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Abstract

The purpose of this study was to investigate quality of movement in a material based (MB), virtual reality based (VRB), and imagery based (IB) darts. Hypotheses were the MB condition would elicit better motor performances than the other conditions and the VRB condition would elicit better motor performances than the IB condition, but still inferior to the MB condition. Results indicated similarities between the MB and IB condition, suggesting participants utilized preconceived concepts of throwing real darts during these two conditions. The VRB condition is believed to be a different motor performance that focuses less on perceptions of throwing darts and focuses more on achieving successes within the virtual environment. Implications for occupational therapy would be utilizing MB occupations to enhance development of a skill. VRB occupations can be utilized should the patient find meaning and purpose in VRB occupations or if the patient cannot engage in a MB counterpart.

Reality, Virtual Reality, and Imagery: Quality of Movement in Novice Dart Players

A central concept in occupational therapy has been the inclusion of meaningful and purposeful occupations to elicit improved therapeutic performance. This concept has been a central theme since the founding of the profession (Meyer, 1922). While this concept has remained stable throughout the profession's history, the tools and specific occupational forms have evolved as a reflection of cultural, technological, and societal developments. This study intends to examine a less than a century-old occupation in its traditional form and in its neo-modern electronic form; namely, darts. Additionally, this study will compare these performances with an imagery nonmaterial based condition.

Though many studies have compared material based occupations to imagery based, little information can be found in regards to studies comparing virtual reality based occupations to material and imagery based occupations. Results from studies comparing material based occupations, imagery based occupations, and rote exercises have shown that material based occupations will elicit a better performance than imagery based occupations and rote exercise (DeKuiper, Nelson, & White, 1993; Hsieh, Nelson, Smith, & Peterson, 1996; Lang, Nelson, & Bush, 1992; Ross & Nelson, 2000). However, this present study will investigate how a virtual reality based occupation, through the use of a motion tracking video game, compares to similar material based and imagery based occupations in terms of motor control and performance.

Nelson (1996) defines meaning as "the person's entire interpretive process when encountering an occupational form, including perceptual, symbolic, and affective experiences" (p. 101). In addition, Nelson (1996) goes on to define purpose as "the experience of wanting an outcome from an anticipated occupational performance" (p. 106). To produce improved motor performance and therefore provide a more effective treatment for the client, occupational therapists should present their client with occupations in which the client can find the greatest amount of meaning and purpose. In order to achieve this amount of meaning and purpose, materials that are familiar, or occupationally embedded, within everyday life are utilized in these occupations.

Several studies have shown that increasing the amount of meaning and purpose of a given occupation will improve measures of motor performance when compared to rote exercises or non-occupationally embedded conditions (Hsieh et al., 1996; Rice, Alaimo, & Cook, 1999; Rice, Davies, & Maitra, 2009; Wu, Trombly, & Lin, 1994). These studies vary in their occupational forms, which is defined by Nelson (1996) as "the composition of physical and sociocultural circumstances external to the person that influences his or her occupational performance", and they vary in their dependent measures for occupational performance vary as well. However, the commonality among these studies is that they investigate how an occupational form with more meaning and purpose than a rote exercise or non-occupationally embedded condition will elicit better motor performance.

Hsieh et al. (1996) studied a comparison between added-purpose occupations and a non-added purpose occupation, or rote exercise, in those with hemiplegia. The added-purpose conditions consisted of a materials based occupation and an imagery based occupation. In the materials based occupation, participants would bend down, pick up a ball, stand up, and then throw the ball at a target. For the imagery based occupation, the participants would perform similar motions from the material based occupation by imagining that he or she was picking up a ball from the floor, stand up, and then throw the imagined ball at the target that was still able to be seen. Finally, the rote exercise condition consisted of the participants bending down to touch the floor, standing up, flexing their elbow, and then extending the elbow quickly. The results of this study found that participants performed significantly more repetitions, and therefore stood for longer periods, in the added-purpose conditions when compared to the non-added purpose condition. Additionally, the number of repetitions between the two added-purpose conditions was not found to be statistically different.

Rice et al. (1999) investigated the effects of three varying levels of occupational embeddedness on movements during a reaching and placing task in healthy females. The three levels of occupational embeddedness were described as follows: The occupationally embedded (OE) condition involved reaching for and placing a labeled soup can, the limited occupationally embedded (LOE) condition involved reaching for and placing a soup can without its label, and the non-occupationally embedded (NOE) condition involved reaching for a placing a clay mass that was of comparable size and shape to the soup cans. The results of this study found statistically significant differences between the LOE and NOE conditions in terms of angular displacement. In addition, there was a significant difference between the OE and NOE conditions in terms of movement units, such that the OE condition elicited fewer movement units.

Another study by Rice et al. (2009) investigated the effects of immediate versus prolonged exposure for objects of varying occupational embeddedness during a reaching and placing task in healthy male and females. The conditions consisted of two groups, in which one would open an opaque door to find the object, which was the immediate exposure condition, and the other group would open a transparent door to find the object, which was the prolonged exposure condition. Once a participant was assigned to a group, the order in which he or she was presented the objects they were to reach for and place was randomized. The objects were a metal cup, which epitomized the occupationally embedded condition, and a clay mass, which represented the non-occupationally embedded condition. The results of this study found that, during the reaching phase of the task, prolonged exposure to the object elicited shorter movement times and fewer movement units. During the reach phase, there was also a significant interaction between the exposure time and object for percentage of movement time to peak velocity and for an average velocity. Additionally, during the transport phase of the task, there significantly fewer movement units in the conditions that involved the cup.

Furthermore, several studies have compared material based occupations, imagery based occupations, and rote exercise in terms of various motor performance measures (DeKuiper et al., 1993; Lang et al., 1992; Riccio, Nelson, & Bush, 1990; Ross & Nelson, 2000; Wichman & Lizotte, 1983; Wu et al., 1994). Material based occupations require the utilization of physical objects in order to perform an occupation. However, imagery based occupations do not require much in terms of the physical manipulation of objects, but involve the imagined manipulation of an object while still performing the motions required to perform the occupation. Finally, rote exercise strictly focuses on patterns of movement.

Riccio, Nelson, and Bush (1990) compared an imagery based occupation to rote exercise in terms of the number of repetitions performed by elderly women living in nursing homes, retirement homes, and foster care homes. Participants were randomized into two groups with a counterbalanced design. One group would receive the rote exercise condition first and the imagery condition second, while the second group would receive the imagery condition first and the rote condition second. For the rote exercise condition, the participants were asked to reach up with her arms as high as she could in an alternating fashion, being that as she brought one arm down to her lap, she would reach up with the other arm. A second part of the rote exercise condition had participants reaching down with both hands to the floor and then bringing both hands up to touch their lap. For the imagery based condition, participants were first asked to reach up with her arms in an alternating fashion as if she were picking apples. The second part of the imagery based condition had participants reach down with both hands and bring her hands back to touch her lap as if she were picking up coins. For both conditions, participants were told to complete as many repetitions until she was too tired to continue. The results of the study found statistically significant more repetitions for the imagery based condition during the reaching up part. The reaching down part of the two conditions was not found to be statistically different with a p=0.055 due to significant differences among participants. However, the result for the reaching down part favors the imagery based condition.

Wu, Trombly, and Lin (1994) investigated a comparison between a materials based occupation, an imagery based occupation, and a rote exercise in terms of reaction time, movement time, movement units, and total displacement in 38 healthy female students. In the materials based condition, participants would reach for and pick up a pencil from a pencil holder that was at a distance and height that was held constant for all participants and then prepare to write his or her name. For the imagery based condition, participants would pretend to reach for a pencil that would have been equal to the distance and heights of the material based condition, and then pretend to prepare to write his or her name. Finally, in the rote exercise condition, participants would reach forward to a point indicated by the experimenter to be of equal height and distance to the other two conditions and was detected by a photoelectric switch. The results of this study supported the idea that materials based occupation elicits better quality of movement and performance than imagery based occupation and rote exercise in that movement time, the number of movement units, and total displacement was less in the material based condition.

A study by Lang, Nelson, and Bush (1992) investigated a comparison between materials based occupation, imagery based occupation, and rote exercise in terms of number of repetitions performed by nursing home residents. The 15 participants were randomly assigned to three counterbalanced groups. The order of presentation for the conditions for each group was then randomized. The materials based condition consisted of the participant being thrown a balloon and then having the participant kick it with one foot as many times as he or she could until they were too tired to continue. The imagery based condition involved the experimenter telling the participants to imagine that a big red balloon was coming toward them and they were to kick it with the same foot as many times as he or she could until they were too tired to continue. The rote exercise condition consisted of the participants being shown a demonstration of a kicking motion and then being asked to perform that kicking motion with the same foot as many times as he or she could until they were too tired to continue. The results of this study supported that a materials based occupation elicited significantly more repetitions than the imagery based and rote exercise conditions. However, there was no statistically significant difference in the amount of repetitions between the imagery based and rote exercise conditions.

DeKupier, Nelson, and White (1993) replicated and extended the previous study by Lang, Nelson, and Bush (1992). Twenty-eight nursing home and retirement home residents were participants in this study comparing a materials based occupation, imagery based occupation, and rote exercise in terms of the speed of the kicks and the vertical distance kicked in addition to the number of repetitions. The conditions were similar to the Lang study in that they involved kicking a balloon, pretending to kick a balloon, and performing a kicking motion. The results of the study were similar to those found in the Lang study as well, as the material based condition elicited more repetitions than the imagery based and rote exercise conditions. Similarly, the number of repetitions did not result in being significantly different between the imagery based and the rote exercise conditions.

Finally, a study by Ross and Nelson (2000) replicated the Wu, Trombly, & Lin (1994) study. This study investigated a comparison between a materials based occupation, an imagery based occupation, and rote movement during a reaching task in terms of reaction time, movement time, the amount of movement units, total displacement, peak velocity, percentage of reach at which peak velocity occurred, and end velocity in 60 healthy female nursing and physical therapy students. The procedure for this study was similar to the Wu et al. (1994) study. In addition, the results of this study were similar to the previous studies as well, as the material based condition elicited a shorter reaction time, shorter movement time, fewer movement units, less displacement, and lower peak velocity during movement than the imagery based condition and the rote exercise condition. There were also no significant differences between the imagery based and rote exercise conditions.

The above mentioned studies provide strong evidence for one of the most central concepts in occupational therapy; namely, that the inclusion of meaningful and purposeful occupations with the addition of meaningful and purposeful materials will elicit improved motor and overall occupational performance. However, little investigation has been done regarding the increasingly popular occupational forms of video games and virtual reality. This present study will investigate whether a virtual reality based video game elicits enhanced performance comparable to material based and imagery based versions of the occupation.

Recently, the culture of virtual reality and video games has become increasingly more prominent in technologically advanced countries. The industry of video games has become a multi-billion dollar industry in recent years, reporting $10.5 billion in revenue in 2009 ("Video

Game Industry Statistics," 2010). In addition, 67% of U.S. households play some type of video game and the average gamer spends eight hours a week playing video games. One can then see that video games have become a substantial component for entertainment in modern, industrialized societies. In addition, it is common to hear about nursing homes and other therapy settings utilizing video games as a form of therapy. A substantial amount of evidence has been developed to support the use of video games in the rehabilitation therapies. Several studies have shown that varying types of populations of all ages and including all sorts of physical, cognitive, and perceptual disabilities have received substantial benefits from the use of video games in therapy (Funk, Germann, & Buchman, 1997; King, 1993; Krichevets, Sirotkina, Yevsevicheva, & Zeldin, 1994; Larose, Gagnon, Ferland, & Pepin, 1989). In addition, Griffths (2003) states that video games can have considerable success in therapy when they are designed to address a specific problem or teach a specific skill. The video game this study intends to examine is a dart game on Kinect Sports: Season Two through the use of the Microsoft Xbox 360 and Kinect sensor.

The history of the game of darts is one that has many mysteries and is difficult to trace back to its exact origins. However, researchers and dart historians, such as world renowned Dr. Patrick Chaplin, have been hard at work in uncovering the history of this beloved game of skill (Chaplin, 2009, 2010; Peek, 2001). Though there are many theories as to the origin of the game of darts, a common thread is the mention of a game that is said to be the predecessor to modern darts known as “puff and dart” or “puff dart”. Instead of throwing the darts, like is custom in modern darts, these darts were blown through a tube at a miniature 3-ringed archery target. Originating in the early 19th century, “puff and dart” was popular until the late 1800’s when the game was considered dangerous as accounts of people accidently inhaling the darts became public. What is typically known as the game of modern darts is traditionally thought to be of English origin; however, a predecessor to this game, known as “flechettes” or “javelots,” originated in France. Flechettes involved the use of the “French dart”, which was a large wooden dart that is thrown. This game of flechettes was then brought into Britain by showmen at fairground sideshows. However, dartboards varied drastically, as many of the showmen would fabricate their own dartboards to weigh the odds in their favor. Though there are many theories as to who invented the modern dartboard, leading historian Patrick Chaplin credits Brian Gamlin with the ingenious numbering pattern (Chaplin, 2010). The numbering system on the modern dartboard rewards skillful and accurate shots, but punishes poor accuracy with lower scores, as the some of the largest scoring sections are directly adjacent to the lowest scoring sections. This was actually proven legally in 1908 in what is known as the “Annakin Case” when a local pub owner brought in the best dart player at the pub to prove that the game of darts was a game a skill and not a game of chance. Being the latter, playing darts in pubs would have been banned. Moving forward through history, the popularity of darts continued to grow throughout England in the early 1900’s. The United States also started to show an interest in the sport as an account of the first dartboard being hung in a bar in Philadelphia was in 1900 (Peek, 2001). As history went through two world wars, accounts of U.S. soldiers playing darts overseas and bringing further interest in the game back to the States are supported theories for the growth of the sport on American soil. Recently, the game of darts in America has not kept up in popularity when compared to England and the rest of Europe. Chaplin (2010) states that when soft-tip, electronic dart games were introduced and took hold in America, the popularity of the sport dwindled, as people were required to pay to play darts in local pubs. In contrast, England strongly and proudly holds onto the roots of the traditional game which was meant to be free to play. England also shows more enthusiasm and pride in the sport by televising its many dart tournaments. However, the game of darts is an occupation in which a vast majority of people internationally can recognize and are familiar with in some sort of fashion.

The game of darts is an occupation in which almost everyone can engage in, as it does not require complex motor and cognitive functions. Because of this, the game of darts can easily be used as a treatment intervention in occupational therapy that can focus on numerous therapeutic goals. Utilizing a virtual reality based game of darts that does not require actual darts or dartboard, but relatively mimics the movements required to play darts, would be beneficial in many occupational therapy situations in which a client finds meaning and purpose in playing darts. For instance, patients with impaired grip and finger control would not have to manipulate actual darts in order to play. The purpose of this study is to examine three iterations of the game of darts. These include its traditional, materials based form, a motion tracking virtual reality video game, and an imagery based form. There are expected to be specific kinematic differences between the three conditions. These differences are hypothesized to be similar in regards to previous studies in which material based occupations elicited better motor performance than comparable imagery based and rote conditions. It is hypothesized that the material based condition in this study will produce better quality motor performances. In addition, it is hypothesized that the virtual reality based condition will elicit a better quality motor performance than the imagery condition, but be of poorer quality than the material based condition.

Methods

Participants

Thirty four participants were recruited for this study. Descriptive statistics for the participants can be seen in Table 1 in the Appendix (Table 1). All participants recruited identified themselves as Caucasian. The ages of the participants ranged from 18 to 53 years of age, and there was an average age of 26.09 years. Nineteen of the participants were female. Only two of the participants recruited were left hand dominant.

Based upon research done by Meira and Tani (2001) and using a common standard deviation of 12, an alpha of .05 and a beta of .8, we anticipate that an n=30 will provide sufficient power to achieve statistical significance. Therefore, this study intended to recruit 36 adults aged 18-55 years. Inclusion criteria included being a novice dart player, of good health, English speaking, and having little to no experience with the video game under investigation. Exclusion criteria included orthopedic injuries that would impair one's dart throwing ability. Participants were recruited from the local university campus and community centers through advertisement flyers, 'word of mouth', and through email.

Apparatus

This study utilized a 20 GB Microsoft Xbox 360, a Microsoft Xbox Kinect Sensor (Microsoft, Redmond, WA), a Sceptre 32" TV, and a Kinect Sports: Season 2 game disc (Microsoft, Redmond, WA). The dartboard used in this study was a Unicorn Pro Player bristle dartboard (Sportcraft Limited, Budd Lake, NJ). Once the dartboard was hung on the wall, rigid foam insulation boards were placed around the dartboard to protect the wall and darts. The darts used were Unicorn GT125 steel tip darts (Sportcraft Limited, Budd Lake, NJ). The shafts of these darts were replaced with Halex 20A aluminum shafts (Regent Sports Corp., Hauppauge, NY). The dartboard was hung in accordance to the rules of the World Dart Federation ("Basics of Darts," 2011), with the distance from center of the bullseye to the floor being 5' 8" and the distance between the throwing line and dartboard being 7' 9.25". To establish the throwing line, a large piece of tape was placed on the floor at the correct distance from the dartboard. The TV was mounted on the wall at a relatively similar height as the dartboard. The Kinect Sensor was placed on the top of the TV and calibrated using options within the settings of the video game. These calibrations ensured effective and appropriate motion tracking from the Kinect Sensor. The kinematics of the throws were measured using (8 Camera System). Data collection took place in the Occupational Therapy Motion Capture Laboratory at The University of Toledo.

Randomization

Participants were randomized into one of three orders of presentation groups using permutated blocks (i.e., 1 block of 9, 2 blocks of 6 and 5 blocks of 3). Randomization was done using a custom software program written using Microsoft Visual Basic 2008 Express Edition. The order of presentations were, 1) real, virtual, imagery; 2) virtual, imagery, real; and 3) imagery, real, virtual. Order of presentation assignments were written into a computer program that informed the investigator once the subject's identification number was entered into a custom built program at the data collection sight.

Dependent Variables and Data Reduction

Though a total of eleven markers were placed on each participant's body and dominant throwing arm, data for the kinematic variables were only analyzed on the marker placed on the dorsal side of the distal phalange of the index finger. The non-analyzed markers were used as references for determining the overall movement and orientation of the subjects. The kinematic variables chosen to be analyzed for this study were displacement, peak velocity (PkV), movement time (MT), percentage of MT to PkV (% MT to PkV), movement units (MU), and max aperture.

Displacement was determined to be the total distance traveled by the marker on the index finger during the entire throwing motion. Displacement was measured in centimeters.

Peak velocity was defined as the maximum speed achieved by the marker on the index finger during the throw and was measured in m/s.

Movement time was determined through analyzing the points in time during the throwing motion that the elbow changed or reversed direction. The throwing motions consisted of flexion of the elbow to a point before reversing direction. Once the elbow direction was reversed, the elbow is rapidly extended along with some shoulder flexion. At some point after the dart is released (real, virtual, or imagined) the elbow reversed direction again. It is these two elbow reversals that define the start and stop of the analyzed portion of the throwing motion. These points were identified using Visual 3-D (C-motion, Maryland) movement analysis software. Specifically, an algorithm was developed based upon the velocity profile of the index finger marker. That is, when the velocity changed from positive to negative and then from negative to positive, the start and stop of the throwing motion was identified. Movement time therefore is the time that elapsed between these two points.

Percentage of MT to PkV was calculated to be the percentage of the movement time of the throw when PkV was reached.

Movement units were defined to be the number of times the velocity profile went from negative to positive and then back to negative again.

Max aperture was defined as the largest distance obtained between the markers on the thumb and index finger during the throws and was measured in cm.

Focused contrasts were calculated to compare the differences between the real and virtual, the real and imaginary and the virtual and imaginary conditions. Because of this alpha was set at .0167 for each dependent variable's analyses. With the exception of max aperature, data were found to be not normally distributed via the Kolmagorov-Smirnov, D'Agostino &

Pearson omnibus, and the Shapiro-Wilk normality tests. Therefore, Wilcoxon signed one-tailed ranked tests were performed on all variables except for max aperture where a one-tailed paired t-test was used instead.

Procedure

This research was approved by the Biomedical Institutional Review Board and informed consent was obtained prior to any data collection. Data were collected from August, 2012 to March, 2013. Upon arrival at the data collection site, participants read and signed informed consent forms and were able to voice any questions or concerns during that time. Participants were assigned an identification number to ensure confidentiality. Participants were, under his or her own volition, able to stop his or her participation in study at any point during data collection. Motion tracking markers were placed on the participant's dominant throwing arm, shoulder, and torso. The procedure involved throwing real darts at a real dart board, "throwing" a virtual dart at a virtual dartboard, and "throwing" an imaginary dart at an imaginary dart board. The throwing line was 7' 9.25" from the dartboard according to the official distance ("Basics of Darts," 2011).

Specifically, in the imagery based condition participants stood behind the throwing line and were asked to imagine throwing a real dart at an imaginary dartboard by moving their "throwing" arm as if they were actually performing the task of dart throwing. Participants were then asked to do this three times. The dartboard was obscured from view during the imagery and virtual conditions.

The materials based condition involved the participant throwing the steel tip darts at the bristle dartboard. Participants stood behind the throwing line and were handed three darts. Participants then threw the three darts, one at a time, at the dartboard. The participants had to establish that he or she can hit the dartboard's scoring zones consistently by hitting any of the scoring zones in three consecutive dart throws. Once the participant demonstrated that he or she could consistently hit the dartboard, his or her next three dart throws were analyzed.

The virtual reality based condition, utilizing the Xbox 360 and Kinect sensor, involved the participant performing the motions necessary to throw virtual darts at a virtual dartboard seen on the TV's screen. The researcher navigated through the opening sequences of the video game in order to prepare the dart game for the participants. Once the dart game started, the participants stood in the area that is detectable by the Kinect Sensor. Participants watched a tutorial video that is played on the video game before the dart game starts. This tutorial video portrayed and explained how participants should move in order to successfully and effectively throw the virtual darts. Participants then had to demonstrate that they could consistently hit the scoring zones on the dartboard by hitting any scoring zone on the dartboard with three consecutive darts. Once a participant demonstrated that they could consistently hit scoring zones on the dartboard, his or her next three throws were analyzed.

Results

Displacement

In the real condition, the average displacement during the throw was 242.4 cm. For the virtual condition, the average displacement was 168.9 cm, and in the imagery condition, it was 258.2 cm. Statistically significant differences were then seen in comparing the real and virtual conditions such that the virtual condition had a significantly less amount of displacement (p = 0.0004). The virtual condition also had a significantly less amount of displacement when compared to the imagery condition (p = 0.0004) When comparing the real and imagery conditions, in terms of their displacement, no statistically significant differences were discovered

(p = 0.33). A table and bar graph further portraying data related to displacement can be seen in the appendix (Table 2) (Figure 1).

Peak Velocity

PkV was the largest under the real condition with an average of 3.751 m/s. The virtual condition had an average PkV of 3.156 m/s and the imagery condition had an average PkV of 2.469 m/s. While no statistically significant difference was seen in comparing the real and virtual conditions in terms of their PkV (p = 0.028) the real condition trended a larger PkV than the virtual condition.. In comparing the PkV's of the real and imagery conditions, the real condition was found to be statistically greater than during the imagery condition (p = 0.0001). In addition, in comparing the PkV's during the virtual and imagery condition, the virtual condition was also found to be statistically greater than the imagery condition (p = 0.0011). A table and bar graph further portraying date related to the PkV of the three conditions can be seen in the appendix (Table 2) (Figure 2).

Movement Time

MT was found to be the smallest in the virtual condition with an average MT of 0.396 seconds. The real and imagery conditions had very similar MT's of 0.6142 seconds and 0.6268 seconds, respectively. Therefore, no statistically significant difference was seen between the real and imagery conditions in terms of MT (p = 0.48). However, the virtual condition has a significantly smaller MT time when compared to the real condition (p = 0.002) and when compared to the imagery condition (p = 0.0001). A table and bar graph further displaying the data related to MT can be seen in the appendix (Table 2) (Figure 3).

Percentage of MT to PkV

In terms of % MT to PkV, the imagery condition was the only condition to have an average over 33% with it being 34.72%. The real and virtual conditions had averages of 24.9% and 24.14%, respectively. In comparing the conditions in terms of their % of MT to PkV, no significant differences were seen between the real and virtual condition (p >0.0167.). However, statistically significant differences were seen when comparing the real condition and imagery condition and when comparing the virtual condition and imagery condition. The imagery condition had a significantly larger % MT to PkV when compared to the real condition (p = 0.0011). Additionally, the imagery condition had a significantly larger % MT to PkV when compared to the virtual condition (p = 0.0110). A table and bar graph further displaying the data related to % MT to PkV can be seen in the appendix (Table 2) (Figure 4).

Movement Units

The largest average of MU's was seen in the imagery condition with an average of 2.475. The next largest average was seen in the virtual condition with an average of 2.25 MU's. The real condition then had the smallest average of MU's with an average of 2.118 MU's. No statistically significant differences, in terms of MU's, were seen in comparing the three conditions (all p>0.0167). A table and bar graph further portraying data related to MU's can be seen in the appendices (Table 2) (Figure 5).

Max Aperture

The average max aperture, the amount of space between the distal phalanges of the thumb and index finger, was found to be the largest in the real condition with an average of 0.112 m. The imagery condition had the second largest average with an average of 0.09757 m. Finally, the smallest average for max aperture was seen in the virtual condition with an average of 0.08314 m. In comparing the real and virtual condition, a statistically significant difference was found (p=0.0001) such that the real condition had a significantly larger max aperture than the virtual condition. This can be similarly said when comparing the real and imagery condition (p=0.0035) such that the real condition had a significantly larger max aperture than the virtual condition. Finally, in comparing the virtual and imagery condition in terms of their max aperture, a statistically significant difference was found in the direction of the imagery condition eliciting a significantly larger max aperture than the virtual condition (p=0.0001). A table and bar graph further displaying the data related to max aperture can be seen in the appendix (Table 2) (Figure 6).

A table containing all *p*-values for each condition comparison and across all kinematic variables can be seen in the appendix (Table 3).

Discussion

The purpose of this study was to investigate the quality of movement in three different iterations of dart throwing. One involved throwing real darts at a real dart board, another involved “throwing” imagined darts at an imagined dartboard, and the third involved utilizing an X-box 360 and the Kinect sensor to “throw” virtual darts at a virtual dartboard seen on a television screen. Results from this study partially support its first hypothesis as the materials based condition elicited better motor performances in terms of PkV and max aperture when compared to the other two conditions. In regards to the study’s second hypothesis, it was partially supported as well. The virtual reality based condition was found to elicit significantly better motor performances in terms of displacement, PkV, and MT when compared to the imagery condition. However, the comparison between the materials based condition and the virtual reality based condition in terms of PkV was not found to be statistically significant and the results are only trending in the direction of the study's hypotheses. This can also be said of the results in MU's of the three conditions.

A major theme from the results of this study is the similarities between the materials based and the imagery based conditions. These two conditions were found to have no statistically significant differences on the dependent variables of displacement, movement time, and movement units. Though there are significant differences seen in the dependent variables of PkV, max aperture, and % MT to PkV. These differences may be attributed to any one of several explanations. First, the differences may be due to the nature of the materials based condition. That is, participants throwing the real dart needed to overcome the inertial properties of the dart, leading to a significantly higher PkV. They also needed to ensure an aperture large enough to eliminate interference with the dart as they released the dart during their throw. Finally, participants may have needed to have relied more on feedback during the materials based condition's throws to ensure that they were throwing the dart with enough force and releasing the dart at an appropriate time to successfully hit the dartboard, with the increased reliance on feedback then results in a significantly lower % MT to PkV. Real darts are more ubiquitous than virtual darts, and the perception of throwing an imaginary dart would most likely be based upon a preconceived notion of throwing a real dart over that of throwing a virtual dart. These results help to establish the idea that the motor performances seen in the imagery based condition is presumably based upon the participants' internal concepts of throwing an actual dart as in the materials based condition.

Another major theme that comes from the results of this study is that the virtual reality based condition elicited motor performances that are quantitatively and qualitatively different in comparison to the other two conditions. Though the motions elicited in the virtual reality based condition visually mimic the motions produced in the materials based and imagery based conditions, the motions in the virtual reality based condition may not have been developed from the concept of throwing a real dart. This is converse to the belief held for the imagery based condition in which the internal concepts that participants have of throwing a real dart are utilized to throw the imaginary dart. In terms of the virtual reality based condition, it is believed that through the interaction and observance of the virtual environment, there is a constant knowledge of performance within the virtual environment that changes the focus and goal during this condition. That is, during the virtual reality based condition, participants were focused more on executing the appropriate motor performances required to elicit successful responses within the virtual environment rather than just throwing the dart, as within the other two conditions. Though the goals of the three conditions were conceptually similar, (e.g., throw the dart and hit the dart board), the virtual reality based condition put the participants within an environment that drastically changed the planning and execution of their motor performances. To elicit the desired response and achieve the goal of throwing the dart and hitting the dartboard within the virtual reality based condition, the participants needed to move and plan their movements in a manner that was detectable by the Kinect Sensor that would then display these responses on the television screen. The parameters set by the Kinect Sensor as to what is an appropriate movement to elicit a response within the virtual environment may have been the major influence on how the participants planned and executed their motor performances, and not upon the intricacies required for throwing an actual dart. For example, the Kinect sensor would not be able to determine the necessary opposition and force required to properly hold and position a real dart between the index finger and thumb. Nor would it be able to perceive the moment for the index finger and thumb to ‘release’ the dart with any type of precision. It could be argued that the success or failure of throwing a dart is based on a lesser part the gross motor control of the shoulder, and elbow, but rather more upon the action, both motor and sensory, of the intrinsic muscles of the hand and fingers. It is also proposed that, because interactions with the X-box 360 and Kinect sensor were so novel to the participants, trying to compare the virtual reality based condition to the other two conditions in terms of dart throwing may have been contrived. Participants may have been more focused on playing the video game during the virtual reality based condition and the dart throwing motion that was analyzed is only associated through their interaction with the video game. Whereas in the materials based condition and the imagery based condition, the focus may have been based soley on throwing an actual dart. This suggestion is offered to explain the significant differences in the motor performances of the virtual reality based condition and to state that these motor performances are entirely different in a qualitative sense when compared to the materials based and imagery based conditions.

In terms of support for this study's hypotheses, the results from the dependent variables of PkV and MU were the only ones that trended towards supporting both hypotheses. In terms of PkV, both the materials based and virtual reality based conditions were significantly more efficient than the imagery based condition, but the materials based condition was not deemed significantly more efficient than the virtual reality based condition. Furthermore, performances in terms of MU were trending towards support of both hypotheses, but the differences were not found to be statistically significant. However, this lends support to previous studies that have found motor performances in materials based conditions to be significantly more efficient than motor performances in imagery based conditions (DeKuiper, 1993; Lang, 1992; Ross, 2000; Wu, 1994).

The majority of these previous studies have compared a materials based occupations to an imagery based counterpart and had some sort of control condition, usually consisting of a rote exercise of similar movements (DeKuiper, 1993; Lang, 1992; Ross, 2000; Wu, 1994). However, this current study, to my knowledge, is the first that compares a materials based and imagery based occupation to a virtual reality counterpart. Comparisons between this study and previous studies can then be made in terms of the findings for the materials based and imagery based conditions. The above cited studies found that the materials based conditions were able to elicit better motor performances than their imagery based conditions (DeKuiper, 1993; Lang, 1992; Ross, 2000; Wu, 1994). Similar results were also found in this study as the materials based condition was able to elicit a better motor performance than the imagery based condition. However, this study also found a strong similarity between the materials based and imagery based conditions. It is believed that the motor performances exhibited by the participants in this study during the imagery based condition come from the concept of materials based dart throw as argued above. Motor planning during the imagery based condition is thought to be based on throwing an actual dart, as it would be in the materials based condition, and it is this similarity in motor planning that could have lead to similarities in resulting and analyzed motor performances in this study.

It is also significant to note the results of % MT to PkV for the three conditions. The materials based condition and the virtual reality based condition had mean % MT to PkV below 33% and the imagery based condition had a mean % MT to PkV that was relatively close to 33%. Though the imagery based condition had a significantly greater % MT to PkV when compared to the other two conditions, these results are indicative of motor performances requiring reliance on feedback for success in their execution as all were approximately 33% or less. Furthermore, from these results, it is believed that the materials based condition and the virtual reality based condition may rely more heavily on feedback to ensure successful execution of motor performances than the imagery based condition.

Clinical applications of these results would be that clinicians can utilize material based, occupationally embedded interventions to increase skill attainment of a desired occupation. In the case of this study, to better increase the skill of dart throwing, it is recommended that clinicians can have their clients throw real darts. Utilizing and increasing a client's skill in a virtual reality based alternative of dart throwing may not increase skill or performance in the materials based form of dart throwing. However, a virtual reality based dart throwing intervention may achieve client goals that are biomechanical in nature, such as increasing range of motion of the upper extremity and increasing muscle strength and endurance. Additionally, for those clients that find a large amount of meaning and purpose in playing darts but are not able to participate in the materials based form of the occupation due to some form of physical limitation, such as amputated fingers or poor fine motor control of the fingers, a virtual reality based dart throwing alternative may be appropriate to increase meaning and participation in occupational therapy services. Furthermore, a client's goals and preferences can help influence the clinical reasoning for choosing a virtual reality based occupation over a material based occupation and vice versa. If developing skill in actual dart throwing is desired by the client, then interventions with real darts is warranted. If the client desires to participate in a video game, then utilizing an X-box with a Kinect sensor or any other video game system would be an appropriate intervention. Clinical reasoning based upon client factors and goals should determine the course of treatment and could involve real darts, virtual dart video-based game, or a combination of both.

There were several limitations associated with this study. The small sample size could have contributed to a potential Type II error. This could have been particularly true in the variables where a potential trend existed, but the comparison failed to reach statistical significance, specifically in terms of PkV and MU. The context and artificial environment of the motion analysis lab could have adversely influenced performance during the three conditions. It is also not certain that participants actually imagined throwing darts during the imagery based condition. While participants were instructed to imagine throwing darts, it is impossible to know whether or not that actually occurred. There are also limitations in terms of the ability to generalize the results of this study, and that it should be done conservatively as a majority of participants were all from the Northwest Ohio area and were all of good health status.

Future research should investigate the newest technology for virtual reality and the quality of movement in interacting with a virtual reality based environment in comparison to its physical, material based environment counterpart. Investigating these technologies will be important to the profession occupational therapy as they will be involved in many meaningful and purposeful occupations for certain clients and the utilization of these technologies can possibly provide increased therapeutic benefits to all types of clients that receive occupational therapy services.

This study investigated the quality of movement during three different iterations of dart throwing. The results portrayed that the materials based condition to elicit superior motor performances when compared to the imagery based condition, yet is it believed that the concepts to develop and execute the performances during these conditions are similar. Conversely, it is believed, by virtue of the expressed kinematics and kinetics, that the motor performances analyzed in the virtual reality based condition may not be developed with the concept of throwing an actual dart, but are results of constrained interactions with the virtual reality environment to achieve desired results specific to the video game. This study suggests that increasing skill in dart throwing would best be accomplished by throwing real darts. If the goal is to increase participation in occupational therapy services and less on the development of a dart throwing skill, both the materials based and virtual reality based iterations of darts would suffice. However, the interests of the client should be of heavy consideration during this decision making process. Regardless of whether an occupation is materials based or virtual reality based, providing occupations that are of significant meaning and purpose to those clients receiving occupational therapy services will increase the quality of care and better obtain the desired therapeutic outcomes.

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Table 1

Participant Descriptive Statistics Table

Demographics	
n	34
Min Age (years)	18
Max Age (years)	53
Average Age (years)	26.09
Right Handed	32
Left Handed	2
Male	15
Female	19

Table 2

Collective Kinematic Data Table

Kinematic Variable/Conditions	**n**	**Min**	**Max**	**Mean**	**SD**
Displacement (cm)					
Real	34	99.63	552.8	242.4	85.28
Virtual	34	72.56	392.3	168.9	84.91
Imagery	34	81.68	698	258.2	128.1
Peak Velocity (m/s)					
Real	34	2.018	6.772	3.751	1.154
Virtual	34	1.155	5.155	3.156	0.8975
Imagery	34	1.1	4.907	2.469	0.9269
Movement Time (s)					
Real	34	0.2567	1.37	0.6142	0.2128
Virtual	33	0.16	0.995	0.3893	0.2248
Imagery	34	0.19	1.797	0.6268	0.3204
% MT to PkV (%)					
Real	34	0.075	0.5933	0.249	0.1409
Virtual	34	0.07667	0.6375	0.2414	0.163
Imagery	34	0.09667	0.8683	0.3472	0.1959
Movement Units					
Real	34	1	6	2.118	0.9775
Virtual	16	1	7	2.25	1.683
Imagery	34	1	6	2.475	1.271
Max Aperture (cm)					
Real	34	0.07368	0.1426	0.112	0.01725
Virtual	34	0.0381	0.142	0.0831	0.0231
Imagery	34	0.03499	0.1389	0.09757	0.02489

Table 3

Results Summary Table

	Real vs Virtual (*p<0.0167)*	Real vs Imagery (*p*<0.0167)	Virtual vs Imagery (*p*<0.0167)
Displacement (cm)	0.0004*	0.3582	0.0004*
PkV (m/s)	0.0276	0.0001*	0.0011*
MT (s)	0.0002*	0.4847	0.0003*
% of MT to PkV (%)	0.2884	0.0011*	0.0110*
MU	0.3808	0.1153	0.4039
Max Aperature (m)	0.0001*	0.0035*	0.0001*

Note. This table displays all *p*-values for each condition comparison across all kinematic variables. Those values marked with * are deemed to be statistically significant at an Alpha level of 0.0167.

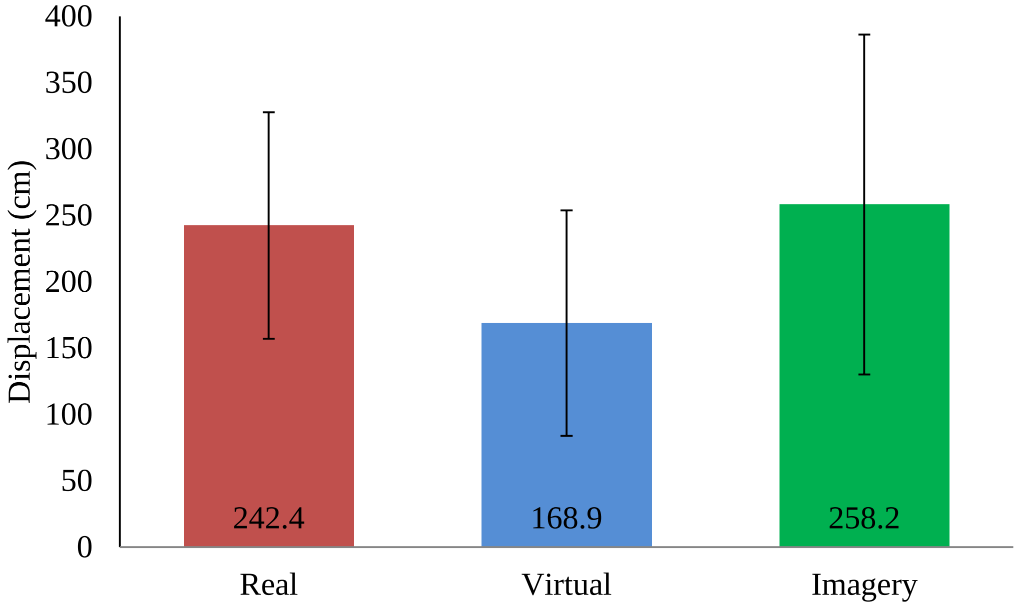

Figure 1. The bar graph displays the average displacement for each condition. Statistically significant differences were seen when comparing the real and virtual conditions and when comparing the virtual and imagery conditions. The virtual condition had a significantly smaller displacement when compared to the real condition (p = 0.0004) and when compared to the imagery condition (p = 0.0004). No statistically significant differences were seen between the real and imagery condition. Alpha was set at 0.0167. Standard deviation bars are also represented in this graph.

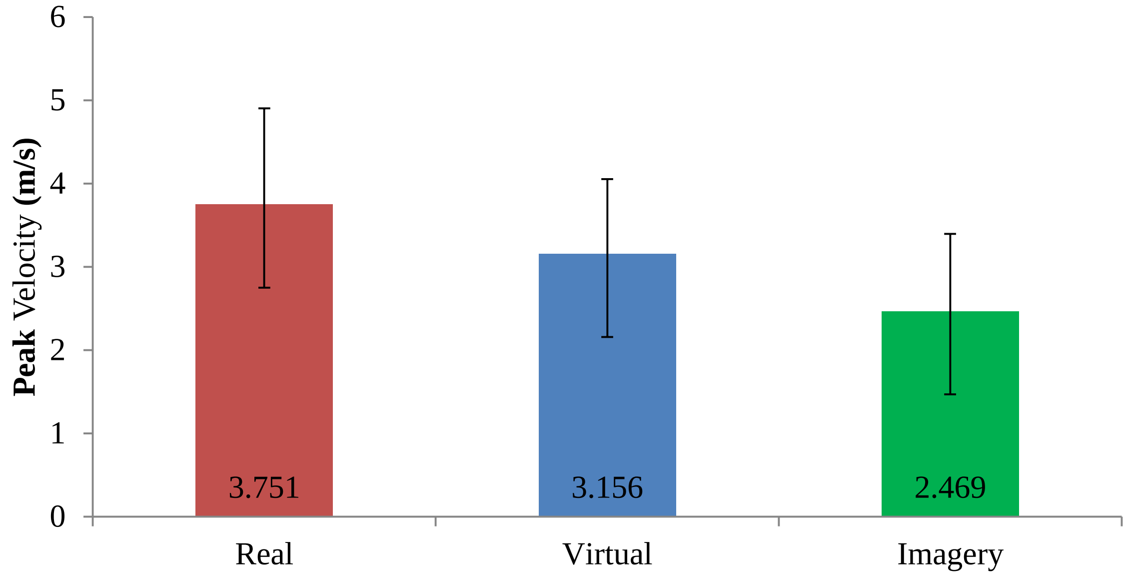

Figure 2. This bar graph contains the average PkV for each condition. Significant differences were seen when comparing the real condition to the imagery condition and when comparing the virtual condition to the imagery condition. The real condition was significantly faster when compared to the imagery condition (p = 0.0001). The virtual condition was also significantly faster when compared to the imagery condition (p = 0.0110). However, no statistically significant difference was found when comparing the real and virtual conditions (p = 0.0276). Alpha was set at 0.0167. Standard deviation bars are represented in the graph.

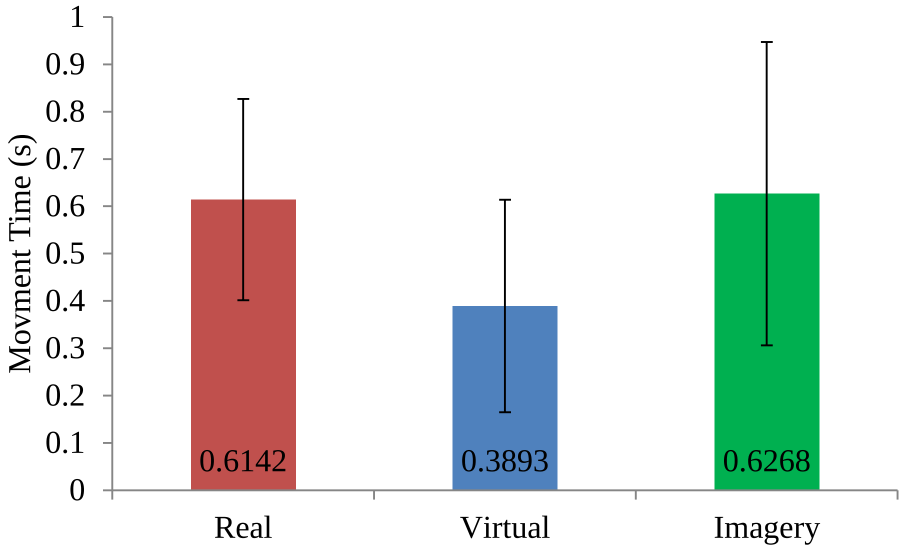

Figure 3. This bar graph displays the average MT for each condition. Significant differences were seen when comparing the virtual condition to the real condition and when comparing the virtual condition to the imagery condition. The virtual condition was significantly shorter than the real condition (p = 0.0002) and the virtual condition was significantly shorter than the imagery condition (p = 0.0003). No differences were seen between the real and imagery conditions (p > 0.0167). Standard deviation bars are also represented on the bar graph.

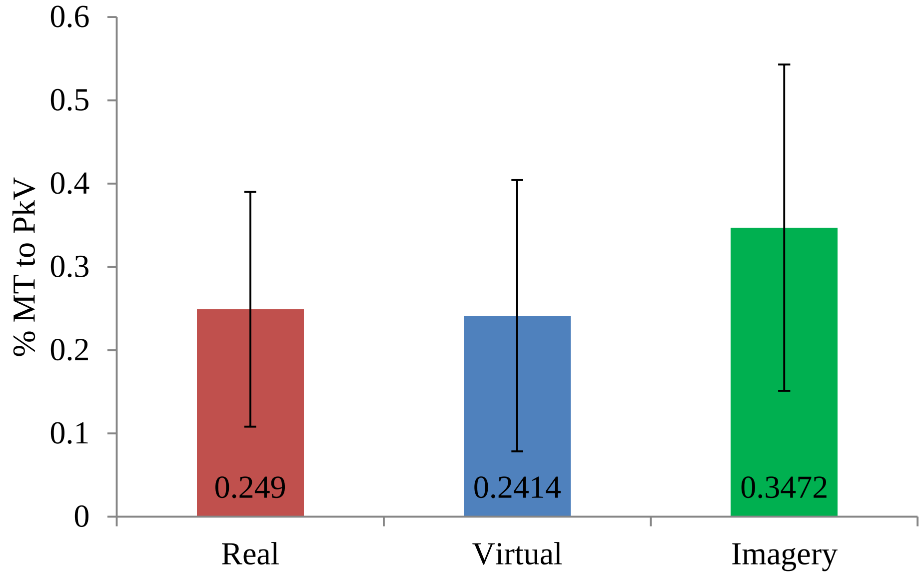

*Figure 4.*This bar graph displays the average % MT to PkV for all conditions. Standard error bars are also represented on this bar graph. A significant difference was seen when comparing the real condition to the imagery condition (p = 0.0011) and when comparing the virtual condition to the imagery condition (p = 0.0110). No significant difference was seen when comparing the real condition to the virtual condition (p>0.0167). Alpha was set at a level of 0.0167.

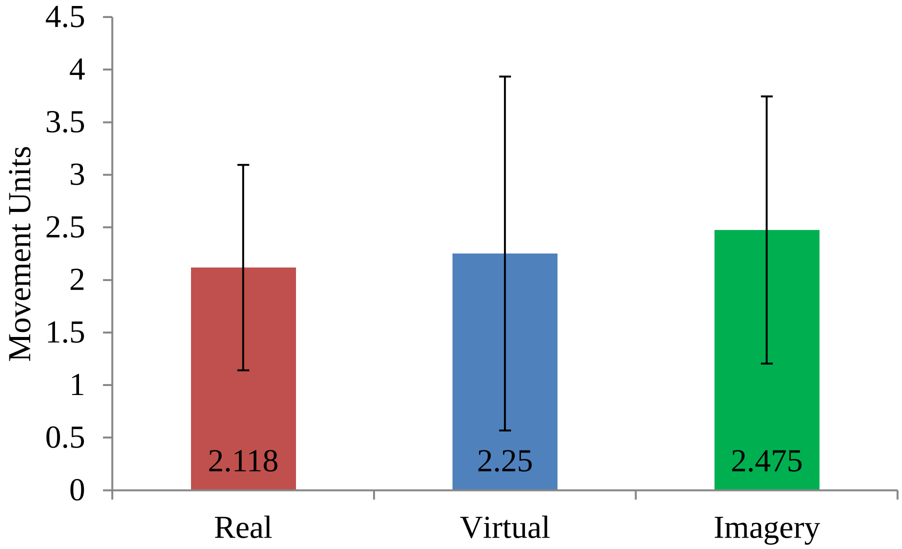

Figure 5. This bar graph displays the average number of MU's for each condition. No significant differences were when comparing the conditions (all p>0.0167). Standard deviation bars are also represented on this bar graph.

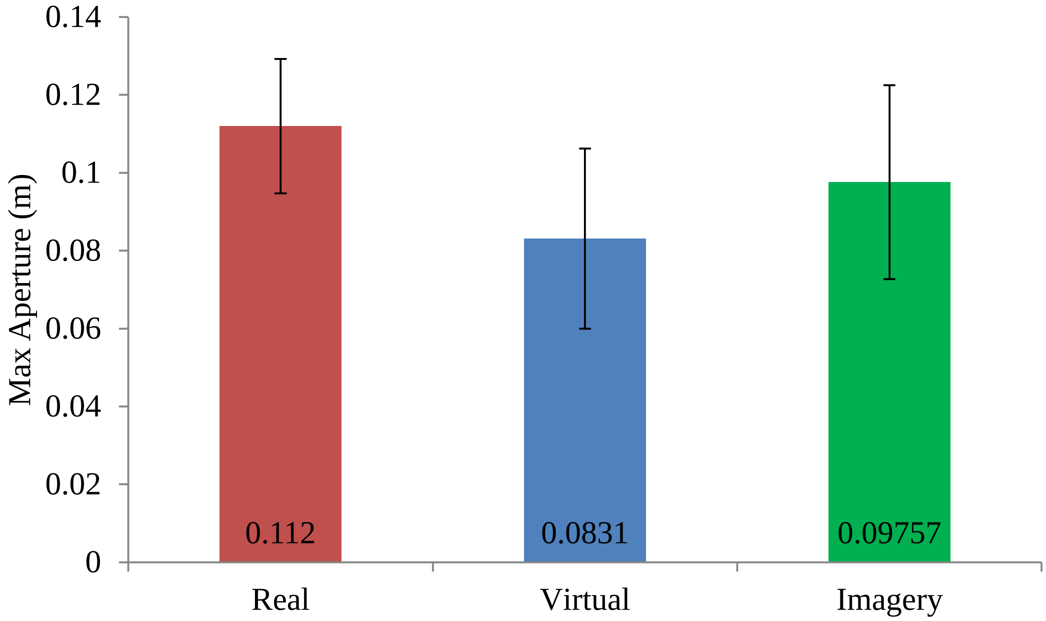

Figure 6. This bar graph displays the average max apertures for each condition. The real condition was found to be significantly greater than the virtual condition (p=0.0001). The real condition was also found to be significantly greater than the imagery condition (p=0.0035). Finally, the imagery condition was found to significantly greater than the virtual condition (p=0.0001). Alpha was set at 0.0167. Standard deviation bars are also represented on the bar graph.