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The Effects of Virtual Reality on Motor Performance in the First Person Point of View

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Table of Contents

Abstract

Previous research has shown that visualization is an effective method used to improve motor performance (Ridderinkhof, 2015) and that similar neural pathways are activated while visualizing and performing a task (Decety, 1989). More recent research has begun to look at whether virtual reality similarly improves motor performance (Bideau, 2004). The advantages of virtual reality include the ability to practice without physical exertion (Ridderinkhof, 2015) and a better cognitive understanding of complex tactics (Science-based cognitive assessment & training, 2019). In the current study, the effects of virtual reality and visualization on motor performance in sports is tested based on the success rate of being able to make free-throws between the Control, Visualization or Virtual Reality groups. I hypothesized that the Virtual Reality group will make more shots than the Visualization or the Control groups because of its more interactive ability. I also hypothesized that participants' self-efficacy will increase after using virtual reality. The results of my research showed that there was no significant difference in shooting ability between groups. On the other hand, the participants in the Virtual Reality group found virtual reality to be significantly more useful than the Control group found counting backwards to be. Virtual reality was not significantly on any of the other self-efficacy questions. Future research should continue to examine the possible effects that virtual reality can have on motor performance as well as self-efficacy improvement.

Introduction

Sports Psychology

Sports psychology is the study of how athletes connect their minds and bodies to be at peak performance (Anshel, 2003). There are many different approaches in this field, including how to maximize physiological conditioning, how cognitive development affects athletes, or how particular moods can affect performance, and how to enhance the performance of a specific sports skill (ie. shooting a soccer ball, hitting a run in baseball, and shooting a basket in basketball) (Anshel, 2003). The most common technique has pointed to physical repetitive practice as a method to enhance muscle memory. However, athletes and coaches are often confined by the limits of physical practice. In other words, athletes can only practice as much as their body lets them. This has led researchers to look to other techniques such as visualization to increase performance (Ridderinkhof, 2015).

Mental Imagery in Sports Psychology. A way to address this issue could be the use of mental imagery, which is an important tool used in everyday life. It refers to how we use new and old experiences or sensations to produce thought-like images to help understand our surroundings. An important question is how we can use visual thoughts to help us engage with our environment.

A more useful form of mental imagery, known as visualization, is one method that people have used to enhance sports performance, mentally and physically (Stanković, Raković, Joksimović, Petković, & Joksimović, 2011). Visualization, due to its goal driven mechanisms, like preparing for a competition, can be extremely useful to athletes (Stanković et al., 2011). It is also referred to as an imaginative capacity used to experience vivid sensations that are lifelike

(Ridderinkhof, 2015). Virtual reality is another visual tool that can be used to experience vivid experiences that are compatible with real world scenarios (Steuer, 1992). Although there is limited research on the effects of virtual reality on sport's psychology, there is compelling data indicating its possible benefits (Reilly, Johansson, Huang, & Churches, 2016; Bideau, 2004). Therefore, both of these techniques, visualization and virtual reality, could be used to guide visual imagery in order to try and increase motor performance in sports.

Impact of Visualization on Sports Performance

Many researchers have targeted visualization as an alternative to physical practice, since physical practice is limited in its usage (Ridderinkhof, 2015). For instance, in the case of power weight lifting, athletes practice one repetition maximum, meaning it is the most weight they could possibly lift for one exercise at a time, so the amount they spend practicing is short with very heavy weights (Ricther, 2012). Ricther (2012), suggests that using mental scripts before working out may help increase ability to perform, and also increase confidence. These mental scripts are mental practices where athletes can still engage in life-like scenarios of weight lifting without the physical burnout (Ricther, 2012).

Visualizing weight lifting does not make the athlete stronger. What it does is activate and create stronger connections of the neural visual pathways of the proper form to weightlift (Ricther, 2012). Otherwise having improper form, such as having your knees buckled rather than pushing outwards, hinders the weightlifters ability to lift heavier things. But, with visual practice the weightlifter can perfect the correct form so that they can increase their ability to lift weights as heavy as possible (Ricther, 2012). This idea supports how helpful visualization can be to athletes despite the problem of physical limitations.

In a study by Bakker (1996), the researcher examined this phenomenon of increasing ability to weightlift through visual practice. The experimenters found that if participants were instructed to visualize lifting a weight in response to prompts of imagery, they had more electromyographic activity (EMG) in their muscles, rather than simple visual cues of the stimulus (Bakker, 1996). In other words, responsive imagery like, 'feel yourself lifting the dumbbell' lead to more activity in regions associated with imagery than simply imagining like 'see yourself lifting the dumbbell'. This study supports how more descriptive imagery can be used to prepare athletes for tasks, such as powerlifting. It also supports how immersive visualization is more helpful.

Furthermore, researchers have hypothesized that visualization activates similar brain regions to the regions activated by motor actions (Jeannerod, 1994). It is proposed that this activation is due to the encoding of a motor action that is applicable to multiple representations, such as visualizing the action and planning the action (Jeannerod, 1994). This theory is supported by the results of a study in which participants completed written or drawing tasks with both hands either by visualizing or actually doing them. They found that there was no time difference between visualizing or performing the same task with the same hand. Tasks included either writing a sentence or drawing a cube. This suggests that mental and real movements can share the same temporal organization of planning tasks (Decety, 1989). It also supports that visualization is able to be just as effective as physical performance.

Visualization has also been shown to directly improve athletic performance (Fery, 2000). Levels of athletic skill is proportionally related to the amount of time spent practicing, and as research has shown, it is also related to amount of time spent visually practicing (Fery, 2000). In the Ferry (2000) experiment researchers tested whether participants could perform better at hitting a tennis serve based on visual or kinesthetic practice. In this experiment, there was a group that practiced by watching someone serve, another group that watched and practiced serving, and another that just practiced without watching someone. Groups that mentally visualized the task along with guidance from an instructor performed better than the visual group without guidance and the guidance group without visual practice on serving a tennis ball to the correct side of the court (Fery, 2000). These results support the idea that, although kinesthetic practice is beneficial, it is even more beneficial in conjunction with kinesthetic practice. In other words, visualizing in conjunction with physical practice gives athletes a better chance to improve their skills.

All in all, using visualization as an aid to physical practice has been shown to prepare athletes for specific skills. In certain situations, visualization has been just as effective as motor performance (Decety, 1989). Visualization enhances planning through temporal organization (Decety, 1989). It allows for neural pathways to be more strongly connected and provides a way to practice beyond physical limitations (Ricther, 2012). Visualization is also more helpful when the language is more immersive (Bakker, 1996) and it maximizes performance when practicing using visual and kinesthetic cues (Fery, 2000). This analysis helps support the idea that athletes can use visualization to reach peak performance.

Impact of Virtual Reality on Sports Performance

Virtual reality includes simulations based on computer programming or real world scenarios like a 3-D video. For the purposes of this paper, virtual reality and visualization are defined as different mechanisms. Virtual reality uses visualization as a part of the process but has much more of a controlled, interactive and stimulating experience of the real world, whereas visualization is a less controlled way for an individual to imagine in their own minds re-enactment or simulations of the real world.

As there is data to suggest that visualization improves performance in cognition and motor skills, there is also research supporting that virtual reality is beneficial for motor performance within sports as well (Reilly et al., 2016). But, while there is published research on the effects that virtual reality and visualization have on motor skills, there is limited data comparing both virtual reality and visualization.

More specifically, the Bideau (2004) study looked at whether virtual reality affects the ability of handball keepers to react to a virtual stimulus, such as a virtual person throwing the ball. In their results they found that there was no difference in the goalkeepers ability to make a save between a throw that was a computer simulation or a throw that was directly simulated based on an actual throw. Therefore, computer simulations are just as effective in representing someone throwing a ball as a model that copied an actual throw (Bideau, 2004). We can infer from this study that computer simulations, like virtual reality, are accurate in their representations of real world scenarios. This data supports that virtual reality can be reacted to the same as a real world stimulus, similar to visualization.

The Reilly et al. (2016) study proposed a virtual reality mechanism to improve how athletes react to and make decisions while using virtual reality (Reilly et al, 2016). In this study coaches proposed the development and customization of a scenario of various sporting events. They would be able to create a virtual simulation, like in a video game, for more complex events like a soccer game. Participants would be able to interact and make decisions, like where to run and where to pass the ball. Because this was a proposed study there were no results, however, results would be determined by performance, decision making and timing. Athletes should be able to repeat experiences to maximize performance without risk of injury (Reilly et al, 2016).

The Reilly et al. (2016) proposed study supports how virtual reality can help athletes develop specific motor skills without physical limitation. It also supports how decision-making is an important part of an athletes performance and how virtual reality can help that as well. This proposed study was important in considering the ways in which virtual reality can be used to affect athletes performance (Reilly et al, 2016).

Moreover, a study by Hodges & Coppola (2015) supports that we learn from watching others (Hodges & Coppola, 2015). In said study, they tested whether participants were able to perform the skill after watching a video of that skill. Observing the video increased their performance. From this study we derive that observing someone perform a skill might have an effect on brain memory activating brain regions so that the participants would be able to perform.

Although there is limited research supporting the direct use of virtual reality in sports, there has been research that has tested the effects of training by watching videos in an effort to increase decision making in baseball athletes (Fadde, 2006). In the Fadde (2006) study, participants watched a pitcher throw a baseball in hopes of training an explicit recognition pattern of a pitcher's throw. Thus, increasing their decision-making in swinging the bat. They compared the video training to the batting average of college baseball players. Because of this study we can infer that watching a more detailed video will increase performance of their skill, adding to the benefit of using a virtual reality headset, due to its ability to demonstrate complex situations. This would be particularly helpful for athletes and coaches.

Furthermore, research has shown how interactive videos are more beneficial for learning than non-interactive videos (Schwan & Reimpp, 2004). More interactive and immersive environments like virtual reality should allow users to adapt their form and cognitive awareness. This was tested through an experiment where participants had to learn how to tie nautical knots by either watching an interactive video where they could pause, play, speed up, reverse, or replay the video or a non-interactive video with no options to adjust. Users of non-interactive videos took longer to complete the knot than interactive video users (Schwan, 2004). Thus, we might think that a virtual reality video with an interactive element of 3-D should increase participants' ability to complete free-throws.

Additionally, it has also been supported that virtual reality can affect free throw skill development. Researchers of a study using videos of free-throws found that watching a simulation of free-throws compared to a real world scenario had no difference in the ability to score baskets. Meaning each group statistically had similar amounts of shots made. This suggests that using virtual reality as a method of learning is just as effective as real world scenarios (Covaci, 2012).

The benefits of virtual reality go far beyond possible motor improvements. They also include being helpful to athletes who are injured. Virtual reality headsets are portable and easy to use, and therefore athletes and coaches should be able to allow athletes the availability of using it at home or in the training facilities. Amateur athletes can also take advantage of this tool to train outside of practice without compromising their physical recovery. Virtual reality bypasses physical limitations of athletes and allows them to create training sessions that are more readily available. Virtual reality can be helpful to athletes who are injured or need more practice time.

While it is clear that virtual reality has a great number of possible benefits for athletes, there has been much more extensive research on the effect of visualization on sport performance. Yet, the limited data on virtual reality remains promising.

Present Study

Due to the supported effectivity of visualization, the numerous possible benefits of virtual reality, and because of the limited amount of data comparing the effects of visualization to virtual reality in sport performance, this study aims to address this gap in the literature. Inspired by the Reilly et al. (2016) proposed study, this current study explores the effects of Virtual Reality, Visualization and a Control group in order to see how each of them impacts motor-performance in sports.

Hypotheses. Although visualization is supported by research to be beneficial for motor performance, I hypothesize that virtual reality will improve motor performance even more. Based on the research that shows how response prepositions have more activation than visual prepositions (Bakker, 1996), I hypothesize that virtual reality will elicit imagery that causes participants to engage with that imagery more than just simply thinking about it. In other words, by seeing a visual stimulus participants may engage with that stimulus by trying to replicate those effects within themselves, causing activation not just visually, but within muscles and other neural pathways (Bakker, 1996). Visualization may cause similar effects, but I hypothesize that because one can control what the participants see in virtual reality, and because of the nature of immersive imagery from virtual reality, participants will have stronger visual activations that will increase motor performance more so than visualization.

Although not directly tested in this project, I also hypothesize that virtual reality is more beneficial than visualization because of the amount of control that virtual reality allows. When visualizing, the athletes have a wide range of available imagery, therefore a coach or trainer could not be able to account for all that an athlete visualizes, even if they use descriptive language. But, if they were to develop a specific program designed to train the athlete via virtual reality, then they could account for exactly what the athlete sees. This would potentially allow for a more beneficial training session.

Overall, I hypothesize that the Virtual Reality group will have a significant improvement of motor performance as opposed to the Visualization group and the Control group, which means that they will have made a more significant amount of free-throws out of 20 when compared to the Visualization and the Control group. I also hypothesize that participants will report having more confidence after having been in the Virtual Reality group as opposed to the Visualization and the Control group.

In my study I will be testing to see if virtual reality will increase motor performance of an athletic skill. I presume that virtual reality will be helpful to athletes and coaches that want to continue to train the mind without physical exertion. I plan to use this study to explore this topic and to further discuss how visual stimulation is an important factor in improving cognition and motor performance.

Method

Participants

Participants in this study were 37 Bard College students (18 male and 19 female). Participants ranged in age from 18-25 (M= 21, SD=1.425) and were randomly assigned to one of three experimental groups. There were 15 participants in the Virtual Reality group, 11 in the Visualization group, and 11 in the Control group. The college grade and ethnicity of the sample varied. (Grade level: 5 freshman, 11 sophomores, 6 juniors, 14 seniors, 1 grad-student). Participants ranged in ethnicity (22 White, 5 Black, 4 Hispanic, 1 Asian, 1 White Hispanic, 2 Black Hispanic, 1 Black Indian, 1 White Other). Participants were entered into a lottery to win a $25 Amazon gift card as compensation.

Materials

Virtual Reality Headset. A virtual reality headset was used to view a virtual reality video. The headset was placed on the participants' heads covering the eyes, so they could only see the video. The brand was Xtreme Cables (see Appendix E). The device weighed 3 ounces.

Pre-Experiment Questionnaire. A pre-experiment survey including questions about demographics (see Appendix B for the survey) was given to participants to complete by hand. This was to collect information about the participants, specifically about their basketball and athletic experience. It included questions about gender, grade-level, number of years with competitive athletic experience, and number of years of competitive basketball experience.

Post-Experiment Survey. A post-experiment survey including questions about confidence in performance, the effectiveness of the task (whether it helped or changed performance), the usefulness of the task and possible future use of task, was given to participants to complete once they finished the basketball shooting exercise (see Appendix C for the survey). This survey was created to collect data about how participants felt about how their task affected their performance. Questions included "On a scale of 1-10, how well do you think you performed?", and "On a scale of 1-10, how well do you think visualization/VR/nothing aided your performance?".

Procedure

After receiving Institutional Review Board approval, (see Appendix G for IRB submission and approval, and Appendix H for NIH Certificate of Completion), flyers promoting the study were posted around campus with information on how to join the study (see Appendix F for flyer).

The experiment was conducted at the Stevenson Athletic Center on the campus of Bard College. Participants shot from the freethrow line 15ft from the basket towards a hoop 10ft high. One basketball hoop was used for the duration of the experiment. Participants were invited to show up from 10 am to 3 pm. The time spent with participants was approximately 15-20 minutes.

Basketball free throws were chosen for the purposes of this study because it is a relatively simple task and one can control the effects of visual and virtual reality responses to the success of making a basket. We can measure the ability of a participant based on how many free throws they made. Although there may be an effect of practice, where participants with more basketball experience made more shots than average, the wide range of experience of basketball skill of the between-subjects design should balance out for any effect. Similar studies have also used free throws as a method for score measurement when comparing simulations to real-world scenarios (Covaci, 2012).

This study was composed of two rounds. For this study, 20 shots were chosen for a single round. This was inspired by the Covaci (2012) study because participants shot 20 free-throws after watching free-throws on video as compared to real shots (Covaci, 2012). I used the same amount of free throws to conduct my experiment. However, in this current experiment, a second round of shooting was added to make sure the virtual reality training was effective. Therefore, a total of 40 shots were collected to account for visual training.

Once the experiment began, the experimenter explained the contents of what they would be doing, then asked participants to read and sign a consent form (see appendix A). After that, they completed a demographic survey (see appendix B). At this point, they were randomly assigned to a group. The survey was completed and groups were instructed to take 10 practice shots. These 10 practice shots were chosen as a baseline score to compare percentage scores made and to get the participants warmed up and ready for the actual rounds.

Participants stood at the free-throw line 15ft from the basket. The experimenter stood next to the basket on either side to help collect the balls, while also collecting data. The experimenter recorded each shot on a predesigned sheet (see appendix D). The sheet included measures for baskets made, hit the rim or backboard, or airballed. Shots were coded as 0 airball, 1 rim/backboard, and 2 made. After the ten shots were completed participants moved on to the respective task that depended on the group assignment.

The Control group (11) were instructed to count backward from 100 for 1 minute and to remain standing while trying not to make any grand gestures, including pretending to shoot, looking around, or taking more than two steps. They were asked to count backward from 100 in order to distract them from visualizing themselves shooting the basketball. The participants then took 20 shots trying to score as many baskets as they could. The participants retrieved their own balls and shot in succession. The experimenter recorded the data. After Round 1 was complete, participants were told to perform the same task but counting down from 200 for 2 minutes and then took 20 more shots. After Round 2 was complete, participants were given a post-survey to fill out asking about the confidence rating (see Appendix C for the survey). Data regarding confidence ratings were collected for each group because previous research has shown that confidence is positively correlated to increased performance (Levy, Nicholls, & Polman, 2011). The same study also found that mental imagery can increase confidence. Another study showed that participants with higher self-efficacy resulted in a higher hit rate in baseball college games (George, 1994).

The Visualization group was instructed to imagine themselves shooting a scoring basket from the first person point of view for one minute. The experimenter timed this minute. Then, they took 20 free throws trying to score as many as possible. The participants retrieved their own balls and shot in succession. The experimenter recorded the data. They were instructed to either sit or remain standing while trying not to make any grand gestures. After that, they again imagined themselves shooting a free throw in the first person point-of-view for two minutes. For the purposes of this study, the first-person point of view has been chosen to support learning of shooting a free throw. It has been shown that elbow and wrist angles are important for free throw shot success (Mullineaux, 2010). Again they shot 20 free throws. After Round 2 was complete, participants were given a post-survey to fill out asking about the confidence rating (see Appendix C for the survey).

The Virtual Reality group used the virtual reality headset to watch a one minute video of a person shooting a scoring basketball free-throw shot. This was done in the hopes that it would trigger brain regions, similar to visualizing, and increase performance due to the virtual reality experience. Moreover, the brain regions activated, along with the muscles activated, will increase the effect of watching someone perform, thus increasing muscle memory. Therefore, when the participants watch the virtual reality video, they will increase their cognitive and muscular activity (Hodges & Coppola, 2015).

Again, they were instructed to either sit or remain standing while trying not to make any grand gestures. The video was a prerecorded video with virtual reality capabilities, posted on YouTube, of a man shooting free throws for two minutes (https://youtu.be/RSzNAUyUVBE). This virtual reality video was chosen as the free throw simulation because watching a video from the first-person point of view would allow participants to see how their arms should be placed in order to correctly make a basket. The Virtual Reality group watched this video to be consistent with the Visualization group, so that they both had a first person point of view. A cell-phone was used to play the video and was placed in the VR headset. Participants wore a headset that wrapped around their heads for the whole minute. The headset covered their eyes so that they would see only the video. They could hear the video at a moderate loudness. After the minute was up, the experimenter instructed them to shoot 20 free throws while they recorded the data. After completing that, they watched two more minutes of the same video and then shot 20 free throws. After Round 2 was complete, participants were given a post-survey to fill out asking about the confidence rating (see Appendix C for the survey).

Finally, each participant was given a debriefing of the study to explain the hypotheses and expected results of the study (see Appendix D for debriefing). Participants were reminded of their chance to win a $25 gift card before they left.

Upon completion of the study, participants were debriefed and the experimenter signed the consent form (see Appendix A for consent form) and uploaded the data collected into an Excel sheet on a password-protected computer. The researcher then put the consent form and surveys in a folder for the remainder of the study.

Results

For this study, an alpha of $p < .05$ was chosen. The data was first subjected to a one-way Analysis of Variance (ANOVA), with planned comparisons conducted using t-tests. The data was analysed based on how many shots participants made out of 40. The data was compared across groups with an one-way ANOVA with groups (Control, Visualization, and Virtual Reality) as a between-subjects factor. Follow-up t-tests were conducted comparing all groups to each other. Additional analyses looked at the impact of participants' athletic experience as well as their self report of how well they thought they did.

Scoring of Shots

In order to calculate the performance of each group the averages of shots were analyzed for shots made, hit the rim/backboard or airballed (see Figure 1 for compiled average shots).

Average shots made for the Virtual Reality group (*M*= 13.933, *SD*= 8.013). Average shots missed (hit the rim or backboard) for the Virtual Reality group (*M*= 24, *SD*= 7.061). Average shots airballed for the Virtual Reality group (*M*= 1.533, *SD*= 3.796).

Average shots made for the Visualization group (*M*= 18.636, *SD*= 7.379). Average shots missed (hit the rim or background) for the Visualization group (*M*= 20.818, *SD*= 7.125). Average shots airballed for the Visualization group (*M*= 0.545, *SD*= 1.508).

Average shots made for the Control group (*M*= 11.363, *SD*= 7.514). Average shots missed (hit the rim or backboard) for the Control group (*M*= 26.09, *SD*= 8.203). Average shots airballed for the Control group (*M*= 2.636, *SD*= 7.447).

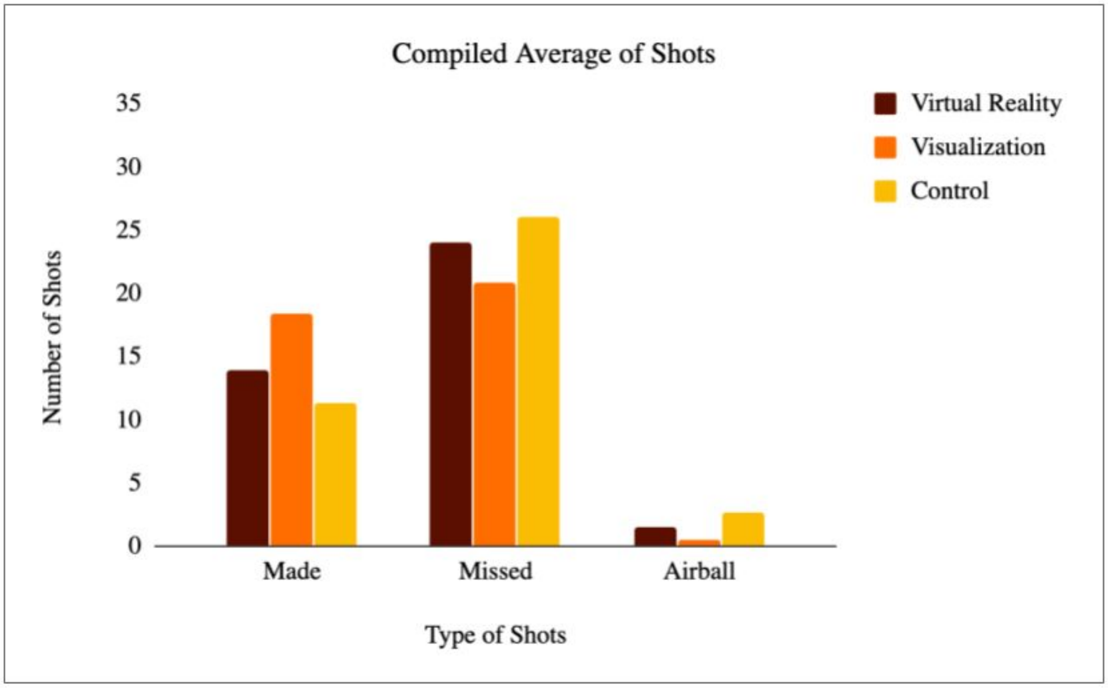

Figure. 1 This figure depicts the total mean number of shots made, missed, and airballed by each of the groups. The Visualization group had the highest mean of scored shots. The Virtual Reality had the highest mean of shots missed. The Control group had the highest mean of shots airballed.

Analysis of Total Shots Made

A one-way between subjects ANOVA was conducted to compare the effect of the experimental group on total shots made in the Virtual Reality, Visualization and Control conditions. Total shots were combined for Round 1 and Round 2 in order to determine if any group significantly performed better than the others. There was not a significant effect of experimental group on total shots made at the $p<.05$ level for the three conditions, $F(2, 34) = 2.549$, $p = 0.093$. Taken together, these results suggest that using virtual reality does not have an effect on shots made (see figure 2.)

An independent-samples t-test was conducted to compare total shots made in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 13.93, *SD*= 8.013) and Visualization (*M*= 18.64, *SD*= 7.379) conditions; t (24)= -1.528, $p = 0.14$. These results suggest that using virtual reality versus visualizing does not have an effect on total shots made.

An independent-samples t-test was conducted to compare total shots made in Visualization and Control conditions. There was a significant difference in the scores for Visualization (*M*= 18.64, *SD*= 7.379) and Control group (*M*= 11.36, *SD*= 7.514) conditions; t (20)=2.29, $p = 0.033$. These results suggest that visualizing does have an effect on total shots made.

An independent-samples t-test was conducted to compare total shots made in Virtual Reality and Control conditions. There was a significant difference in the scores for Virtual Reality (*M*= 13.93, *SD*= 8.013) and Control group (*M*= 11.36, *SD*= 7.514) conditions; t (24)= 0.828, $p = 0.415$. These results suggest that using virtual reality does not have an effect on total shots made.

Given the results from this analysis, the Visualization group performed better than the Virtual Reality group. There were no other significant differences between the groups.

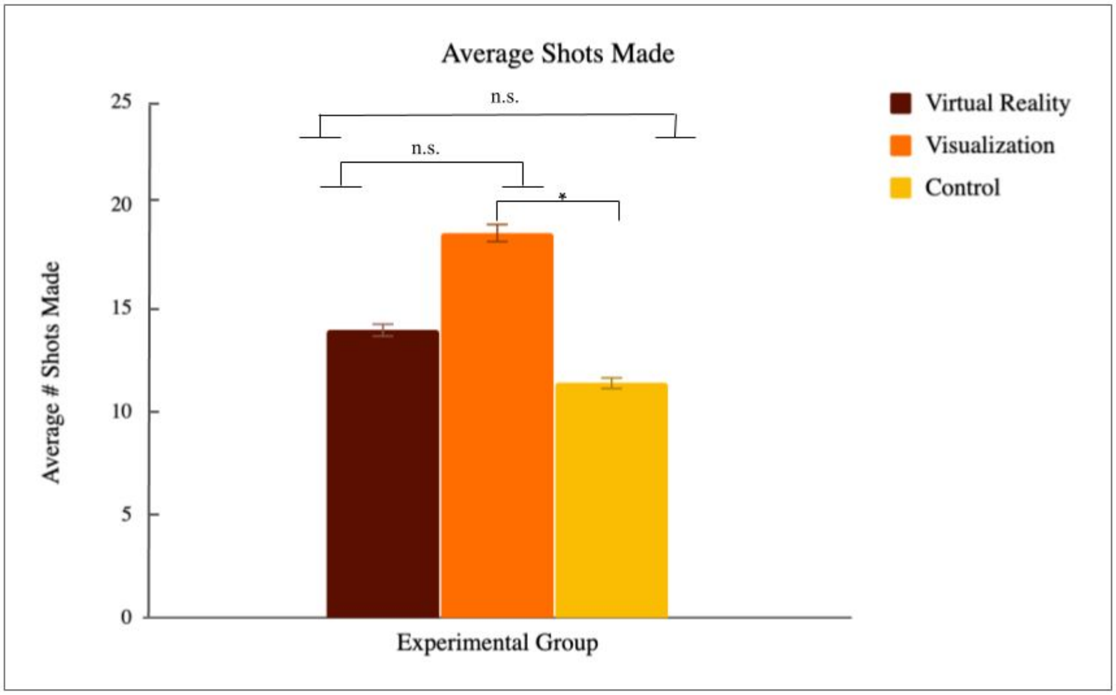

Figure. 2 This figure depicts the total mean number of shots made by each of the groups. The Visualization group had the highest mean of scored shots, but it was not significantly different than the Virtual Reality or The Control groups. Error bars show standard error, * indicates p<.05, ** indicates p<.01 and n.s., stands for "not significant".

Correlation of Athletic Experience to Total Shots Made

A Pearson product-moment correlation coefficient was computed to assess the relationship between athletic experience and total shots made. There was a positive but non-significant correlation between the two variables, $r = 0.182$, $n = 33$, $p = 0.296$. Overall, there was a weak, positive correlation between athletic experience and total shots made.

Analysis of Athletic Experience

A one-way between subjects ANOVA was conducted to compare experimental groups on athletic experience in the Virtual Reality, Visualization and Control conditions. There was not a significant effect of the experimental group on total shots made at the $p<.05$ level for the three conditions, $F(2, 33) = 1.578$, $p = 0.222$. Taken together, these results suggest that athletic experience does not have an effect on shots made between groups.

An independent-samples t-test was conducted to compare experimental groups on athletic experience in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 9.8 yrs, *SD*= 5.659) and Visualization (*M*= 8.60 yrs, *SD*= 5.4000 conditions; t (23)= 0.529, p = 0.602. These results suggest that athletic experience does not have an effect on total shots made between Virtual Reality and Visualization groups.

An independent-samples t-test was conducted to compare experimental groups on athletic experience in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= 8.60 yrs, *SD*= 5.400) and Control (*M*= 6.00 yrs, *SD*= 5.099) conditions; t (19)= 1.135, p = 0.271 These results suggest that athletic experience does not have an effect on total shots made between Visualization and Control groups.

An independent-samples t-test was conducted to compare athletic experience on total shots made in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 8.60 yrs, *SD*= 5.400) and Control (*M*= 6.00 yrs, *SD*= 5.099) conditions; t (24)= 1.762, p = 0.091. These results suggest that athletic experience does not have an effect on total shots made between Virtual Reality and Control groups.

Therefore, there did not appear to be differences in the athletic experience across groups.

Analysis of Total of Practice Round versus Round 1 Shots

A one-way between subjects ANOVA was conducted to compare the effect of the task on baseline versus total shots made Round 1 in the Virtual Reality, Visualization and Control conditions. This was done to determine if the groups had any significant improvements between their baseline scores and Round 1 scores. The difference of percentage of scores between the groups was analyzed (% Round 1 made-% Practice Round made). There was not a significant effect of the task on Practice Round versus Round 1 total shots made at the $p<.05$ level for the three conditions, $F(2, 33) = 0.075$, $p = 0.928$. Taken together, these results suggest that each task does not have an effect on shots made in the Practice Round versus Round 1. (See Figure. 3)

An independent-samples t-test was conducted to compare total shots made Practice Round versus Round 1 in the Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 10, *SD*= 14.005) and Visualization (*M*= 7.27, *SD*= 19.412) conditions; $t(23) = -0.408$, $p = 0.687$. These results suggest that using virtual reality versus visualizing does not have an effect on total shots made Practice Round versus Round 1.

An independent-samples t-test was conducted to compare total shots made Practice Round versus Round 1 in the Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= 7.27, *SD*=19.412) and Control (*M*= 8.18, *SD*= 21.27) conditions; $t(20) = 0.105$, $p = 0.917$. These results suggest that visualizing does not have an effect on total shots made Practice Round versus Round 1.

An independent-samples t-test was conducted to compare total shots made Practice Round versus Round 1 in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 10, *SD*= 14.005) and Control (*M*= 8.18, *SD*= 21.27) conditions; $t(23) = -0.258$, $p = 0.798$. These results suggest that virtual reality does not have an effect on total shots made Practice Round versus Round 1.

The percentages scores made for the Practice Round and the first Round did not differ between groups.

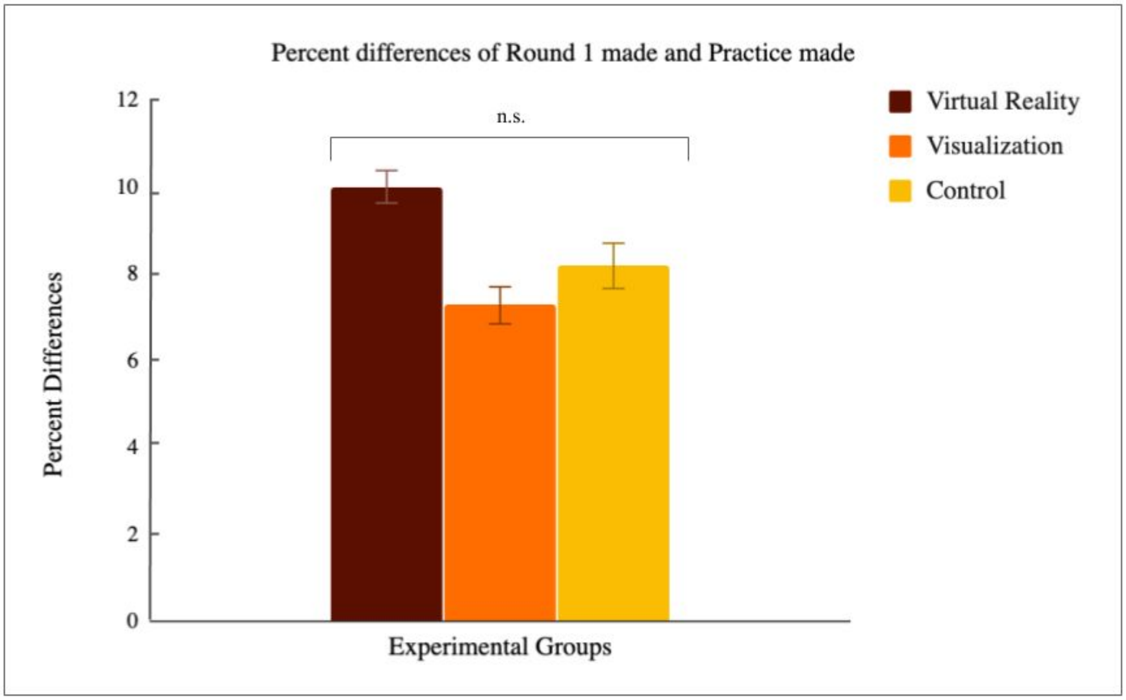

Figure. 3 This figure depicts the difference scores of Round 1 and Practice Round of the total number of shots made by each of the groups. The Virtual Reality group had the highest mean of difference scores, but it was not significantly different than the Visualization or the Control groups. Error bars show standard error, * indicates p<.05, ** indicates p<.01 and n.s., stands for “not significant”.

Analysis of the Total of Round 1 Shots versus Round 2 Shots

A one-way between subjects ANOVA was conducted to compare the effect practicing group on total shots made Round 1 versus Round 2 in the Virtual Reality, Visualization and Control conditions. There was not a significant effect of practising on total shots made at the $p<.05$ level for the three conditions, $F(2, 34) = 1.546$, $p = 0.228$. Taken together, these results suggest that practising shooting after 2 rounds does not have an effect on total shots made between Round 1 and Round 2.

An independent-samples t-test was conducted to compare total shots made Round 1 versus Round 2 in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 1.00, *SD*= 2.777) and Visualization (*M*= -1.18, *SD*= 3.454) conditions; *t* (24)= 1.762, *p* = 0.091. These results suggest that using virtual reality versus visualization does not have an effect on total shots made Round 1 versus Round 2.

An independent-samples t-test was conducted to compare total shots made Round 1 versus Round 2 in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= -1.18, *SD*= 3.454) and Control (*M*= -0.09, *SD*= 3.177) conditions; *t* (20)= -0.76, *p* = 0.456. These results suggest that visualization does not have an effect on total shots made Round 1 versus Round 2.

An independent-samples t-test was conducted to compare total shots made Round 1 versus Round 2 in the Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 1.00, *SD*= 2.777) and Control (*M*= -0.09, *SD*= 3.177) conditions; *t* (24)= 0.931, *p* = 0.361. These results suggest that using virtual reality does not have an effect on total shots made Round 1 versus Round 2.

Thus, total Round 1 shots and total Round 2 shots did not differ between groups.

Analysis of Confidence Ratings

ANOVAs for Confidence Rating. A one-way between subjects ANOVA was conducted to compare the effect of the experimental group on confidence ratings in the Virtual Reality, Visualization and Control conditions. This was done to see if the tasks made participants more or less confident about their ability to shoot (see figure 4).

There was not a significant effect of the experimental group on ‘confidence performance’ (see Appendix C for survey question) made at the $p<.05$ level for the three conditions, $F(2, 33) = 1.197$, $p = 0.315$. Taken together, these results suggest that the tasks do not have an effect on ‘confidence performance’ between the conditions.

There was a significant effect of the experimental group on ‘changed performance’ (see Appendix C for survey question) made at the $p<.05$ level for the three conditions, $F(2, 34) = 2.593$, $p = 0.09$. Taken together, these results suggest that the tasks do not have an effect on ‘changed performance’ between the conditions.

There was not a significant effect of the experimental group on ‘aided performance’ (see Appendix C for survey question) made at the $p<.05$ level for the three conditions, $F(2, 34) = 2.15$, $p = 0.132$. Taken together, these results suggest that the tasks do not have an effect on ‘aided performance’ between the conditions.

There was a significant effect of the experimental group on ‘usefulness’ (see Appendix C for survey question) made at the $p<.05$ level for the three conditions, $F(2, 34) = 4.551$, $p = 0.018$. Taken together, these results suggest that the tasks do not have an effect on ‘usefulness’ between the conditions.

There was a significant effect of the experimental group on ‘use again’ (see Appendix C for survey question) made at the $p<.05$ level for the three conditions, $F(2, 34) = 4.47$, $p = 0.019$. Taken together, these results suggest that the tasks do not have an effect on ‘use again’ between the conditions.

The only confidence ratings that were significantly different between groups were perceived ‘change performance’, ‘usefulness’, and ‘use again’.

Independent t-tests for Virtual Reality and Visualization. An independent-samples t-test was conducted to compare ‘confidence performance’ in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for the Virtual Reality (M= 4.87, *SD*= 2.1) and Visualization (*M*= 5.5, *SD*= 1.9) conditions; t (23)= -0.766, p = 0.451. These results suggest that using virtual reality does not have an effect on confidence performance.

An independent-samples t-test was conducted to compare 'changed performance' in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for the Virtual Reality (*M*= 6.47, *SD*= 1.767) and Visualization (*M*= 7.18, *SD*= 1.601) conditions; t (24)= -1.06, p = 0.3. These results suggest that using virtual reality does not have an effect on whether virtual reality changed performance.

An independent-samples t-test was conducted to compare 'aided performance' in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 6.33, *SD*= 1.952) and Visualization (*M*= 7.64, *SD*= 1.804) conditions; t (24)= -1.735, p = 0.096. These results suggest that using virtual reality does not have an effect on whether virtual reality aided performance.

An independent-samples t-test was conducted to compare 'usefulness' in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for the Virtual Reality (*M*= 5.6, *SD*= 1.352) and Visualization (*M*= 4.55, *SD*= 2.979) conditions; t (24)= -1.217, p = 0.235. These results suggest that using virtual reality does not have an effect on usefulness.

An independent-samples t-test was conducted to compare 'use again' in Virtual Reality and Visualization conditions. There was a significant difference in the scores for the Virtual Reality (*M*= 3.53, *SD*= 2.066) and Visualization (*M*= 5.64, *SD*= 2.873) conditions; t (24)= 2.176, p = 0.04. These results suggest that using virtual reality does have an effect on whether participants would use visualization again.

Independent t-tests for Visualization and Control. An independent-samples t-test was conducted to compare 'confidence performance' in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= 5.5, *SD*= 1.9) and Control (*M*= 4.18, *SD*= 1.779) conditions; t (19)= 1.642, p = 0.117. These results suggest that visualization does not have an effect on confidence.

An independent-samples t-test was conducted to compare 'changed performance' in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= 7.18, *SD*= 1.601) and Control (*M*= 5.18, *SD*= 2.822) conditions; t (20)= 2.044, p = 0.54. These results suggest that visualization does not have an effect on whether participants thought it changed their performance.

An independent-samples t-test was conducted to compare 'aided performance' in Visualization and Control conditions. There was a significant difference in the scores for Visualization (*M*= 7.64, *SD*= 1.804) and Control (*M*= 6.27, *SD*= 1.489) conditions; t (20)= 1.933, p = 0.067. These results suggest that visualization does have an effect on whether visualization aided performance.

An independent-samples t-test was conducted to compare 'usefulness' in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= 4.55, *SD*= 2.979) and Control (*M*= 3, *SD*= 2.145) conditions; t (20)= -1.396, p = 0.178. These results suggest that visualization does not have an effect on whether visualization was useful.

An independent-samples t-test was conducted to compare 'use again' in Visualization and Control conditions. There was a significant difference in the scores for Visualization (*M*=

5.64, *SD*= 2.873) and Control (*M*= 3, *SD*= 1.549) conditions; *t* (20)= -2.679, *p* = 0.014. These results suggest that visualization does have an effect on whether participants would use visualization again.

Independent t-tests for Virtual Reality and Control. An independent-samples t-test was conducted to compare 'confidence performance' in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 4.87, *SD*= 2.1) and Control (*M*= 4.18, *SD*= 1.779) conditions; *t* (24)= 0.875, *p* = 0.39. These results suggest that virtual reality does not have an effect on confidence.

An independent-samples t-test was conducted to compare 'changed performance' in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 6.47, *SD*= 1.767) and Control (*M*= 5.18, *SD*= 2.822) conditions; *t* (24)= 1.428, *p* = 0.166. These results suggest that virtual reality does not have an effect on whether participants thought it changed performance.

An independent-samples t-test was conducted to compare 'aided performance' in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 6.33, *SD*= 1.952) and Control (*M*= 6.27, *SD*= 1.489) conditions; *t* (24)= 0.086, *p* = 0.932. These results suggest that virtual reality does not have an effect on whether participants thought it aided performance.

An independent-samples t-test was conducted to compare 'usefulness' in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 5.6, *SD*= 1.352) and Control (*M*= 3, *SD*= 2.145) conditions; *t* (24)= -3.792, *p* = 0.001. These results suggest that virtual reality does have an effect on whether participants thought it was useful.

An independent-samples t-test was conducted to compare 'use again' in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 3.53, *SD*= 2.066) and Control (*M*= 3, *SD*= 1.549) conditions; t (24)= -0.719, p = 0.479. These results suggest that virtual reality does not have an effect on whether participants would use it again.

The only significant difference found between the Virtual Reality group and Visualization group was 'use again'. This was also the only difference found between the Visualization group and the Control group. The only difference between the Virtual Reality group and the Control group was 'usefulness'.

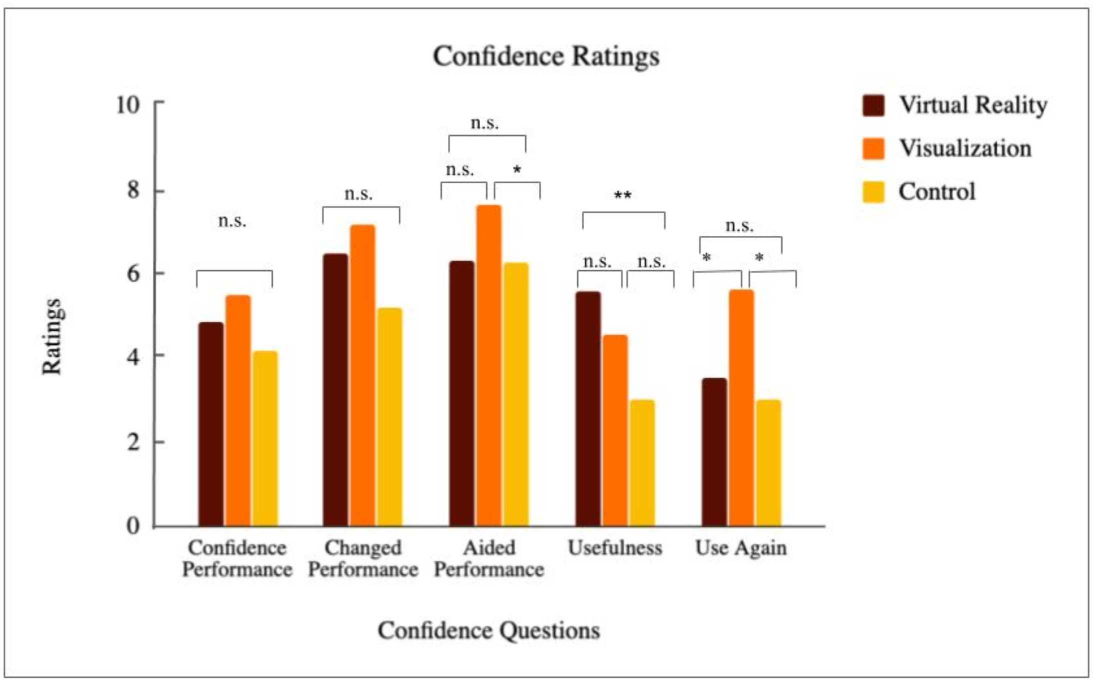

Figure. 4 This figure depicts the confidence ratings of the groups. 'Confidence performance' and 'changed performance' did not have any significant differences. 'Aided performance' was only significant between Visualization and Control groups. 'Usefulness was only significant between Virtual Reality and Control groups. 'Use again' was only significant between Virtual Reality and Control groups. Error bars show standard error, * indicates p<.05, ** indicates p<.01 and n.s., stands for "not significant".

Analysis Excluding Bottom Half of the Scores

To control for performance a median split analysis was used to split the data between high and low performers. The median was 14, so a filter was made to exclude scores less than 14. A one-way between subjects ANOVA was conducted to compare the effect of the experimental group (excluding participants with total shots less than 14) on total shots made in the Virtual Reality, Visualization and Control conditions. There was not a significant effect of the experimental group on total shots made at the $p<.05$ level for the three conditions, $F(2, 18) = 0.418$, $p = 0.665$. Taken together, these results suggest that even excluding the bottom half of the scores does not have an effect on total shots made between groups (see figure 5).

An independent-samples t-test was conducted to compare experimental groups (excluding participants with a score less than 14) for total shots made in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 20.29 (*SD*= 6.873) and Visualization (*M*= 20.78 (*SD*= 6.220) conditions; t (14)= -0.15, p = 0.883. These results suggest that when excluding the bottom half of scores virtual reality does not have an effect on total shots made between Virtual Reality and Visualization groups.

An independent-samples t-test was conducted to compare experimental groups (excluding participants with a score less than 14) for total shots made in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (*M*= 20.78 (*SD*= 6.220) and Control group (*M*= 17.60 (*SD*= 6.066) conditions; t (12)= 0.923, p = 0.374. These results suggest that when excluding the bottom half of scores visualization does not have an effect on total shots made between Visualization and Control groups.

An independent-samples t-test was conducted to compare experimental groups (excluding participants with a score less than 14) for total shots made in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 20.29 (*SD*= 6.873) and Control group (*M*= 17.60 (*SD*= 6.066) conditions; t (10)= 0.699, p = 0.501. These results suggest that when excluding the bottom half of scores virtual reality does not have an effect on total shots made between Virtual Reality and Control groups.

Analysis Excluding Top Half of Scores

Another filter was placed to exclude scores of more than 14 to account for the bottom half of the scores. A one-way between subjects ANOVA was conducted to compare the effect of the experimental group (excluding participants with total shots more than 14) on total shots made in the Virtual Reality, Visualization and Control conditions. There was not a significant effect of the experimental group on total shots made at the $p<.05$ level for the three conditions, $F(2, 17) = 0.007$, $p = 0.993$. Taken together, these results suggest that even excluding the top half of the scores does not have an effect on total shots made between groups (see figure 5).

An independent-samples t-test was conducted to compare experimental groups (excluding participants with a score greater than 14) for total shots made in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 9, *SD*= 3.775) and Visualization (*M*= 9, *SD*= 2.828) conditions; t (9)= 0, p = 1.00. These results suggest that when excluding the top half of scores virtual reality does not have an effect on total shots made between Virtual Reality and Visualization groups.

An independent-samples t-test was conducted to compare experimental groups (excluding participants with a score greater than 14) for total shots made in Visualization and

Control conditions. There was not a significant difference in the scores for Visualization (*M*= 9, *SD*= 2.828) and Control (*M*= 8.78, *SD*= *4.79)* conditions; *t* (9)= 0.062, *p* = 0.952. These results suggest that when excluding the top half of scores visualization does not have an effect on total shots made between Visualization and Control groups.

An independent-samples t-test was conducted to compare experimental groups (excluding participants with a score greater than 14) for total shots made in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 9, *SD*= 3.775) and Control (*M*= 8.78, *SD*= *4.79)* conditions; *t* (16)= 0.109, *p* = 0.914. These results suggest that when excluding the top half of scores Virtual Reality does not have an effect on total shots made between Virtual Reality and Control groups.

There were no significant differences found for the top half or bottom half of the performers.

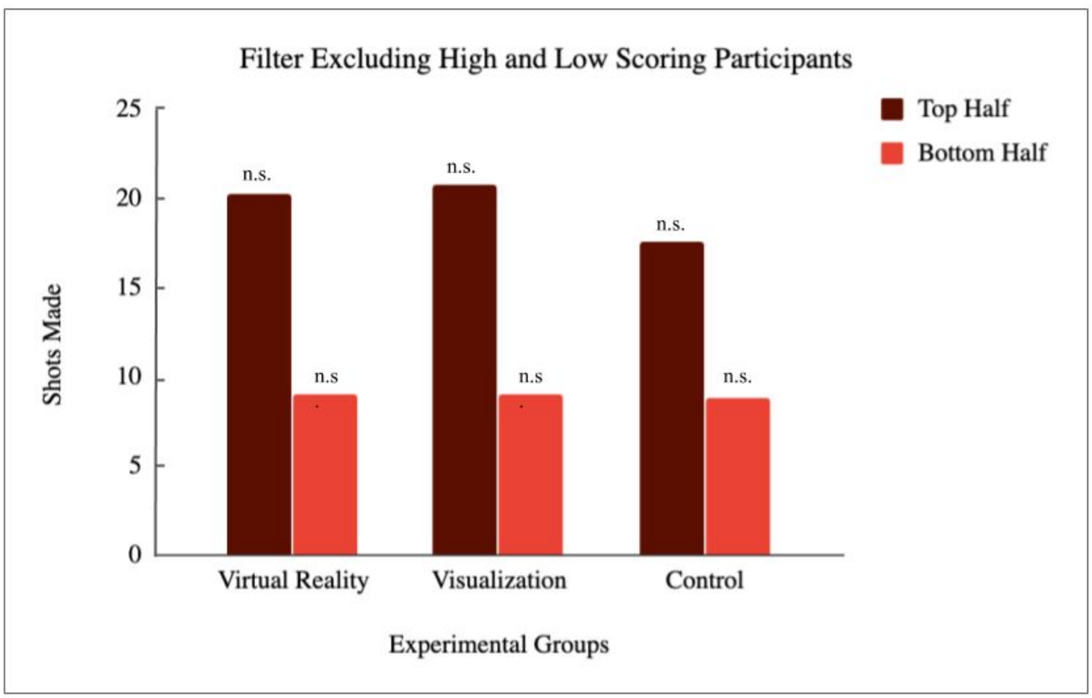

Figure. 5 This figure depicts the total mean number of shots made by each of the groups with a filter to exclude participants with more than 14 shots and another filter to exclude participants with less than 14

shots. None of the groups were significantly different. Error bars show standard error, * indicates $p<.05$, ** indicates $p<.01$ and n.s., stands for "not significant".

Effects of Outliers on the Data

Another filter was placed to exclude outliers with less than 6 shots total made and more than 27 shots total made in order to have a more concise idea of the data. ($n = 31$). A one-way between subjects ANOVA was conducted to compare the effect of the experimental group (excluding participants with total shots less than 6 and more than 27) on total shots made in the Virtual Reality, Visualization and Control conditions. There was not a significant effect of the experimental group on total shots made at the $p<.05$ level for the three conditions, $F(2, 28) = 0.569$, $p = 0.558$. Taken together, these results suggest that even excluding the outliers does not have an effect on total shots made between groups (see figure 6).

An independent-samples t-test was conducted to compare experimental groups (excluding outliers) for total shots made in Virtual Reality and Visualization conditions. There was not a significant difference in the scores for Virtual Reality (M= 13.54, SD= 6.213) and Visualization (M= 16.11, SD= 5.349) conditions; $t\ (20)= -1.009$, $p = 0.325$. These results suggest that when excluding the outliers virtual reality does not have an effect on total shots made between Virtual Reality and Visualization groups.

An independent-samples t-test was conducted to compare experimental groups (excluding outliers) for total shots made in Visualization and Control conditions. There was not a significant difference in the scores for Visualization (M= 16.11, SD= 5.349) and Control (M= 13.33, SD= 6.819) conditions; $t\ (16)= 0.962$, $p = 0.351$. These results suggest that when excluding the outliers visualization does not have an effect on total shots made between Visualization and Control groups.

An independent-samples t-test was conducted to compare experimental groups (excluding outliers) for total shots made in Virtual Reality and Control conditions. There was not a significant difference in the scores for Virtual Reality (*M*= 13.54, *SD*= 6.213) and Control (*M*= 13.33, *SD*= 6.819) conditions; t (20)= 0.073, p = 0.942. These results suggest that when excluding the outliers virtual reality does not have an effect on total shots made between Virtual Reality and Control groups.

Removing the outliers did not report any differences between the groups.

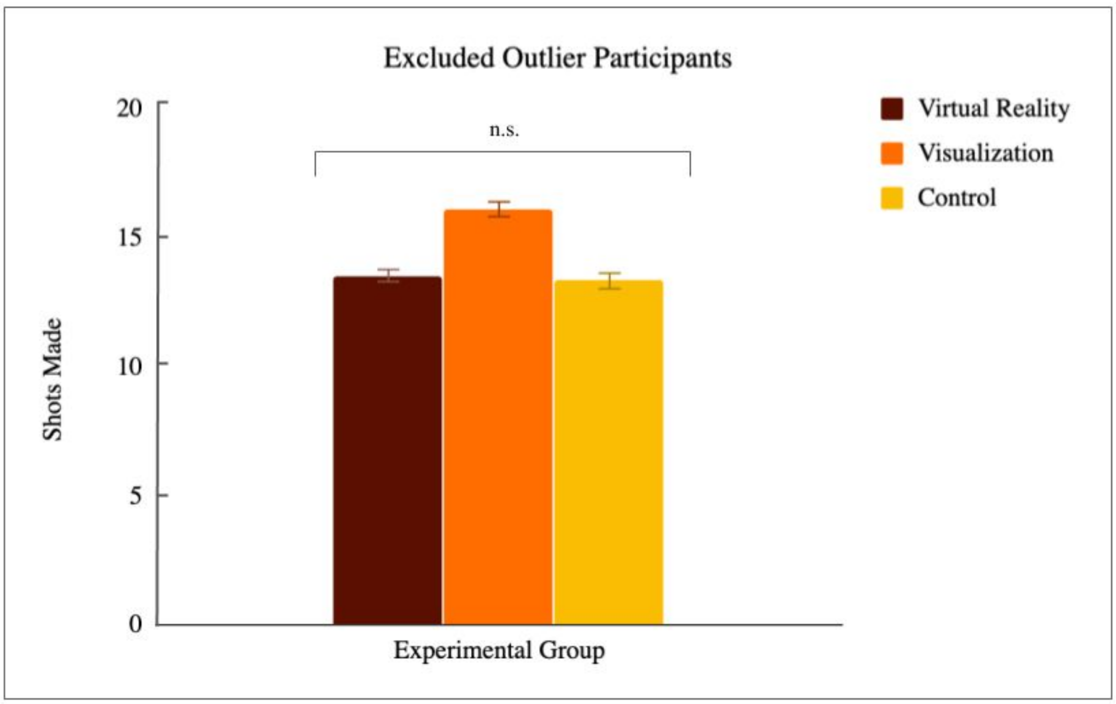

Figure. 6 This figure depicts the exclusion of participants with less than six shots total made and more than 27 shots total made. The Visualization group had the highest mean of scored shots, but it was not significantly more than the Virtual Reality or the Control groups. Error bars show standard error, * indicates p<.05, ** indicates p<.01 and n.s., stands for “not significant”.

Discussion

The purpose of this study was to test if virtual reality could improve motor performance in sports when compared to visualization. Due to its immersive abilities (Schwan, 2004), and because we learn from watching others (Hodges & Coppola, 2015), I hypothesized that virtual reality would be more beneficial in increasing motor performance, as measured by basketball free throws, than visualization. However, the data did not support this hypothesis. In fact, on average, the Visualization group scored more shots than the Virtual Reality group and the Control group. However, the Virtual Reality group did outperform the Control group on total shots made. This trend does support that virtual reality does have the capacity to improve motor performance in sports.

Even though the Difference Percentages between the Practice Round and Round 1 were not significant, virtual reality does seem to have a higher difference on average, which means that Round 1, after watching the virtual reality video, showed better performance than the Practice Round. This is an interesting finding because it supports the idea that virtual reality does have the ability to increase motor performance more so than visualization. This effect did not continue between groups from Round 1 to Round 2. There were no noticeable differences between groups.

I ran an ANOVA to test for an effect of athletic experience but there were no significant differences between groups. There was also no correlation between athletic experience and total shots made. These results seem to suggest that anyone, no matter experience, can on average improve their motor skill using virtual reality and visualization. However, in my study, I found that the Control group, which had the least average of athletic experience by chance, did worse and the Virtual Reality group which had the largest average of athletic experience by chance, did better. We could infer that athletic experience, rather than no experience, has an impact on a participant's ability to perform. Previous research has shown that athletes are attuned to kinematic information by virtue of their sport experience (Weast, Shockley, & Riley, 2011), thus potentially affecting the data. Further research should test this effect specific to virtual reality, in other words, how athletes versus non-athletes perform after using virtual reality.

Another area that this study tested was the confidence ratings of each group. I predicted that participants would feel more confident after using virtual reality. The data supports mixed findings on this. The questions 'confidence performance' and 'changed performance' did not have any significant differences. Visualization was more significantly different than the Control group in 'aided performance', meaning participants felt visualization aided their performance. Visualization was also more significantly different than the Virtual Reality and Control groups in 'use again', meaning they chose that they would use visualization again. However, participants did rate virtual reality as more useful than visualization and significantly more useful than doing nothing.

From these results, we can infer that virtual reality may not make participants feel more confident than visualization but it is more effective than doing nothing. Virtual reality was also rated as most useful on average amongst the participants. Even though my hypothesis was not directly supported, virtual reality may have the capacity to increase confidence, as previous research has shown that mental imagery can have a positive impact on confidence (Levy, 2011).

Other analyses were done to see what the effect of excluding certain participants would do. One of these was to exclude the top half of the scores and another the bottom half of the scores. Nothing significant was found after using both of these filters. A different filter was then placed to exclude the outliers of the dataset. Still, there were no significant differences found.

These results may not seem relevant to the original hypothesis in totality, however, it still supports that virtual reality can improve the motor performance of athletes as opposed to doing nothing. Using virtual reality as a method to train can still be beneficial for athletes and coaches. With little research supporting the use of virtual reality in sports, this study is one step forward into the inspection of virtual reality.

Study Limitations

Improvements in data collection could have made a difference in data significance. For instance, taking into account the order of shots made compared to those missed, could have led to different results. More specifically, if participants in the Virtual Reality group made most of their first shots, and participants in the Visualization group missed most of their first shots, we could infer that virtual reality has a stronger initial effect. Also, recording the shots as made, hit rim but went in, hit backboard but went in, hit rim and missed, hit backboard and missed, and airballed could have also led to more specific results.

General limitations include not being able to use a more immersive virtual reality experience due to expense. A previous study showed that participants learned physical tasks such as tai chi better in a 3D virtual environment rather than a 2D video system. The difference between the two experiences was that the teacher was either flat like a screen or made to be 3 dimensional with polarized glasses and lighting to make it seem to the participants that the teacher was an active figure (Patel, Bailenson, Hack-Jung, Diankov, & Bajcsy, 2006). This supports that more immersive, multidimensional experiences provide better learning opportunities for participants.

Obscuring variables. A major limitation could have been various obscuring variables, which were overlooked and not considered in the data collection or analysis.

Gymnasium and Surrounding Environment. One of these obscuring variables could include the environment of the gymnasium at the time of data collection. Most of the data collected from participants occurred when no one was in the gymnasium, however, there were few times, uncontrollable to the experimenter, where the gym was occupied at the time of data collection. Not having a private facility for data collection, could have led to participants being distracted while shooting or being nervous performing in front of others. Having a private session could help eliminate any obstructing variable like these so participants could perform adequately.

Differences Between Reality and Video. The gymnasium in the virtual reality video and the gymnasium used at Bard were very different. This could have affected the way participants were visualizing and learning to shoot. The video was also not representative of a person's technique of shooting. If the researcher had filmed the participant shooting, then had the participant use the footage to watch themselves back, there might have been differences in the results. Moreover, future research could consider using a third-person point of view in order to counteract the first person point of view to see if that had an effect.

Basketball Experience. Past practice or lack of practice could have also skewed the results. Some participants had many years of basketball experience and some had none. That difference could have been distributed unevenly between groups, although when the data was filtered for outliers, no differences were found. The number of participants could have also affected the data. A number of 45 participants were predicted to take part in the study, however, due to the unexpected COVID-19 pandemic, data collection was not able to be completed leaving the groups with an uneven number of participants: 15 in the Virtual Reality group and 11 in the other two.

Future Implications

Previous research has shown that visualization can help athletes train without physical limitations and improve performance (Ricther, 2012), and this current study also supports that using visualization as a technique to train athletes is effective and improves motor performance. This means that visualization can be an extremely effective tool to train athletes. Moreover, this study shows that virtual reality may have a promising future within many other fields. While non-significant, the current study supports that using virtual reality shows some improvements in motor performance. Future research can take the finding from this study as a baseline to expand on the use of virtual reality in motor performance.

Since using virtual reality shows some improvements in motor-performance, there are various ways in which it could be used in sports. These include developing programs for athletes and coaches in order to improve their athletic skills beyond physical limitations. Other advantages of using virtual reality in sports include being able to apply this method when players are injured and cannot play. Virtual reality may aid in keeping an athlete's mind sharp so that when they are ready to return to play they are just as good, if not better, than they were before in their skill and decision-making (Ridderinkhof, 2015). Virtual reality may also be beneficial because one can use it on their own time, at home, in the gym or field. More interactive virtual reality can also help increase high cognitive skills such as decision-making and tactical understanding. With this method one can interact with plays over and over again, so that one can make the best decisions out on the field (Science-based cognitive assessment & training, 2019).

With more studies like the current one, virtual reality could become a beacon for improving training and learning in multidimensional environments in sports as well as other areas in science, medicine, and engineering.

With further research, virtual reality can be expanded upon so that we can learn all the possible uses and contributions within sports and other areas of interest. For example, in a previous study, researchers tested the effects of virtual reality tools, like spatial visualization skills, in perceiving the buckling of a structural component like a column. Participants recorded having a better understanding of this concept after using virtual reality to view this motion (Fogarty, McCormick, & El-Tawil, 2018). This study supports how beneficial virtual reality can be in the realm of engineering. It also supports the idea that using virtual reality to view and improve a topic can be used, like in the current study of free-throws.

Conclusion

Although, in the present study, no significant data was found supporting an improvement of free-throws made, the Virtual Reality group did outperform the Control group in shots made. This supports the idea that virtual reality may improve motor performance, which would need to be further assessed in future studies. This study also supports the use of visualization as a method of training. The implications of this study supports the interest of developing programs as a part of training regimes for virtual reality.

References

Anshel, M. H. (2003). Sport psychology: From theory to practice. B. Cummings.

Bakker, F. C., Boschker, M. S., & Chung, T. (1998). Changes in muscular activity while imagining weight lifting using stimulus or response propositions. *Journal of Sport and Exercise Psychology*, *20*(3), 313-324.

Bideau, B., Multon, F., Kulpa, R., Fradet, L., & Arnaldi, B. (2004, June). Virtual reality applied to sports: do handball goalkeepers react realistically to simulated synthetic opponents?. In *Proceedings of the 2004 ACM SIGGRAPH international conference on Virtual Reality continuum and its applications in industry* (pp. 210-216). ACM.

Covaci, A., Postelnicu, C. C., Panfir, A. N., & Talaba, D. (2012, February). A virtual reality simulator for basketball free-throw skills development. In *Doctoral Conference on Computing, Electrical and Industrial Systems* (pp. 105-112). Springer, Berlin, Heidelberg.

Decety, J., & Michel, F. (1989). Comparative analysis of actual and mental movement times in two graphic tasks. *Brain and cognition*, *11*(1), 87-97.

Fadde, P. J. (2006). Interactive video training of perceptual decision-making in the sport of baseball. Technology, Instruction, Cognition and Learning, 4(3), 265-285.

Féry, Y. A., & Morizot, P. (2000). Kinesthetic and visual image in modeling closed motor skills: The example of the tennis serve. *Perceptual and motor Skills*, *90*(3), 707-722.

Fogarty, J., McCormick, J., & El-Tawil, S. (2018). Improving student understanding of complex spatial arrangements with virtual reality. Journal of Professional Issues in Engineering Education and Practice, 144(2), 04017013.

George, T. R. (1994). Self-confidence and baseball performance: A causal examination of self-efficacy theory. Journal of sport and exercise psychology, 16(4), 381-399.

Hodges, N.J., & Coppola, T. What we think we learn from watching others: the moderating role of ability on perceptions of learning from observation. Psychological Research 79, 609–620 (2015).

Jeannerod, M. (1994). The representing brain: Neural correlates of motor intention and imagery. *Behavioral and Brain Sciences*, *17*(2), 187-202.

Levy, A. R., Nicholls, A. R., & Polman, R. C. J. (2011). Pre‐competitive confidence, coping, and subjective performance in sport. Scandinavian Journal of Medicine & Science in Sports, 21(5), 721-729.

Mullineaux, D. R., & Uhl, T. L. (2010). Coordination-variability and kinematics of misses versus swishes of basketball free throws. *Journal of Sports Sciences*, *28*(9), 1017-1024.

Patel, K., Bailenson, J. N., Hack-Jung, S., Diankov, R., & Bajcsy, R. (2006, August). The effects of fully immersive virtual reality on the learning of physical tasks. In Proceedings of the 9th Annual International Workshop on Presence, Ohio, USA (pp. 87-94).

Reilly, B., Johansson, M., Huang, Y., & Churches, L. (2016). U.S. Patent Application No. 14/694,770.

Richter, J., Gilbert, J. N., & Baldis, M. (2012). Maximizing strength training performance using mental imagery. *Strength & Conditioning Journal*, *34*(5), 65-69.

Ridderinkhof, K. Richard, and Marcel Brass. "How kinesthetic motor imagery works: a predictive-processing theory of visualization in sports and motor expertise." *Journal of Physiology-Paris* 109.1-3 (2015): 53-63.

Schwan, S., & Riempp, R. (2004). The cognitive benefits of interactive videos: learning to tie nautical knots. Learning and instruction, 14(3), 293-305.

Science-based cognitive assessment & training (2019).

Stanković, D., Raković, A., Joksimović, A., Petković, E., & Joksimović, D. (2011). Mental Imagery and Visualization in Sport Climbing Training. Activities in Physical Education & Sport, 1(1).

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. Journal of communication, 42(4), 73-93.

Weast, J. A., Shockley, K., & Riley, M. A. (2011). The influence of athletic experience and kinematic information on skill-relevant affordance perception. The Quarterly Journal of Experimental Psychology, 64(4), 689-706.

Appendix A

Consent Form

Principal Investigator

Alina Augustin

Psychology Program

Bard College

Project Title

The effects of Virtual Reality in the 1st person point of view on motor performance

Introduction

You are being asked to be a volunteer in a research study in the Psychology Program at Bard College. Please read the following information carefully and feel free to ask questions if any of the information is unclear.

Purpose

The purpose of this research study is to better understand if certain visual aids enhance motor performance of athletic skills.

Study Procedure

If you decide to participate, you will be asked to complete a questionnaire that provides us with basic demographic information including your age and gender. You will then be asked to complete a round of 5 practice shots followed by 2 rounds of 20 shots from the free-throw line. In between these rounds you will be asked to view a virtual reality video or complete a visualization task or count down from 100 and 200. Finally, you will be asked to complete a survey assessing the extent to which you thought each method enhanced your performance. The total duration of the experiment will be no longer than thirty minutes and you are free to withdraw from the study at any time.

Risks and Discomforts

There is minimal potential risk and discomfort from participating in this study.

Benefits

You are not likely to benefit directly from participating in this study. However, what we learn from this experiment will inform how visual aids can benefit athletes.

Compensation

If you are enrolled in a psychology course you will be compensated through a chance to win a $25 gift card to Amazon. If you decide to withdraw from the study at any time, you will still be enrolled in the chance to win $25..

Exclusion/Inclusion Criteria

Participants must be over 18.

Confidentiality

Several procedures will be followed to keep your personal information confidential. Your records will be kept under a code number rather than by name. This consent form is the only form associated with this research study that contains your name. At the completion of your participation, the data associated with your performance and the questionnaire responses will be separated from this consent form. After doing so, it will be very difficult to link your name to any of the data that you provide. Only I will be able to see your records and will keep them encoded without your name in an excel sheet that only I have access to. Once data has been logged your questionnaire will be kept in a folder locked in a room until the experiment is finished. After the completion of the study, your questionnaire will be shredded in order to keep your info confidential. Your name will not appear when the results of this study are presented or published. Your privacy will be protected to the extent provided by law. To ensure that this research is carried out in the proper way, the Bard College IRB may review study records.

In Case of Injury/Harm

If you are injured as a result of being in this study please contact the Principal Investigator, Alina Augustin, at aa8235@bard.edu or 845-234-8857.

Participant Rights

Your participation in this study is voluntary. Neither refusal to participate nor participation discontinued at any time will invoke penalty or loss of benefits to which the subject is otherwise entitled.

Questions about your Rights as a Research Participant

If you have any questions about your rights as a research participant, you may contact the chair of the Bard College IRB, Laura Kunreuther, at irb@bard.edu.

Questions about the Study

If you have any questions, you may contact Alina Augustin at aa8235@bard.edu or 845-234-8857

If you sign this form it means that you have read (or have had read to you) the information given in this consent form, and would like to be a volunteer in this research study.

____

Participant Name (printed)

____ _______________

Participant Signature Date

____ _______________

Signature of Person Obtaining Consent Date

Appendix B

Pre-questionnaire Participant #

Name :

Age :

Gender :

Current Grade Level :

Ethnicity (circle one): White Black or African American Hispanic Asian

Native Hawaiian or Pacific Islander American Indian or Alaskan Native Other

Home state :

Athletic Experience :
(number of years playing at a competitive level ex: playing on a team sport)

Basketball Experience :
(number of years playing Basketball competitively on a team)

Appendix C

Post-questionnaire

On a scale of 1-10, how well do you think you performed?

1 2 3 4 5 6 7 8 9 10

Poorly Mediocre Excellent

On a scale of 1-10, do you think visualization/VR/nothing changed your performance?

1 2 3 4 5 6 7 8 9 10
Not at all Indifferent Drastically changed

On a scale of 1-10, how well do you think visualization/VR/nothing aided your performance?

1 2 3 4 5 6 7 8 9 10
Made it worse Neutral Made it better

On a scale of 1-10, how useful is visualization/VR/nothing as a method of learning?

1 2 3 4 5 6 7 8 9 10

Useful Neutral Not helpful

On a scale of 1-10, how likely are you to use visualization/VR/nothing again?

1 2 3 4 5 6 7 8 9 10

Likely Neutral Not likely

Appendix D

Debriefing

Thank you for your participation in this study! The purpose of this study was to assess how. virtual reality compared to visualization affects motor performance. We hypothesize that VR will have a greater effect than visualization on the ability to shoot a free throw. If successful, this experiment will provide additional research on the benefits of VR.

If you have any questions or concerns, please contact Alina Augustin (aa8235@bard.edu).

Appendix E

Xtreme Cables Virtual Reality Set

Appendix F

Promotional Flyer

Appendix G

IRB Submission Fall 2019

I have read the IRB's Categories of Review, and my proposal qualifies for a
Expedited review

Do you have external funding for this research?
No.

When do you plan to begin collecting data for this project? (begin date):
12/01/2019

When do you plan to end your data collection for this project? (end date):
5/01/20

Title
The effects of Virtual reality in the 1st person point of view on motor performance.

Research Question (250 words or less):

In my study I will be testing to see if virtual reality will improve motor performance of an athletic skill. Previous work has shown that visualizing performing an athletic skill improves performance. I am extending to VR because I think will be helpful to athletes and coaches that want to continue to train the mind without physical exertion. I plan to use my senior project to explore this topic and to further discussion to how visual stimulation is an important factor in improving cognition and motor performance. I hypothesize that VR will significantly improve motor performance as opposed to the visualization group and the control group. Specifically, they will make more basketball free throws out of 40 when compared to the visualization group and the control group.

Will your participants include individuals from specific populations (e.g., children, pregnant women, prisoners, or the cognitively impaired)?

No.

How will Participants be recruited?
Participants will be recruited from the Bard College undergraduate population. I will recruit students on Bard College campus using flyers posted around the school with information on how they can sign up (Appendix E). Interested students will be asked to email the primary investigator to set up a 30minute appointment at the gym. All information provided by the participants will be confidential. Participants will be entered to win a raffle for a $25 gift card.

Briefly describe the procedures you will be using to conduct your research. Include descriptions of what tasks your participants will be asked to do, and about how much time

will be expected of each individual. NOTE: If you have supporting materials (recruitment posters, printed surveys, etc.) please email these documents separately as attachments to IRB@bard.edu. Name your attachments with your last name and a brief description (e.g., "WatsonConsentForm.doc").

I will start to run participants throughout December, until february using the Stevenson Athletic Center. I will block off half of the gym so that we will have a side to our own use. Ideally I will have participants come when there is no one in the gym during the mornings or after hours. The time spent with participants will run approximately 20-30 minutes. I will send them specific times via email when the participants can meet me in the gym.

Once they come, I will explain the contents of what we will be doing, have them read and sign a consent form (see appendix A), and then they will complete a survey asking their age, name, athletic experience, basketball experience, other demographics etc (see appendix B). At this point they would have already been randomly assigned to a group. All groups will have 5 practice shots and then perform in two rounds of shooting from the free throw line, which is about 15ft from the base of the basket. The first round will consist of 1 minute stimulus then 20 shots. The second round will begin with now 3 minutes of stimulation and then 20 shots.

Participants in the control group will proceed to shoot 20 free throws after 1 minute of counting down from 100. Then the will count down from 200 for 3mins and then shoot 20 free throws. They will be instructed to either sit or remain standing while trying not to make any grand gestures.

Participants in the visualization group will be instructed to imagine themselves shooting a scoring basket in the first person point of view for 1 minute then they will shoot 20 free throws. After that they will again imagine themselves shooting a free throw in the 1st person POV and shoot 20 free throws. They will be instructed to either sit or remain standing while trying not to make any grand gestures.

Participants in the VR group will watch 1 min of a person shooting a scoring basket for 1 minute with the VR goggles and then shoot 20 free throws. After completing that they will again watch 3 minutes of the same video and then shoot 20 free throws. Participants will wear VR goggles that wrap around their heads. The goggles cover their eyes so that they will see only the video that the phone projects. The goggles weigh 3 ounces. Again, they will be instructed to either sit or remain standing while trying not to make any grand gestures.

After each participant is done in all groups they will fill out a survey of how well they feel like they improved after using each technique (See appendix C) . I will then give each participant a debriefing of the study (See appendix D). Then they will be added into the $25 gift card giveaway.

Approximately how many individuals do you expect to participate in your study?

60

Please describe any risks and benefits your research may have for your participants. (For example, one study's risks might include minor emotional discomfort and eye strain. The same study's benefits might include satisfaction from contributing to scientific knowledge and greater self-awareness.)

There is minimal potential risk and discomfort from participating in this study. participants will be asked to take 45 free throws over the course of 20-30 minutes.

Have you prepared a consent form and emailed it as an attachment to IRB@bard.edu? Please note: you must submit all necessary consent forms before your proposal is considered complete.
Yes.

Verbal description of consent process

Before the study begins, all participants will be asked to read and sign a consent form, which will provide them with a brief overview of the study, the potential risks, and compensation procedures. Participants will be reminded that they are able to end the experiment at any time. The experiment will begin once a participant has signed the consent form.

Procedures to ensure confidentiality

The following procedures will be followed to keep personal information confidential: The records will be kept under a code number rather than by name. Only the primary investigator will be able to see the records and will keep them encoded without their names in an excel sheet that only I have access to. Once data has been logged the questionnaires will be kept in a folder locked in a room until the experiment is finished. After the completion of the study the questionnaires will be shredded in order to keep the information confidential. Participants names will not appear when the results of this study are presented or published. Their privacy will be protected to the extent provided by law.

Will it be necessary to use deception with your participants at any time during this research? Please note: withholding details about the specifics of one's hypothesis does not constitute deception. However, misleading participants about the nature of the research question or about the nature of the task they will be completing does constitute deception.
No.

Debriefing Statement

Thank you for your participation in this study! The purpose of this study was to assess how. virtual reality compared to visualization effects motor performance. We hypothesize that VR will have a greater effect than visualization on the ability to shoot a free throw. If successful, this experiment will provide additional research on the benefits of VR.

If you have any questions or concerns, please contact Alina Augustin (aa8235@bard.edu).

IRB Approval

Date: November 14, 2019
To: Alina Augustin
Cc: Tom Hutcheon, Deborah Treadway
From: Laura Kunreuther, IRB Chair

Re: The Effects of VR in the first person point of view on motor performance

DECISION: APPROVED

Dear Alina,

The Bard Institutional Review Board reviewed your proposal under expedited category 7,

(i) Research activities that present no more than minimal risk to human subjects, and

(ii) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your proposal is approved, contingent on the very minor changes listed below, through November 15, 2020. Your case number is 2019NOV15AUG.

- The timing seems a bit short. Please change the consent form to say 45 - 60 minutes for the whole process (from the time you walk in until you leave).
- You might consider making the survey completely anonymous by having each participant assigned a number rather than being identified by name.

Please submit your minimal changes and notify the IRB if your methodology changes or unexpected events arise.

We wish you the best of luck with your research.

Laura Kunreuther
IRB Chair

Appendix H

Human Subjects Certificate

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **Alina Augustin** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 03/05/2018.

Certification Number: 2672260.