The application of skill transfer in sports using Virtual reality with Darts

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ABSTRACT

Virtual reality is a platform in which users can interact with a world that is entirely nonphysical. This lends the ability for people to learn new skills and transfer their learning to the real world. One such application of this is through training in darts that has been done via the HTC Vive and XBox Game Kinect [1, 2]. In this study I show the application of skill transfer through training in a custom implemented Virtual Reality darts game with the Meta Quest 2 conducting a study to see if throwing accuracy can improve. I have divided the participants (6 participants) into two groups (virtual training, control) in which the two groups complete 10 throws in the pre and posttest measuring how close they are able to get to the bullseye. After the pretest the virtual training group conducted 2 training sessions in the Meta Quest 2 in which the objective is to throw 25 darts in the simulated environment. The control group did not conduct any training sessions after the pretest. It was shown that the virtual training group improved in the post test while the control group had negligible differences. The results showed that there was an effect of training in a simulated environment which suggests skill transferability in the sport of Darts.

KEYWORDS

Virtual reality; Skill transfer; Bullseye

1. Introduction

With new developments in the virtual reality space, it brings the possibility for more advanced, wide scale, affordable virtual reality headsets that people can utilize in their everyday lives. With the head mounted display (HMD) users can interact with a virtual environment and be immersed with visual, auditory, and haptic feedback. One aspect that is of particular interest is the training and skill transfer in sports with virtual reality. Skill transfer is the method in which by training in one medium the user can apply their learned skills in another.

One of the most popular headsets is the Meta Quest 2 that is created by Meta. Released in 2020 for a price of $399 offers many improvements over its predecessors. The base version allows for 128GB of storage utilizing the Qualcomm Snapdragon XR2 processor, a better high-resolution display than previous HMDs in Oculus Quest or Rift headsets. Previous versions of HMDs required users to be tethered such as the HTC Vive which restricted user's movement and hampered gameplay. The Meta Quest 2 is untethered and allows users to move freely in the play zone that they specify. [1]

The Meta Quest 2 also allows for immersive virtual reality environments. Users can experience VR visually with LCD panels with a per-eye resolution of 1832x1920 with a 120Hz refresh rate allowing games to be played smoothly and avoid screen tearing.

Audio can be played through the headset. Haptic feedback is provided by the two meta quest 2 controllers that allow users to interact with objects in their virtual environment. These aspects of Meta Quest 2 make it an affordable product for users to try out virtual reality. [1]

The HMD allows for many users to play various sports games that users can play in the comfort of their home like 2MD: VR Football Evolution that allows for a user to be able to play football, and Eleven Table Tennis that allows people to play with AI and scale the difficulty. Unlocking the possibility for users to train in the comfort of their own home without needing the equipment or physical players to play with. If skill transfer can be shown to exist in a particular sport, then it would give users convenience to be able to apply their learned skills in virtual reality to the real world.

Darts has been chosen as the application for virtual reality training as it allows for the evaluation of throwing accuracy. Darts, also known as dart throwing, is a competitive sport in which a participant throws darts at a dartboard to score points. The dartboard is made up of 20 radial sections with the middle containing a bullseye each signifying different point values. Darts is commonly played with two people in a format named as 301 or 501 in which the objective for the player is to get to zero the fastest. For testing purposes, the radial distance from the bullseye was considered as it is a method to compare participants results on a common objective.

With darts in virtual reality, it allows the user to experiment with the throwing motion and try to use the dart to hit the bullseye on the dartboard. This motion may allow for users to replicate their results in virtual reality to the physical game. If this can be shown, then it would show the efficacy of skill transfer of darts in a VR setting.

2. Previous Background

There has been limited previous work in the application of darts for training in virtual reality. Here are the main studies that have been conducted in the field.

In 2015 the work done by Judith Tirp in "Virtual realities as optimal learning environments in sport – A transfer study of virtual and real dart throwing" focused on transfer learning in throwing accuracy and quiet eye duration (QED). Quiet eye is the gaze behavior right before throwing the dart. For the physical environment tests were conducted with the rules of World Dart Federation (WFD) where the center of the bull's eye is 1.73m above the ground and the throw line is 2.37m away from the board. Darts used are 24 grams each. For the virtual environment they used a video projector and Xbox using the Xbox Kinect motion sensor in order to simulate throwing. Participants' gaze behavior was recorded through SMI Eye tracking Glasses 2.0. [2]

From 38 participants that all had little experience with darts, the authors divided them into a control group, virtual group, and physical group. For all groups participants were asked to throw 15 times for the real and virtual dartboard during testing. Two sessions were done where after the first session the training groups received training in their respective environment by practicing 50 throws in the week whereas the control group did not practice at all. [2]

From previous studies they mention that longer quiet eye leads to superior results. In the results quiet eye duration increased for all groups in the physical and virtual darts. When measuring the throwing accuracy from distance to the bull's eye the study

found that the real group and virtual training group improved while the control group accuracy decreased. This study suggests there is a transfer from virtual and real tasks. [2]

Figure 1: Example of Dart Throw in Previous Work

In this study it utilizes an Xbox Kinect in order to simulate the virtual environment. The Kinect is not a head mounted display (HMD) and is not widely used anymore so there could be discrepancies when users train in a virtual environment with a head mounted display.

More recently in 2020, "The Trade-Off of Virtual Reality Training for Dart Throwing: A Facilitation of Perceptual-Motor Learning with a Detriment to Performance" by Stefanie Drew, utilized an HMD to study how a single session of VR training on darts can compare to those who train in the real world.

Setup of the physical board is done by WFD regulations as mentioned above in the previous study. For the virtual environment an HTC Vive CPO EE HMD was used, and participants simulated training with the game VR Darts Zone. There are some issues with the virtual environment that affect the study, for example VR Darts Zone scales the virtual environment to the height of the HMD. All participants utilize the standard HTC hand controller where a trigger must be held and released to simulate the holding and releasing of a dart and it has different weight and shape than a physical dart. [3]

41 participants participated in this study. They were split into a VR training group and a real-world group. A pretest was conducted where users threw two sets of five darts on the physical board and were measured on the distance of the dart to the bullseye. After the pretest participants in the virtual training group trained in the virtual environment each throwing 100 darts over 24 minutes. In the real-world group, they trained with physical darts and dartboard. In the post test tests were conducted the same as the pretest.

From the results, dart throw accuracy in the pretest was found to not be significantly different from the virtual reality training group to the real-world training group. After training was completed in the post-test results showed that the real-world training group had much more of an improvement than the virtual reality training group. In fact, participants in the virtual reality training group performed significantly worse after training. Contrary to the previous study, the authors found that virtual training had a negative effect on real world performance and as such further investigation is needed whether training can be done effectively in virtual reality. [3]

Since the number of studies that have been done in this space are so few more studies are needed in order to verify the claims of the previous work that have been done. In addition, other studies do not make use of the meta quest 2, a much more advanced HMD than the HTC Vive, which we utilize in this project.

3. Description of Project

In this study the objective of this project was to see if there exists skill transfer between virtual reality and the real world in the game

of darts. Thus, a study was conducted in order to verify if training in a virtual game of darts improved targeting accuracy of a participant in the real world.

3.1 Description of Project

The study was conducted with the Meta quest 2, a headset mounted display, in order to display the virtual environment. The platform that I used to develop the virtual reality game of darts in Unity 2021.3.4f1. In order to get accurate 3D meshes of the darts and dartboard to be used in the virtual environment I have installed the Darts Kit created by Clockwise.

Figure 2: Virtual Dart Mesh vs Actual Dart

After importing the meshes into the project I resized the meshes substituting 1 unit as 1 meter. I then set the mass of the dart to .022 which is 22 grams the same weight as the physical dart. The virtual dart dimensions are also set to the same standard as the physical dart.

In order to replicate the physics of the virtual dart to the real world I added gravity through adding a rigidbody to the dart and made alterations to the force when it is released to simulate it as close to possible to darts in the real world. In order to throw the dart, I used the meta quest 2 controller and created a script which allows for users to hold down the right trigger in order to simulate grabbing the dart. When the trigger is released in tandem with making the arm motion to throw the dart the projectile is launched at the dartboard.

Figure 3: Virtual Dartboard Mesh vs Actual Dartboard

Using the metric of 1 meter to 1 unit and WFD standards, the virtual dartboard has a diameter of .451 units, and it is placed within a wooden cabinet in order to replicate the real-world environment. The dartboard is made up of radial slices with the bullseye in the middle. The center of the dartboard to the floor is 1.72 units and the distance from the dartboard to the person is 2.37 units.

In virtual reality when a participant throws a dart at the dartboard the radial distance from the bullseye is calculated and the radial distance and the respective point value derived from the location hit is shown to the user. The total point value accumulated is shown and able to be reset by using the meta quest controller. The reason respective point values for the dart board when a specific radial section is hit by the dart is to replicate the point scoring system of the dart board and make it as accurate as possible to the official game of darts.

For the physical testing an Eastpoint Bristle dartboard and cabinet was used which uses the same WFD standards regarding the size and weight of the dartboard and darts.

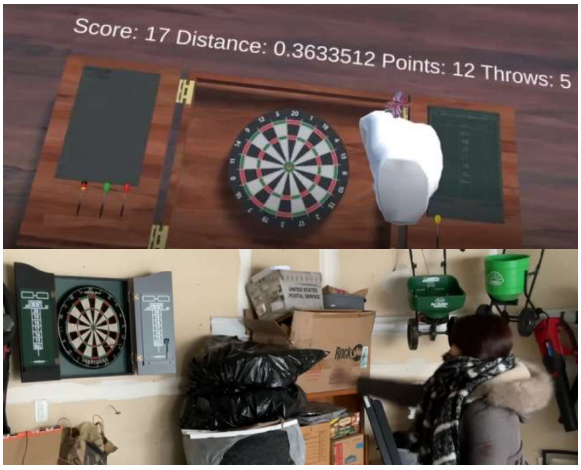

Figure 4: Throw at Dartboard

3.2 Limitations

When conducting the experiment, I gathered 6 participants from the age range 20 - 50 years old which all have little experience in the game of Darts. I was given consent from all the participants to participate and gathered the participants the city of Rogers, Minnesota. I have divided the 6 participants into 2 groups. A virtual reality training group and a control group. Both groups were asked to go through a pretest and were told to use their right hand to throw the dart at the bullseye in the middle of the dartboard. The participants then each completed two sets of five throws for a total of 10 throws on the dartboard. After the participant completes a set of five throws in which the targeting accuracy is recorded by measuring the radial distance from each dart to the bullseye. If the participant misses the dartboard, then the radius of the dartboard, the maximum distance from the bullseye to the edge of the dartboard, is recorded. This metric allows us to compare results from one participant to another.

The virtual training group after the pretest goes through 2 training sessions utilizing the virtual darts game each throwing a total of 25 throws onto a virtual dart board. The control group does not undergo any training. After training is complete a post test is conducted on both groups using the same procedure as the pretest.

3.3 Project Results

Group	Condition	N	Mean ± SD (cm)	Variance	Difference
Control	Pretest	3	11.68 ± 5.9	34.8292	
Control	Posttest	3	12.20 + 5.37	28.9024	-0.52
Virtual	Pretest	3	15.37 ± 2.15	4.62	
Virtual	Posttest	3	12.31 ± 2.95	8.71	3.06

Figure 5: Results from Experiment

From the experiment that was conducted the participants claimed they had little to no experience with the game of darts. With the control and virtual group, it was found that in the pretest that the control performed better in targeting accuracy than the virtual group. Targeting accuracy is computed from the radial distance from the bullseye to the dart. In the virtual group after training was complete targeting accuracy improved in the virtual group whereas the control group got slightly worse.

In the pretest control group, with three participants the targeting accuracy mean was 11.68 cm with a standard deviation of 5.9. This standard deviation is high due to the over performance of one participant compared to the other two participants. After the posttest was conducted the targeting accuracy mean was found to be 12.20 cm and the standard deviation is 5.37. The targeting accuracy was close between the two tests (-0.52) with the control group performing slightly worse in the posttest. The worse performance could have been due to the limited number of throws that were recorded in the pretest and posttest.

In the pretest virtual group, with three participants the targeting accuracy mean was

12.20 cm with a standard deviation of 5.37. This standard deviation is lower than the control group as the performances was closer in these participants than the control group. During training there was two sessions of 25 throws completed in a virtual environment. In the posttest the targeting accuracy was found to be 12.31cm and the standard deviation is 2.95. The targeting accuracy was improved between the two tests (3.06) with the virtual group improving on their targeting accuracy.

In order to see if the results are significant I first used an independent sample t-test on the two groups using a significance level of 0.05. Conducted as a two-sided test with the null hypothesis that the two groups are not significantly different and an alternative hypothesis that the two groups are significantly different. I first compared the control and the virtual group on the pretest and got a p-value of 0.537 which would not reject the null hypothesis and suggesting that the two groups could be found from the same distribution.

I then conducted the independent sample t-test on the pretest and posttest between the two groups. Using the same two sided test I first took a look at the control group and received a p-value of 0.769 and from the virtual group I received a p-value of 0.155. As they are both over the significance level from these results it suggests that there is not enough information to suggest the two results are significantly different from pretest to posttest.

As a result, with the analysis that I conducted there is not enough information to conclude that training in a virtual environment improves the targeting accuracy of the participant although there are considerable constraints which I address later on.

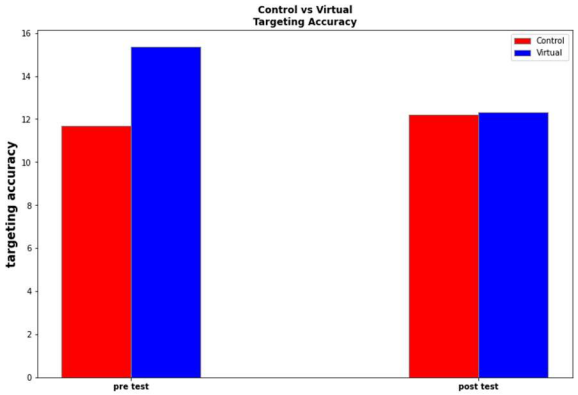

Figure 6: Targeting Accuracy from the Groups

5. Assessment

The project was interesting to undertake especially since it was in the field of virtual reality which is still a new field to research. I did have trouble finding articles on training in sports with darts as I suspect that virtual reality is still a relatively new field.

I was able to create a virtual game of darts which I implemented a scoring system to help participants understand if they are performing well. I found that most studies involving target accuracy just utilized the radial distance from the bullseye which seemed to be a good metric to compare other participant's scores. If there was more time it would be interesting to see if an experiment could be done with targeting a specific area of the dartboard as the actual game of darts involves accuracy all over the dartboard and not just the bullseye itself.

There were some complications that could have affected the study. First, there was a limited number of participants that I was able to gather for the study. I had some trouble finding participants for the project especially since I had limited time to complete my study thus my results could be slightly skewed towards the individual aptitude of my participants.

With the problems of the variance in the control group and the small number of participants, it is possible that the results could be different if the project was replicated again.

6. Limitations

There are a lot of limitations with this study. With the meta quest 2 the participant uses the quest controller holding down the trigger button to hold the dart and then simultaneously release the trigger and move the controller to throw the dart. This is an unnatural motion which does not perfectly replicate the throwing motion in real life.

There also is another issue in which the physics of the dart are also inaccurate to real world physics. The VR dart game was created in Unity and uses Rigidbody gravity, mass and velocity at time of release to determine the dart trajectory when thrown. I have also fixed the dart rotation with the point facing the dart board as there was inconsistency with tracking the controller and that is the proper way to throw the dart.

These issues all introduce complications with how darts are thrown in virtual reality and can affect the skill transfer between the virtual environment and the physical environment. In physical darts, there are some complications with how to compute targeting accuracy. I determine that if a participant misses the dartboard, then the radius of the dartboard is measured instead. This does not capture the true distance from the bullseye so the results could be different when accounting for this. In addition, there are also issues when a dart bounces off the dartboard. Although, a participant might hit the dartboard with the dart since it does not stick to the dartboard it counts as a miss and the radius of the dartboard is counted.

There are also some issues with the study as well. I would have liked to conduct more of a long-term experiment where multiple sessions can be conducted over weeks so that there can be more of a definitive analysis of the effect of virtual reality training on the physical environment.

7. Direction for Future Work

If I was able to conduct the project on the same premise, I would implement changes to try to fix the problems mentioned above. One problematic issue that I see with this study is how participants train in the virtual environment and so one approach that would be interesting to take would be to try to create a custom controller in order to resolve the unnatural motion when throwing the dart. To solve the problem with the physics one approach that I could take would be to see if other VR darts games can replicate the physics better than my custom implementation in unity.

In order to fix the physical issues with the project we could have the participant retry their throw until it is within the boundaries of the dartboard, or another possibility would be to measure the radial distance from the bullseye even if it is outside the dartboard. To stop the darts from bouncing off the dartboard one possibility is that it hits another dart on the dartboard. So after each throw that the participant takes we could reset the dartboard to make sure there are no obstacles in the next dart's path.

Regarding the study it would have been beneficial to include another group such as a physical training group which would train in a physical environment for darts. This would allow us to determine the difference of training via a virtual medium and a physical medium. One of the main issues with the study is the number of participants that were able to be acquired for the study. I was only

able to conduct the study with 6 participants which could create a problem with how reliable the results from the experiment are. If this study could be done again then it would have to be run with more participants in order to get more conclusive results.

REFERENCES

[1] Justin Eastzer Meta VR Headset Specs Compared: Quest Pro vs. Quest 2 (November 2022). Retrieved December 2, 2022 from https://www.cnet.com/tech/computing/meta-vr-headset-specs-compared-quest-pro-vs-quest-2/

[2] Tirp, J., et al. Virtual realities as optimal laerning environments in sport - A transfer study of virtual and real dart throwing (2015). Retrieved November 30, 2022 from https://www.semanticscholar.org/paper/Virtual-Realities-as-Optimal-Learning-Environments-Tirp-Steingroever/4c4900e90fb2e670c82e9fbc95f66aca32c9bc38

[3] Stefanie A Drew, et al. The Trade-Off of Virtual Reality Training for Dart Throwing: A Facilitation of Perceptual-Motor Learning With a Detriment to Performance (May 2020). Retrieved November 30, 2022 from https://pubmed.ncbi.nlm.nih.gov/33345050/