Psychological Test and Assessment Modeling, Volume 57, 2015 (1), 57-69

Virtual realities as optimal learning environments in sport – A transfer study of virtual and real dart throwing

Judith Tirp[1], Christina Steingröver[2], Nick Wattie[3], Joseph Baker[4] & Jörg Schorer[2]

Abstract

Virtual realities offer a safe and repeatable learning environment, which is optimal for skills that are difficult to replicate in real-world settings. Previous research has demonstrated transfer of motor skill between basketball and darts but not of perceptual performance (Rienhoff et al., 2013). Our study considered the transferability of a specific skill between virtual and real learning environments - in our case throwing accuracy (TA) and quiet eye duration (QED) in dart throwing. Participants (n = 38) were separated into three groups (virtual training, real training, & control) and completed 15 throws in pre- and post-tests on a real and on a virtual (Microsoft XBox Kinect) dartboard. The training groups performed three sessions of 50 throws each. QED was measured using SMI eye tracking glasses and TA was defined as radial distance from the bull's eye. Results showed significant differences in TA for group and condition; the real training group outperformed the control group and TA was better in the virtual group. The interaction of test and group was significant. Both training groups improved between tests while the control group performed worst. Results for QED showed a significant increase between tests. Furthermore, significant differences for condition and a significant interaction of condition and test were measured. QED was longer and enhanced in the virtual group. Our results generally showed the efficiency of both training modalities and the slight difference in training effects between groups suggests transferability between tasks.

Keywords: virtual environments, transfer, quiet eye

[1] *Correspondence concerning this article should be addressed to:* Judith Tirp, Institut für Sportwissenschaft, Fakultät 4: Human- und Gesellschaftswissenschaften, Carl von Ossietzky Universität Oldenburg, Postfach 2503, 26111 Oldenburg, Germany; email: judith.tirp@uni-oldenburg.de

[2] University of Oldenburg, Germany

[3] University of Ontario Institute of Technology, Canada

[4] York University, Toronto, Canada

In many learning contexts (e.g., various forms of surgery; Aggarwal et al., 2007), virtual settings are becoming the norm for training; however, in the context of motor learning, virtual environments are rarely discussed (Kretschmann, 2008). Over the past decade, gaming hardware has been developed that facilitates whole body movement for controlling sporting situations in virtual games (Wiemeyer & Schneider, 2012) suggesting that these technologies might have some application for identifying optimal learning environments for motor and perceptual skills. In addition to increased consistency and reliability in the training environment, virtual realities may offer the possibility to create and manipulate individual training tools and optimize contexts to the specific constraints of the learner. However, Kretschmann (2008) noted that the interaction and transfer between virtual and real training tools need to be examined.

There is increasing research concerning the applicability of virtual games in physiological contexts, such as fitness (Baranowski, Buday, Thompson, & Baranowski, 2008; Wolf, Barnhart, Ellison, & Coogler, 1997), rehabilitation (Deutsch et al., 2011; Wiemeyer, 2010), prevention (Wiemeyer, 2010), and balance training (Brumels, Blasius, Cortright, Oumedian, & Solberg, 2008). Moreover, pilot training (Johnston & Weiss, 1997), astronauts (Johnston & Weiss, 1997), laparoscopic skills (Torkington, Smith, Rees, & Darzi, 2001) or driver simulators (Casutt, Theill, Martin, Keller, & Jäncke, 2014) have become commonplace. As such, virtual reality has an important role in the modern world. The development of virtual games and hardware (smartphones, computers, simulators and video game consoles) is rapidly advancing. Currently, it is possible to create new worlds in virtual realities that can be manipulated in a structured way as well as creating standardised situations (Miles, Pop, Watt, Lawrence, & John, 2012). Surprisingly, little research has been done on virtual environments and their application to sport (cf. Miles et al., 2012). In particular, the potential transfer of perceptual-motor skill between virtual and real conditions in a sporting context is an interesting research area.

A classic topic of skill acquisition research is the issue of transferability. Over a hundred years ago, Thorndike (1914) mentioned the possibility of transfer between 'identical elements' parted in different tasks. Baker and Côté (2006; expanded from Schmidt & Wrisberg, 2000) proposed that identical elements could include (1) physical conditioning elements, which relate to general physiological changes shared between similar modes of activity (e.g., all aerobic training will promote system-wide cardiorespiratory changes), (2) movement elements, which relate to the anatomical and biomechanical similarities between tasks (e.g., overhand throwing in baseball and handball), (3) perceptual elements, which relate to the environmental information used to make performance related decisions (e.g., the need to recog- nize offensive and defensive patterns of play) and (4) conceptual elements, which relate to similarities in the strategies, rules and guidelines governing behavior during competition (e.g., gymnas- tics and diving share some conceptual elements regarding judging aesthetics of performers' movements) (Rienhoff et al., 2013, p. 1-2). Although these elements are normally considered in questions on transfer between sport disciplines, they might also be relevant for one sporting discipline in two different training settings (virtual and real). For comparing the transfer between virtual and real motor learning settings it is necessary that both conditions show many interfaces in perceptual-motor behaviour (Osgood, 1949; Wiemeyer & Hardy, 2013).

Osgood (1949) showed that transfer is possible when the tasks are similar. In addition, it seems to be important that the learning environments between virtual and real sessions differ as little as possible (Wiemeyer & Hardy, 2013).

There have been studies considering the influence and capabilities of virtual games in perceptual-motor learning and transfer contexts. For instance, Heinen, Velentzas, Walter and Goechel (2009) investigated the influence of virtual learning on motor learning in golf putting. They proposed that putting performances could be improved by virtual golf training even if the senso-motory feedback (absence of golf club) differed to real golf putting. They used the Wii^{TM} game console, which uses a joystick for playing the virtual games, and showed an improvement in real and virtual golf putting despite the missing sensory-motor feedback. Heinen et al. (2009) indicated positive transfer between virtual golf putting training and putting performance under real conditions. Interestingly, they found no differences between the virtual and real training groups in real golf putting, however, they did not examine whether real training would transfer to virtual tasks. Rosenberg, Landsittel and Averch (2005) looked for an improvement in laparoscopic skills by training some hand-eye coordination skills with the Microsoft Xbox360 (Top Spin, Racing, Amped 2). Ruffaldi and Filippeschi (2013) demonstrated that a virtual environment and a specific program could be used to train technique in rowing. Another study looking at virtual bowling showed that participants of the virtual training group were able to improve their scores in a real bowling alley by training on a virtual bowling game. In comparison, the non-training group did not improve their scores; however, neither group trained in a real bowling alley (Siemon, Wegener, Bader, Hieber, & Schmid, 2009). Wiemeyer and Schneider (2012) investigated whether throwing performance in basketball shooting was improvable and transferable in real and virtual basketball throws. Participants from German basketball clubs had to perform free throws under both conditions. After a training phase (750 throws) in either real throwing or virtual throwing they performed both tasks again with results reflecting both virtual and real training can improve motor skills.

Another interesting aspect of perceptual motor training is the transfer of visual and attentional skills in virtual learning contexts. Green and Bavelier (2003) indicated that playing action-video game leads to better attentional capacity within the virtual training area (0-5° from fixation). As well, Green and Bavelier (2003) showed that action video game players were able to increase visual attention and spatial distribution in non-training areas (10-30°). Furthermore, there were differences in an attentional blink task testing visual attention between video gamers and non-gamers. Similarly, Satyen and Ohtsuka (2001) observed an improvement in attention skills as a result of video game training (i.e., PacMan on the Nintendo 64 console). Moore and Müller (2014) indicated that expert baseball players were able to transfer their visual anticipation (i.e., skill in a temporal occlusion task) to a similar task (cricket batting). In summary, it seems that experts in a range of disciplines, including sport, are able to transfer their perceptual capacities to similar tasks but there is less research examining the transfer of these perceptual processes between virtual and real settings in a motor learning context with novices.

One perceptual skill that may be transferable and that has been associated with better sporting performance is the phenomenon of the quiet eye (Klostermann, Kredel, &

Hossner, 2013; Vickers, Rodrigues, & Edworthy, 2000; Vine, Moore, & Wilson, 2011). The quiet eye is a perceptual phenomenon associated with peak performance in targeting tasks and is defined as the last fixation prior to the initiation of the movement (Vickers, 2007). Prior research shows expertise differences for the quiet eye duration in sporting tasks such as golf putting (Vickers, 1992), basketball (Harle & Vickers, 2001; Oudejans, Koedijker, Bleijendaal, & Bakker, 2005; Vickers, 1996), shotgun shooting (Joe, Bennett, Holmes, Janelle, & Williams, 2010) and dart throwing (Rienhoff, Baker, Fischer, Strauß, & Schorer, 2012; Vickers et al., 2000). Experts seem to have an earlier start to their final fixation and show a longer quiet eye duration compared to lesser skilled performers (Vickers, 2007). Another interesting attribute, first observed by Harle and Vickers (2001) in basketball free throws, is the trainability of the quiet eye behaviour. They showed that basketball experts improved their quiet eye duration after six weeks of training. Several studies have replicated these results for experts in targeting sports like golf putting (Vine et al., 2011) and football penalty kicks (Wood & Wilson, 2011). Furthermore, Vine and Wilson (2011) demonstrated that novices also improved the quiet eye duration in different golf putting tasks as an effect of quiet eye training. Rienhoff, Hopwood, Fischer, Baker, Strauss, and Schorer (2013) considered whether basketball experts were able to transfer their gaze behaviour from a sport specific task (basketball free throw) to a novel task (dart throw). They showed that experts transferred some aspects of their throwing performance (motor result) but not quiet eye duration (perceptual performance). However, the quiet eye seems to be a sport specific skill, especially relevant in targeting tasks, which has not been considered in a virtual learning context.

Miles et al. (2012) suggested that there was a need for further research on virtual transfer in order to gain a deeper insight into possible applications (e.g., in high performance sport). In the current study we focused on the transfer of throwing accuracy (motor result) and quiet eye duration (perceptual performance) between real and virtual dart throwing. More specifically, we investigated whether expertise associated perceptual behaviour can be trained in a simple virtual environment (i.e., the Microsoft Xbox360) and then transferred back into the real world. Our goal was not to replicate findings on the differences between experts and novices but to investigate whether novices were able to improve and transfer motor and perceptual performances in a dart throwing task. As Heinen et al. (2009) noted, the senso-motor feedback differs from virtual games to real situations. Microsoft Xbox360 which has a "body tracking system" was used in this study. Therefore, the players under virtual conditions did not use a real dart arrow or a joystick to handle the software. The aim of this study was two-fold. First, we wanted to investigate whether virtual or real training lead to superior results and better perceptual performance (cf. Rienhoff et al., 2013). Our second aim was to examine the transferability of these acquired skills between virtual and real tasks. We hypothesized the transfer of perceptual performance between virtual and real dart throwing and that this would result in superior motor results.

Methods

Participants

The sample was made up of 38 participants, 12 female and 26 male. Participants were divided into three groups (control group, virtual learning group & real learning group) and had normal or corrected to normal vision. The control group consisted of 15 individuals with a mean age of 25.0 years (9 male, 6 female). The virtual learning group included 11 participants with a mean age of 24.8 years (6 male, 5 female). Twelve participants were part of the real learning group with a mean age of 26.0 (11 male, 1 female). All participants were inexperienced in dart throwing and provided informed consent prior to the conductance of the experiment.

Apparatus

Pretest, posttest and the training sessions were performed in a laboratory setting. According to the rules of the World Dart Federation (WDF), the dart board was fixed with the center of the bull's eye on 5ft 8in (1.73 m) above the ground. The throw line, also referred to as the oche, was marked on the floor 7ft 9¼ in (2.37 m) from the face of the board. The dartboard was removable so that the virtual throws could be performed in the same laboratory setting. The wall was used as a projection screen for a digitally projected virtual dartboard. To compensate for the missing depth of the real dartboard, the throw line was moved three centimeters forward. Having a diameter of 17 ¾ in (45.1 cm), the virtual dartboard corresponded to the size of a real WDF dartboard. For the virtual dart setting, the video projector and Xbox were placed on a low table (31 ½ in or 80 cm) between the throw line and the dart board, the Xbox Kinect motion sensor was installed 9 ½ in (25 cm) above the dartboard. The software used for the virtual dart study was Microsoft's Kinect sport 2 operating on the commercially available system.

Participants' gaze behavior was recorded during pre- and post-tests with a mobile eye-tracking-system (SMI Eye Tracking Glasses 2.0). During data collection, the eye-tracking-glasses were connected to a notebook (Lenovo ThinkPad) via a USB cable. This setup enabled participants to move freely and conduct their throwing task without movement constraints. To ensure the glasses' fine adjustment, a three point calibration was conducted for each participant. In addition to the recording program IVIEW X (contained in the SMI Experiment Suite 360), the throws were recorded by a digital video camera to note throwing accuracy. The external camera within the eye tracking glasses produced videos from the visual field (including the arm movement), so we were able to define the start of the extension phase of each throw. The video camera (Sony, HDR-CX320, 8.9 megapixels) was adjusted to the respective dartboard and recorded throwing accuracy during every test run. All participants in the real condition used competition-style steel darts with a weight of 24 grams. In the virtual condition, participants did not throw a dart at the end of the arm extension nor did they hold any piece of sports equipment in their hand.

Study design

Our study design included three stages. During the pre- and posttests, all participants completed 30 throws on the dartboard, 15 each on the real and virtual dartboard. After participants completed 15 throws, the test situation was converted from virtual to real or vice versa within a few seconds. The order of the two tasks was counterbalanced. In this manner, possible learning effects between real and virtual darts (and vice versa) which might have occurred within the pretest were counterbalanced for the statistical analysis. At the beginning of every test-block and after the conversion of the experiment set-up, participants had five free test-trials to familiarize themselves with the laboratory situation. These throws were neither recorded nor were they part of the test. All participants received the same instructions, namely to take their throwing position and to focus on the target (bull´s eye), to focus on the target until the dart left their hand, to perform the throw as usual and to keep the target focused after the throw. After the test was completed, throwing accuracy and quiet eye duration were documented. The data collection procedure was identical during pre- and post-tests.

Training protocol

Between the two test sessions, both training groups received training while the control group did not practice at all. While the virtually practicing group used the virtual dartboard, the real dart practicing group threw the darts at a real dartboard. Each participant in the training groups completed three training sessions consisting of 50 throws within one week. All participants received the same instructions based on prior studies in which quiet eye duration was practiced (Causer, Holmes, & Williams, 2011; Vine et al., 2011). The design of our study fulfills the main criteria and methodological requirements for the application of serious games in motor learning and virtual transfer (Wiemeyer & Hardy, 2013).

Dependent measures and statistical analyses

Referring to Vickers (2000), a dart throw can be divided into three successive stages, namely alignment, flexion and extension. As mentioned earlier, in this context quiet eye is defined as the final fixation on the target prior to the extension of the arm towards the target. In the current study, the quiet eye was the final fixation or tracking gaze located on the dartboard, within 3° of visual angle for at least 100 ms (Vickers, 2007). Since experts' quiet eye has been shown to be of a significantly longer duration than novices' quiet eye, high levels of performance are associated with longer fixations of critical objects, irrespective of the task conditions (Vickers, 2007). Therefore, a longer quiet eye duration should result in better throwing performance. The last fixation prior to the extension of the arm was detected and measured using the *BeGaze* software that is a component of the Experiment Suite 360 which reports the duration of the quiet eye in milliseconds (ms).

Throwing accuracy was measured as radial distance from the bull´s eye. Therefore the digital video camera was used and based on the videos the x and y axis position for the bull´s eye and the deviation in x and y direction for each throw was determined. Using the VLC media player 2.1.3 software for Microsoft Windows 7, pictures were generated from the video recording. The snapshots were opened with Microsoft Paint to define the coordinates for the bull´s eye and the dart position. The radial deviation was measured with pixel distance (px) and was converted in cm. Using these data, the distance between the target (bull´s eye) and the location of the dart was calculated.

As mentioned earlier, analyses of throwing accuracy and gaze behavior were conducted separately. First, two separate analyses of variance tested group differences in throwing accuracy and quiet eye duration. For main effects concerning test and condition we used a repeated measure analysis of variance (ANOVA). For the interaction of training groups, conditions, and tests, a repeated measures analysis of variance (ANOVA) was applied. All data were analyzed by SPSS 22.0 and G*power 3.1 (Faul et al., 2007).

Results

The descriptive results for throwing accuracy showed an improvement in throwing accuracy for the training groups. While the analysis of variance revealed no significant differences between tests, $F(1,35) = 0.48$, $p = .50$, $f = .11$, $1\text{-}\beta = .20$, the interaction of group and test was significant, $Fs(2,35) = 6.17$, $p < .01$, $f = .59$. As seen in Figure 1, the training groups improved between tests, while the control group got a little worse. We also revealed significant differences between groups, $F(1,35) = 3.46$, $p= .04$, $f = .44$. Post-hoc Scheffé tests showed significant differences between the real training and control group ($D = 1.14$, $SE = .43$, $p = .04$). We also showed significant differences between conditions, $F(1,35) = 163.71$, $p < .01$, $f = 2.16$. Interestingly, the throwing accuracy for virtual dart throwing ($M = 3.02$, $SE = 0.23$) was better than real dart throwing ($M = 7.36$, $SE = 0.27$). The interactions of condition and group, $Fs(1,35) = 8.50$, $p = .15$, $f = .34$, $1\text{-}\beta = .94$, of condition and test, $Fs(1,35) = 0.41$, $p = .66$, $f = .08$, $1\text{-}\beta = .11$, as well as of test, group and condition, $Fs(2,35) = 0.41$, $p = .67$, $f = .15$, $1\text{-}\beta = .32$, were not significant.

For quiet eye duration, an improvement for all groups from 589.94 ms ($SE = 62.08$) to 951.43 ms ($SE = 94.04$) was shown, $F(1,35) = 10.85$, $p < .01$, $f = .58$. We revealed no significant differences between groups, $F(1,35) = 0.20$, $p = .82$, $f = .11$, $1\text{-}\beta = .18$. But the statistical analysis for condition showed significant differences, $F(1,35) = 27.16$, $p < .01$, $f = .92$. Quiet eye duration was significantly higher in virtual dart throwing ($M = 963.25$, $SE = 6.81$) compared to real dart throwing ($M = 57.11$, $SE = 43.24$). In addition, we observed a significant interaction for condition and test, $Fs(1,35) = 4.17$, $p = .05$, $f = .36$, the improvement in virtual dart throwing was higher compared to real dart throwing (cf. Figure 2). Again, the interactions of group and test, $Fs(2,35) = 0.22$, $p = .98$, $f = .03$, $1\text{-}\beta = .06$, of condition and group, $Fs(1,35) = .027$, $p = .76$, $f = .13$, $1\text{-}\beta = .25$, as well as of test, group and condition $Fs(2,35) = 0.32$, $p = .73$, $f = .14$, $1\text{-}\beta = .27$, were not significant.

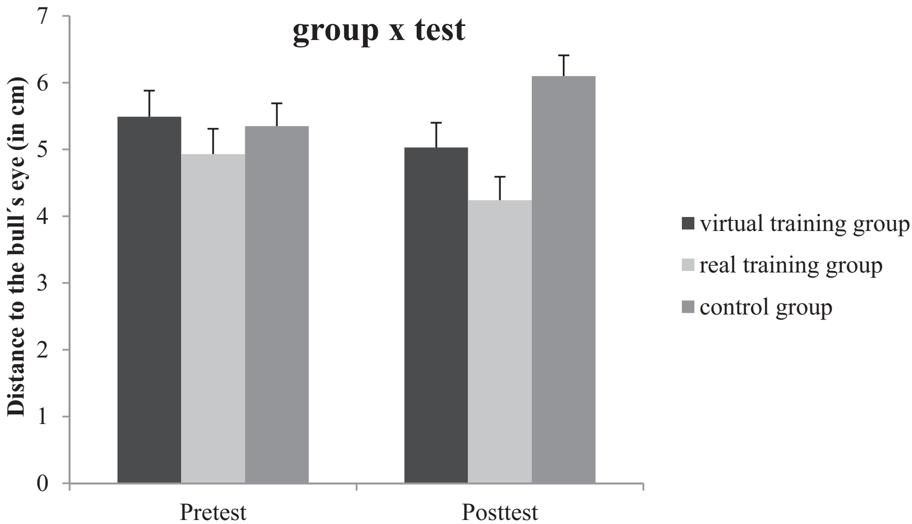

Figure 1:
Interaction of group and test in throwing accuracy in both conditions combined. Mean throwing accuracy in pre- and post-test for all groups.

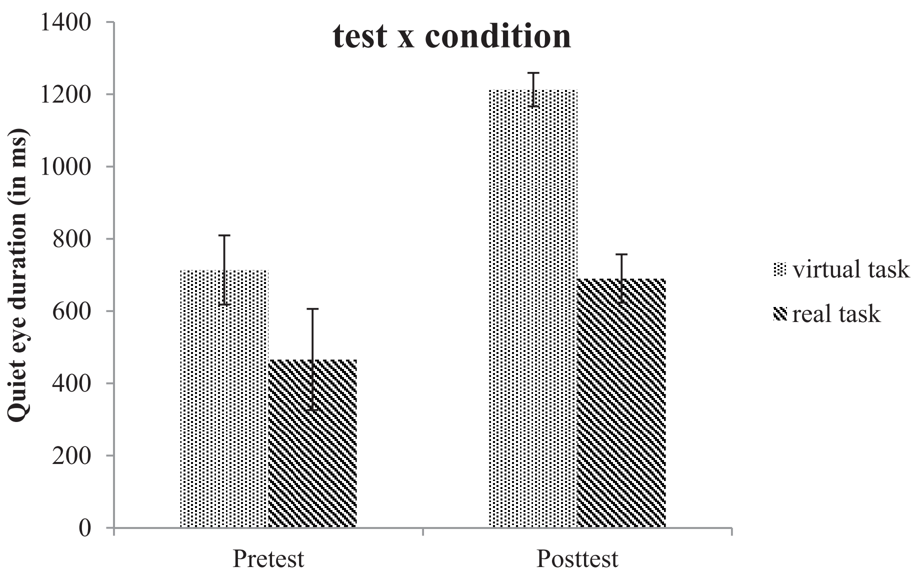

Figure 2:
Interaction of condition and test in quiet eye duration for all groups combined. Mean quiet eye duration in pre- and post-test in virtual and real dart throwing.

Discussion

Our first hypothesis considered whether virtual or real training leads to superior results and better perceptual performance. For quiet eye duration, we found a significant increase from pre- to post-test. For throwing accuracy this was not the case, although this might be due to the significant interaction of tests and groups. While both training groups improved their performance from pre- to post-test, this was not the case in the control group. Controls actually performed slightly worse during the posttest than during the pretest. Together these results show the efficiency of our training intervention not only on motor performance but also on the interacting perceptual processes (cf. Schorer, Rienhoff, Loffing, & Hagemann, 2015).

Our second hypothesis focused on the transferability of skills acquired in virtual or real environments. Here we found a more complicated picture of results. For both dependent variables we found significant differences between conditions. While shorter quiet eye duration and high errors were revealed in the real dart throwing, in the virtual condition quiet eye durations were longer and the distance to the bull´s eye was smaller. Additionally, we found a significant interaction of tests and conditions for quiet eye duration. An increase of quiet eye duration was revealed for the virtual and real tasks. This pattern of results was not visible in throwing accuracy. Because the three-way interactions did not reach significance, the interaction between tests and conditions cannot be interpreted as an indicator of missing transfer. Moreover, due to the lack of differences in the size of training effects between groups in both dart throwing tasks, it can be concluded that there was strong transfer between both conditions.

This is especially interesting given that there was an interaction of test and condition on quiet eye duration. One of the main findings in this line of research is that longer quiet eye duration leads to superior results (Harle & Vickers, 2001; Vine et al., 2011). One aim of training interventions should, therefore, be to enhance the duration of quiet-eye during training. In the current study the virtual condition resulted in longer quiet eye duration than in the real task. Unfortunately, this was neither more enhanced in the virtual training group nor did it result in a better throwing accuracy in interaction of tests and conditions. As a result, we can only suggest this interaction reflects better adaptation within the task to the cross hair presented in the virtual condition. This finding suggests some interesting avenues for future work regarding the orientation of visual attention during training.

While this study adds some interesting results regarding the relationship between real-world and virtual training, there were some limitations. For instance, while we assumed a high degree of similarity between tasks, future studies should improve on two aspects. First, the motor performance could be more similar between the tasks. While we did not collect the kinematics in the virtual and real tasks, our direct observations indicated that throwing patterns were quite different. Second, the process of aiming between both tasks differed considerably. In the real task, participants used their hand to position their movement during aiming. In the virtual environment, the movement of the hand resulted in a direct movement of the cross hair. Once the bull´s eye was aimed at, the participants simply flexed their arm and extended it again to throw. As reflected in the smaller amount of throwing error, this appeared easier than throwing a real dart. Future studies should, therefore, try to improve the similarity between tasks as much as possible.

Considering the differences in the development of the perceptual skills and the motor results, our results raise questions regarding the degree to which training must couple motor execution with the perceptual skill of quiet-eye. While one of the specific aspects of the quiet-eye is its coupling of perceptual and motor behaviour, future research should consider what happens when those skills are trained separately. For instance, it is possible that no-vision training of the motor performance might provide similar results to coupled forms of training. Results from Maxwell and colleagues (Maxwell, Masters, & Eves, 2000; Maxwell, Masters, Kerr, & Weedon, 2001) showed improvements in golf putting without participants being able to look at the target. Although there were several noteworthy differences in the studies of Maxwell and colleagues (e.g., instructions), this might be an interesting avenue for future research.

Altogether, this study presents an interesting starting point for the research of perceptual skills in virtual environments. While our results are only a stepping stone in this area, they do suggest transfer between virtual and real tasks (cf. Rose et al., 2000; Torkington et al., 2001). Moreover, they show that perceptual-motor skills can be trained in novices in a relatively short amount of training (Schorer et al., 2015). It will be interesting to see how this field develops over time, especially since virtual sports (e.g., virtual soccer leagues) are becoming increasingly more prominent.

References

Aggarwal, R., Ward, J., Balasundaram, I., Sains, P., Athanasiou, T., & Darzi, A. (2007). Proving the Effectiveness of Virtual Reality Simulation for Training in Laparoscopic Surgery. *Annals of Surgery, 246*(5), 771-779 710.1097/SLA.1090b1013e3180f1061b1009.

Baker, J., & Côté, J. (2006). Shifting training requirements during athlete development: The relationship among deliberate practice, deliberate play and other sport involvement in the acquisition of sport expertise. In D. Hackfort & G. Tenenbaum (Eds.), *Essential processes for attaining peak performance* (pp. 93-110). Aachen: Meyer and Meyer.

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real: video games and stories for health-related behavior change. *American Journal of Preventive Medicine, 34*(1), 74-82. doi: 10.1016/j.amepre.2007.09.027

Brumels, K. A., Blasius, T., Cortright, T., Oumedian, D., & Solberg, B. (2008). Comparison of Efficacy Between Traditional and Video Game Based Balance Programs. *Clinical Kinesiology, 62*(4), 26-31.

Casutt, G., Theill, N., Martin, M., Keller, M., & Jäncke, L. (2014). The Drive-Wise Project: Driving Simulator Training increases real driving performance in healthy older drivers. *Frontiers in Aging Neuroscience, 6*. doi: 10.3389/fnagi.2014.00085

Causer, J., Holmes, P. S., & Williams, A. M. (2011). Quiet eye training in a visuomotor control task. *Medicine and Science in Sports and Exercise, 43*(6), 1042-1049. doi: 10.1249/MSS.0b013e3182035de6

Deutsch, J. E., Brettler, A., Smith, C., Welsh, J., John, R., Guarrera-Bowlby, P., & Kafri, M. (2011). Nintendo wii sports and wii fit game analysis, validation, and application to stroke rehabilitation. *Top Stroke Rehabil, 18*(6), 701-719. doi: 10.1310/tsr1806-701

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534-537. doi: http://www.nature.com/nature/journal/v423/n6939/suppinfo/nature01647_S1.html

Harle, S. K., & Vickers, J. N. (2001). Training quiet eye improves accuracy in the basketball free throw. *Sport Psychologist, 15*(3), 289-305.

Heinen, T., Velentzas, K., Walther, M., & Goebel, R. (2009). (Video-)Spielend Bewegungen lernen?! Einsatz und Erforschung der Effekte digitaler Sportspiele. *f.i.t. - Forschung . Innovation . Technologie Das Wissenschaftsmagazin der Deutschen Sporthochschule Köln, 2*.

Joe, C., Bennett, S. J., Holmes, P. S., Janelle, C. M., & Williams, A. M. (2010). Quiet Eye Duration and Gun Motion in Elite Shotgun Shooting. *Journal of Sport and Exercise Psychology, 32*, S67-S67.

Johnston, R., & Weiss, P. (1997). Analysis of virtual reality technology applied in education. *Minimally Invasive Therapy & Allied Technologies, 6*(2), 126-127. doi: doi:10.3109/13645709709152716

Klostermann, A., Kredel, R., & Hossner, E. J. (2013). The "quiet eye" and motor performance: task demands matter! *J Exp Psychol Hum Percept Perform, 39*(5), 1270-1278. doi: 10.1037/a0031499

Kretschmann, R. (2008, October 16-17). *Development of competencies by playing digital sports-games?!* Paper presented at the In Proceedings of the 2nd European Conference on Game-based Learning, Barcelona, Spain.

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2000). From novice to no know-how: A longitudinal study of implicit motor learning. *Journal of Sports Sciences, 18*(2), 111-120.

Maxwell, J. P., Masters, R. S. W., Kerr, E., & Weedon, E. (2001). The implicit benefit of learning without errors. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 54*, 1049-1068.

Miles, H. C., Pop, S. R., Watt, S. J., Lawrence, G. P., & John, N. W. (2012). A review of virtual environments for training in ball sports. *Computers & Graphics, 36*(6), 714-726. doi: http://dx.doi.org/10.1016/j.cag.2012.04.007

Moore, C., & Müller, S. (2014). Transfer of expert visual anticipation to a similar domain. *The quarterly journal of experimental psychology (Hove), 67*(1), 186-196. doi: 10.1080/17470218.2013.798003

Osgood, C. E. (1949). The similarity paradox in human learning; a resolution. *Psychological Review, 56*(3), 132-143.

Oudejans, R. R. D., Koedijker, J. M., Bleijendaal, I., & Bakker, F. C. (2005). The education of attention in aiming at a far target: Training visual control in basketball jump shooting. *International Journal of Sport Psychology, 3*, 197-221.

Rienhoff, R., Baker, J., Fischer, L., Strauß, B., & Schorer, J. (2012). Fields of vision influence sensory-motor control of skilled and unskilled dart players. *Journal of Sport Science & Medicine, 11*, 542-550.

Rienhoff, R., Hopwood, M. J., Fischer, L., Strauss, B., Baker, J., & Schorer, J. (2013). Transfer of motor and perceptual skills from basketball to darts. *Frontiers in Psychology, 4*, 593. doi: 10.3389/fpsyg.2013.00593

Rose, F. D., Attree, E. A., Brooks, B. M., Parslow, D. M., Penn, P. R., & Ambihaipahan, N. (2000). Training in virtual environments: Transfer to real world tasks and equivalence to real task training. *Ergonomics, 43*(4), 494-511.

Rosenberg, B. H., Landsittel, D., & Averch, T. D. (2005). Can video games be used to predict or improve laparoscopic skills? *J Endourol, 19*(3), 372-376. doi: 10.1089/end.2005.19.372

Ruffaldi, E., & Filippeschi, A. (2013). Structuring a virtual environment for sport training: A case study on rowing technique. *Robotics and Autonomous Systems, 61*(4), 390-397. doi: http://dx.doi.org/10.1016/j.robot.2012.09.015

Satyen, L., & Ohtsuka, K. (2001). Strategies to develop divided attentionskills through video game training. In D. Harris (Ed.), *Engineering psychology and cognitive ergonomics* (Vol. 6, pp. 191-199). UK: Ashgate: Aldershot.

Schmidt, R. A., & Wrisberg, C. A. (2000). *Motor learning and performance. A problem-based learning approach* (3. ed.). Champaign: Human Kinetics.

Schorer, J., Rienhoff, R., Loffing, F., & Hagemann, N. (2015). Efficacy of training interventions for acquiering perceptual cognitive skill. In J. Baker & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise*. London: Routledge.

Siemon, A., Wegener, R., Bader, F., Hieber, T., & Schmid, U. (2009). *Video Games can Improve Performance in Sports - An Empirical Study with WiiTMSports Bowling*. Paper presented at the Proceedings of the KI Workshop on Human-Machine-Interaction, Paderborn, Germany.

Thorndike, E. L. (1914). *Educational psychology: Briefer course*. New York: Columbia University Press.

Torkington, J., Smith, S. G. T., Rees, B. I., & Darzi, A. (2001). Skill transfer from virtual reality to a real laparoscopic task. *Surgical Endoscopy, 15*(10), 1076-1079. doi: 10.1007/s004640000233

Vickers, J. N. (1992). Gaze control in putting. *Perception, 21*(1), 117-132. doi: 10.1068/p210117

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 342-354. doi: 10.1037//0096-1523.22.2.342

Vickers, J. N. (2007). *Perception, cognition and decision training: The quiet eye in action.* Champaign, IL: Human Kinetics.

Vickers, J. N., Rodrigues, S. T., & Edworthy, G. (2000). Quiet eye and accuracy in the dart throw. *International Journal of Sports Vision, 6*, 30-36.

Vine, S., Moore, L., & Wilson, M. (2011). Quiet eye training facilitates competitive putting performance in elite golfers. *Frontiers in Psychology, 2*. doi: 10.3389/fpsyg.2011.00008

Wiemeyer, J. (2010). Gesundheit auf dem Spiel? – Serious Games in Prävention und Rehabilitation. *Deutsche Zeitschrift für Sportmedizin, 11*, 252-257.

Wiemeyer, J., & Hardy, S. (2013). Serious Games and Motor Learning: Concepts, Evidence, Technology *Serious Games and Virtual Worlds in Education, Professional Development, and Healthcare* (pp. 197-220). IGI Global.

Wiemeyer, J., & Schneider, P. (2012). Applying Serious Games to Motor Learning in Sport. *International Journal of Game-Based Learning (IJGBL), 2*(4), 61-73. doi: 10.4018/ijgbl.2012100104

Wolf, S. L., Barnhart, H. X., Ellison, G. L., & Coogler, C. E. (1997). The effect of Tai Chi Quan and computerized balance training on postural stability in older subjects. Atlanta FICSIT Group. Frailty and Injuries: Cooperative Studies on Intervention Techniques. *Journal of the American Physical Therapy Association, 77*(4), 371-381.

Wood, G., & Wilson, M. R. (2011). Quiet-eye training for soccer penalty kicks. *Cognitive Processing, 12*(3), 257-266. doi: 10.1007/s10339-011-0393-0