experience of controlling the arm of an avatar will also alter the participant's judgement of how far he/she is able to reach. We argue that in contrast to the initial study with this manipulation the participant's perceptual ruler is not changed and therefore expect little to no change in estimated maximum reaching distance.

5 Conclusion

Finally, it can be said that the approach presented in this study can be considered as a basis for future research to further investigate the relevant cognitive processes involved in collaborative spatial problem solving. This study was intentionally designed to be very controlled and therefore does not compare to any application of real life problem solving. The goal was to design a task that allows to quantify performance in spacial problem solving tasks. Also the study proved virtual reality to be a well suited method of research for the field of collaborative spatial problem solving. The main finding was that groups perform significantly better than individuals in the designed spatial problem solving task. Further research will have to show if the same applies for more complex variations of the task and how important factors like perspective and communication are.

Bibliography

[1] J. Müsseler. *Allgemeine Psychologie*, pages 588–615. Springer Berlin Heidelberg, 2015. ISBN 9783662487013.

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