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).

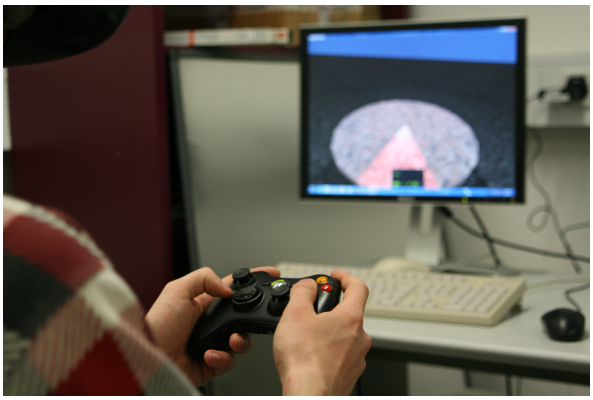

Figure 1: XBox controller used to make decisions in the trial phase.

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 1 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. 6

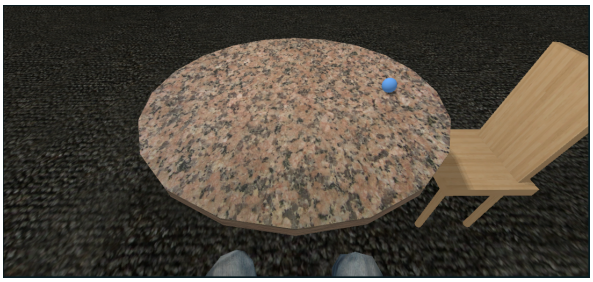

Figure 2: Virtual environment: table with ball and empty chair.

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 that 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.

2.3 Procedure

The experimenter explained the details of the experiment to each participant before the experiment. Participants will perform a virtual reality task and will wear a head mounted display during the entire experiment. They will sit during the entire experiment and see a round virtual table in front of them. The task will be to judge if they can reach an object that appears on different locations on the table. It is important for the participants to imagine that they can not lean forward to reach the object. Furthermore it is important to make the decision imagining to sit on a chair that appears on different locations around the table for each trial. And sometimes that chair will have their actual location. The usage of the XBox controller was explained like in the section Apparatus. Finally participants were informed that later during the experiment HTC Vive controllers will be used to track their hand movements.

The whole experiment consists of two trial phases and one adaptation phase between the trial phases.

Each trial phase consists of 336 Trials. One trial is to judge if the participant would be able to reach the ball on the table and consists of two steps. First, a red light on the table indicates where an empty chair will appear. The participant confirms the light indicator using the XBox controller. Second, the empty chair appears and the participant decides also via XBox controller if he or she would be able to reach the ball.

In the adaptation phase participants can interact with objects on a square table in a virtual environment similar to the one in the trial phase. In preparation of the adaptation phase the distance between the participants wrists sitting in a T-position is measured. 4 The measurement is used as an input variable for the virtual environ-

ment to visualize the participant's arm length. There are two conditions. One group of participants will see a representation of their arm that is only 80% of their actual arm length and the other group of participants will see a representation of their arm that is 120% of their actual arm length. In order to control their virtual arm a controller will be attached to the writs of the dominant arm of the participant. 5 Therefore the virtual arm can mirror the actual movements of the participant. The task in the adaptaion phase is to reach out to 3 objects on the table. The objects disappear if the participant is able to reach them and they remain on the table if the participant is not able to reach them. Participant's are not allowed forward to reach the objects. There 20 repetitions with 3 objects each. 3

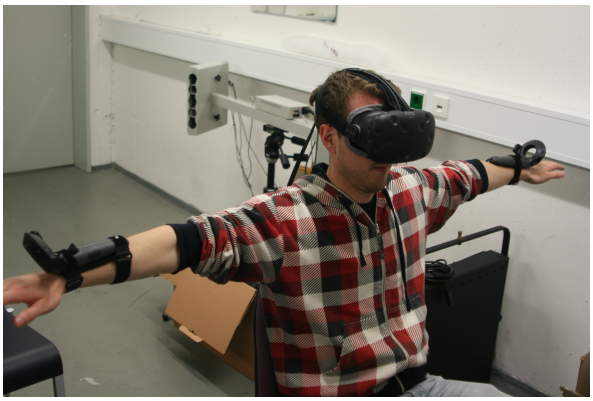

Figure 3: Two HTC Vive controller attached to the participant's arms to measure and calibrate the virtual arm.

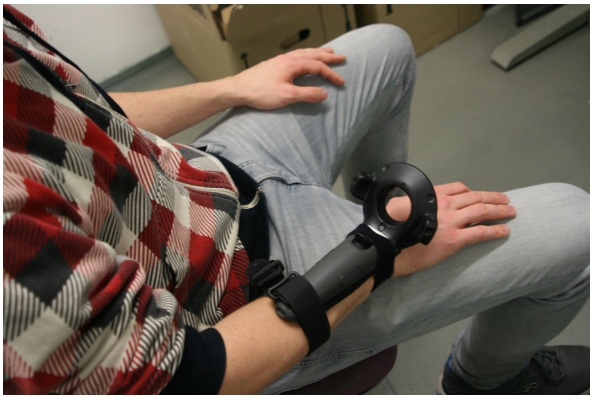

Figure 4: HTC Vive controller attached to the participant's arm to track hand and arm movements.

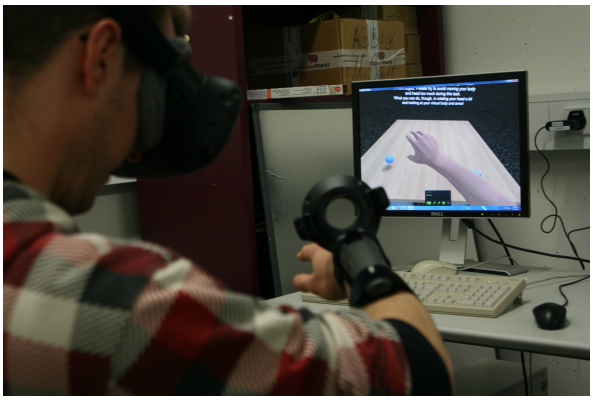

Figure 5: HTC Vive controller attached to the participant's arm to track hand and arm movements.

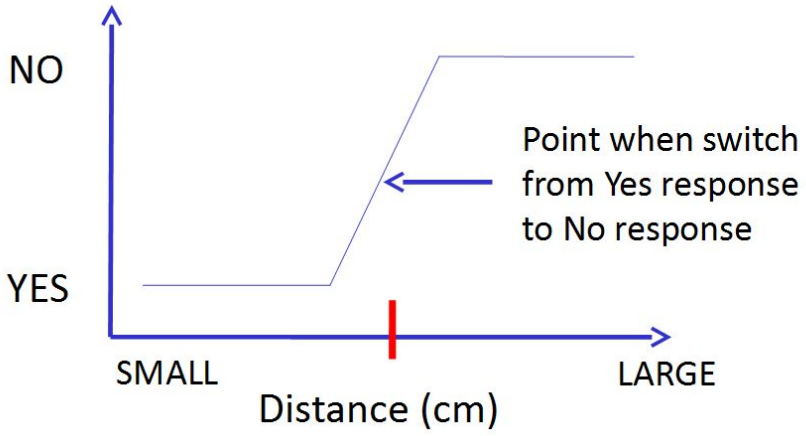

Figure 6: cross over.

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.

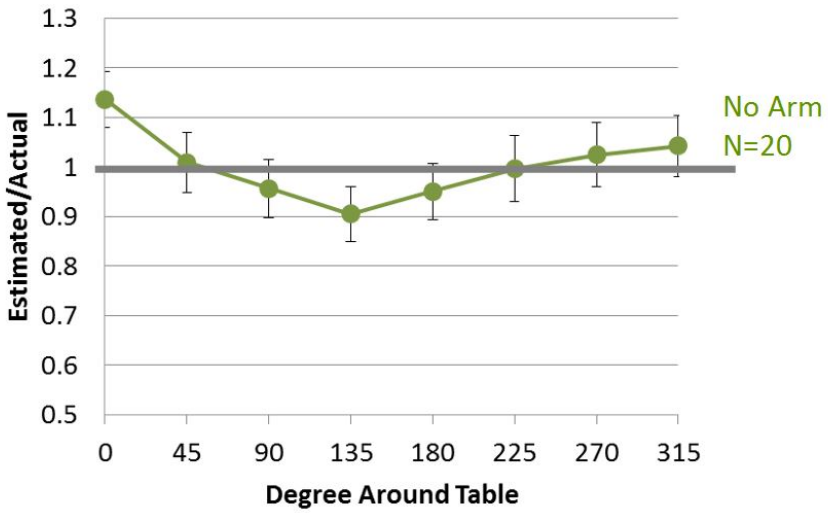

Figure 7: no arm co.

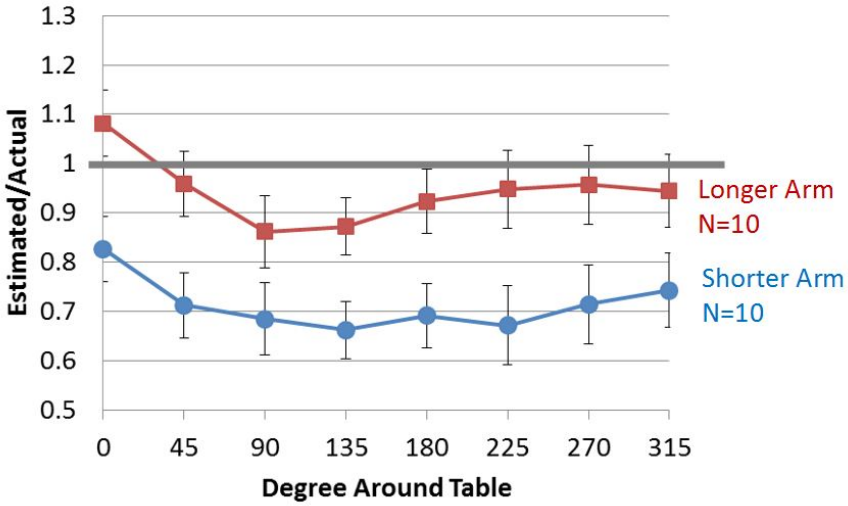

Figure 8: short long arm co.

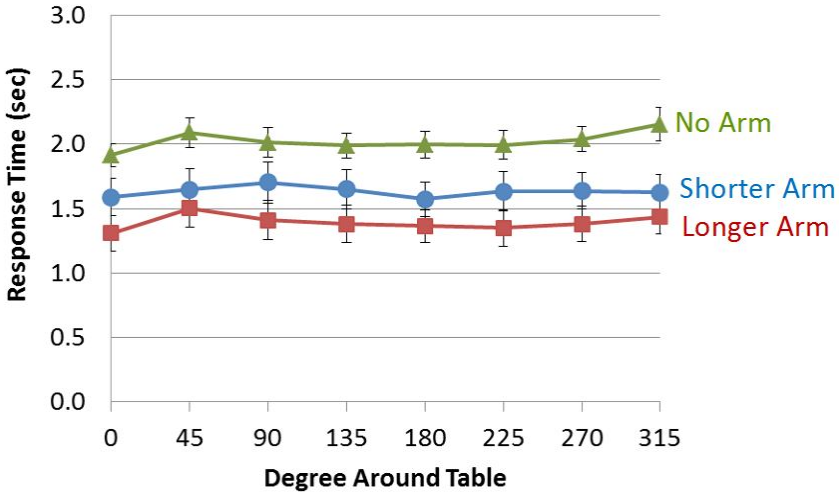

Figure 9: all response time.

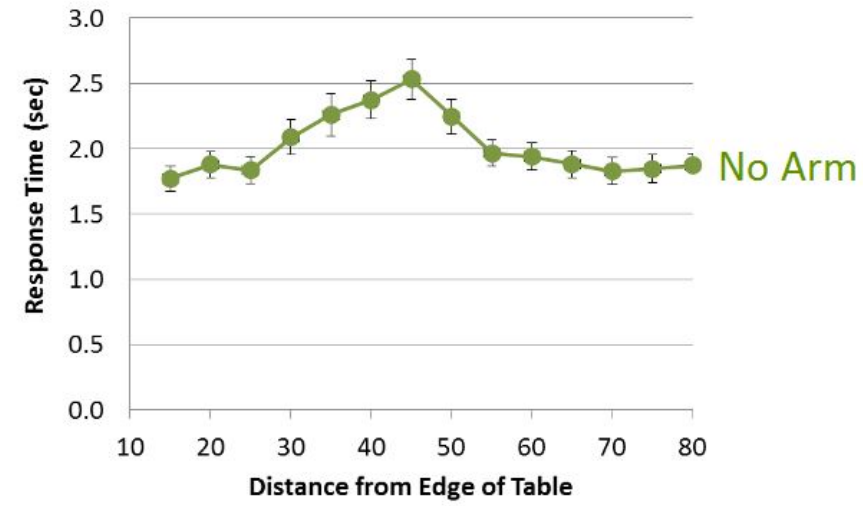

Figure 10: all response time.

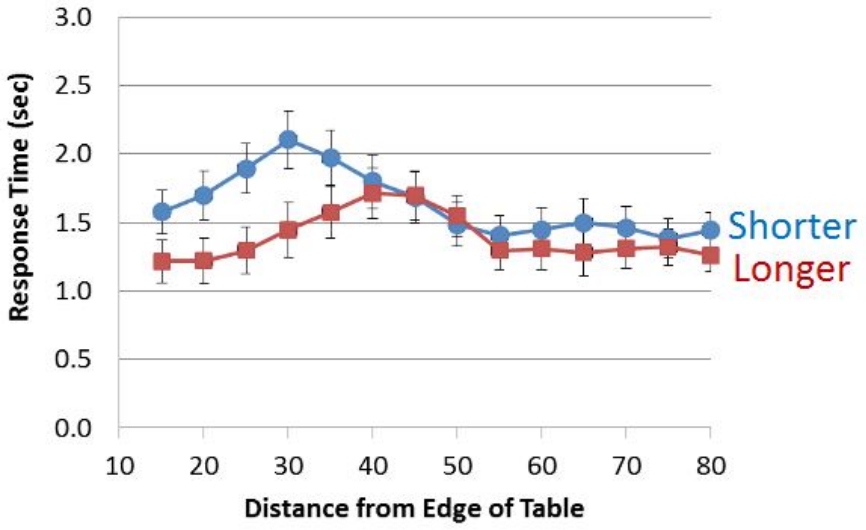

Figure 11: all response time.

3.1 Time to complete

The time to complete is the average of all task durations. Figure 13 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.

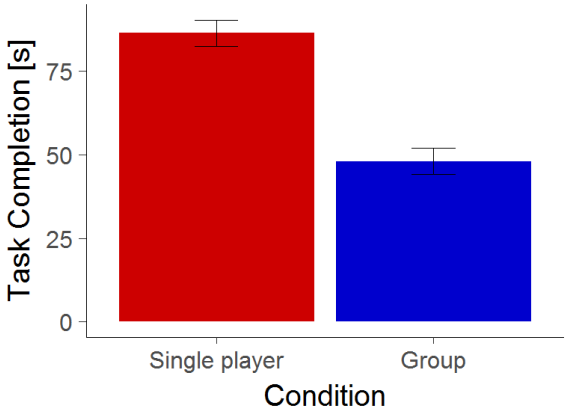

Figure 12: Average time to complete in single and group condition.

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 14 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.

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 15 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

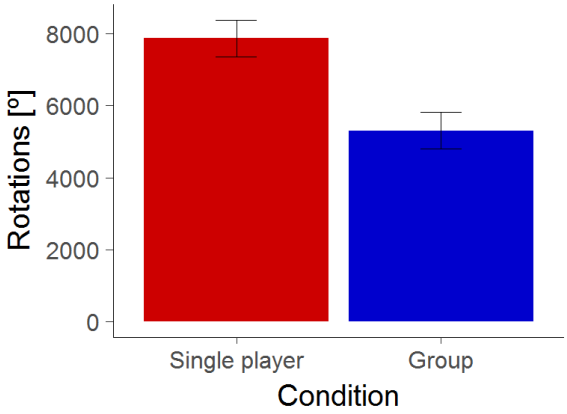

Figure 13: Average sum of rotations in degrees in single and group condition.

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, $p < 0.001$.

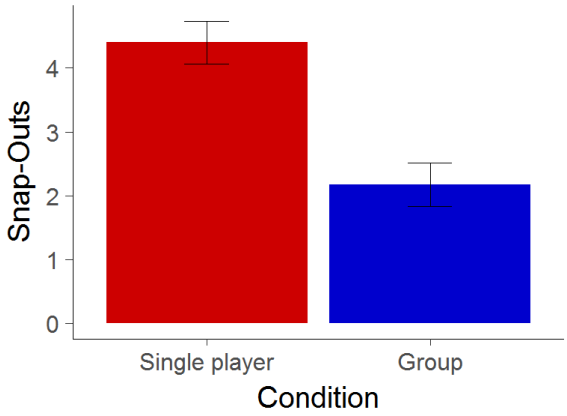

Figure 14: Average number of cube snap-outs in single and group condition.

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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