Training Visual Control in Wheelchair Basketball Shooting

Raôul R. D. Oudejans, Sjoerd Heubers, Jean-René J. A. C. Ruitenbeek, and Thomas W. J. Janssen

We examined the effects of visual control training on expert wheelchair basketball shooting, a skill more difficult than in regular basketball, as players shoot from a seated position to the same rim height. The training consisted of shooting with a visual constraint that forced participants to use target information as late as possible. Participants drove under a large screen that initially blocked the basket. As soon as they saw the basket they shot. When training with the screen, shooting percentages increased. We conclude that visual control training is an effective method to improve wheelchair basketball shooting. The findings support the idea that perceptual-motor learning can be enhanced by manipulating relevant constraints in the training environment, even for expert athletes.

Key words: far aiming, perceptual learning, visual attention training

Wheelchair basketball is played in over 75 countries. First played as an organized sport over 50 years ago, it has become the most popular of all wheelchair sports (Malone, Nielsen, & Steadward, 2000). During the last decades, a large number of players have changed from amateurs to semiprofessionals, and interest for the game keeps growing (Goosey-Tolfrey, Butterworth, & Morriss, 2002). Similar to regular basketball, success in wheelchair basketball depends mostly on the player's skill in throwing the ball through the rim. However, this skill is even more difficult than in regular basketball, as the rim is the same height as in regular basketball (3.05 m), while wheelchair

Raôul R. D. Oudejans is with the Faculty of Human Movement Sciences at VU University Amsterdam. Thomas W. J. Janssen is with the Faculty of Human Movement Sciences at VU University Amsterdam and the READE Rehabilitation Center Amsterdam, The Netherlands. Sjoerd Heubers is with the Rehabilitation Center Amsterdam, The Netherlands. Jean-René J. A. C. Ruitenbeek is with the Hogesshool, Rotterdam, The Netherlands.

players sit in a low position and are unable to use upward leg force to help project the basketball (Goosey-Tolfrey et al., 2002; Malone et al., 2000). Because almost all force is generated with the arms and trunk, it is difficult to apply the required force to the ball to reach the basket (Goosey-Tolfrey et al., 2002; Malone et al., 2000).

For regular basketball, Oudejans and colleagues provided insight into the visual control of basketball free throws and jump shots (De Oliveira, Oudejans, & Beek, 2006, 2008, 2009; Oudejans & Coolen, 2003; Oudejans, Van de Langenberg, & Hutter, 2002). They investigated the information sources used and when this information is optimally detected for successful shooting. These insights provide starting points for how the visual control of shooting can be trained to improve shooting performance (cf. Oudejans & Koedijker, 2010; Oudejans, Koedijker, Bleijendaal, & Bakker, 2005).

In general, most sports training focuses on physical conditioning, improving technical skills, and game tactics. Relatively little training aims at improving players' perceptual skills (Abernethy, 1996), while there is accumulating evidence that perceptual expertise is an important factor in several sports (see Williams & Ward, 2003). A key question is whether it is possible to speed up or optimize perceptual skill development through training (Adolphe, Vickers, & Laplante, 1997; Oudejans et al., 2005; Williams

& Ward, 2003; cf. Davids, Button, & Bennett, 2008; Renshaw, Davids, & Savelsbergh, 2010; Vickers, 2007). In the current study, we investigated the effects of an on-court visual control training program on expert wheelchair basketball players' shooting performance.

Oudejans et al. (2002) found that expert basketball jump shooting relied almost exclusively on seeing the rim late during the unfolding of the movement, that is, the last 300-400 ms before ball release. However, this also appeared to depend on whether players had a high or low shooting style. With a high style, the ball "is lifted up past the face into position from which the shot is completed with an extension of the right elbow and a flexion of the wrist and fingers" (Hay, 1993, p. 240). The low style has been described as pushing, during which the ball and hands remain below or at eye level for almost the entire shooting action (Kreighbaum & Barthels, 1981). The main difference between the two styles regarding visual control is whether the shooter can see the basket only before (low style) or also after (high style) the ball and hands enter the line of sight to the rim (Oudejans et al., 2002).

De Oliveira et al. (2006) found that late pick-up of visual information characterized expert jump shooting in both low and high style shooters, implying that it is crucial to detect visual information as late as the style allows; about 300–400 ms before the ball enters their line of sight for the low style (see also De Oliveira et al., 2008) and the 300–400 ms after that moment for the high style (De Oliveira et al., 2006). Regardless of style, it may be that players do not efficiently use the latest and most updated visual information during a basketball shot. With specifically designed visual control training, it may be possible to optimize the timing of visual information detection in basketball shooting. Previous research showed it is possible to accelerate perceptual learning in sport. For instance, Adolphe et al. (1997) trained 3 elite volleyball receivers who exhibited nonoptimal gaze behavior. Gaze behavior improved in several ways, indicating that perceptual training can be effective, even with expert athletes. Harle and Vickers (2001) succeeded in improving female collegiate basketball players' visual information pick-up as well as free-throw performance. In the latter study, training involved explicit instructions about gaze behavior.

Oudejans et al. (2005) examined the effects of implicit visual control training on talented junior basketball players' high style jump shooting. Using specific constraints rather than explicit instructions during shot training, players had to use the latest possible and, thus, most useful information (De Oliveira et al., 2006; Oudejans et al., 2002). Constraints were created by a screen or with liquid crystal (LC) goggles. With the screen, the player stood behind a screen and could not see the basket. At the moment the player made a jump shot, the rim became visible as it was possible to look over the screen while airborne. This provided a sufficient time span to detect information from

the rim (see Oudejans et al., 2002). With the LC goggles, vision was provided only during the final 300–400 ms prior to ball release. Results revealed that players improved their shooting percentages by more than 10%.

The latter study fits well with the principles of the constraints-led approach, a theoretical framework for understanding how children and adults acquire movement skills for sport and exercise (Davids et al., 2008; Renshaw et al., 2010). A starting point of this approach is that "important constraints, such as information available during practice, the structure of practice tasks and the skill level of the learner, interact to facilitate learning" (Davids, 2010, p. 14). The study by Oudejans et al. (2005) is one of few examples from the constraints-led approach that shows visual control training may enhance performance. Importantly, the general principle of constraining relevant information in the training environment holds promise for enhancing performance. Given several limitations of that study, a replication of the findings with different manipulations and task constraints was necessary.

Therefore, the aim of the current study was to investigate whether a visual control training program designed specifically for expert wheelchair basketball players could also improve their shooting performance. Again, training consisted of a shooting drill with a visual constraint but tailored to the specific task constraints of wheelchair basketball shooting. Once more, we used a large screen but in such a way that the wheelchair players had to drive underneath it to see the basket. As in the study of Oudejans et al. (2005), the screen forced participants to use information as late as possible. The effectiveness of the program with this new group would support the applicability of the general principle behind the training program: forcing players to use the most useful information for the task by manipulating (visual) constraints in the training environment (Oudejans & Koedijker, 2010; see Davids et al., 2008; Renshaw et al., 2010). Support for this general principle of the constraints-led approach (Davids et al., 2008) would open more possibilities for interventions in sport beyond those tested here and by Oudejans et al. (2005). Needless to say, success of the screen training would have immediate relevance for wheelchair players who wish to improve their shooting.

Compared to the Oudejans et al. (2005) study, we made several improvements to the design. Oudejans et al. (a) used a single-subject design with few participants, (b) had one intervention period, and (c) examined game shooting percentages with limited control over several external factors, such as seasonal fluctuations. In the current study, we used a pretest-posttest design and two training periods, one with and one without the screen. This design provided a controlled check of the screen training effectiveness. We hypothesized that shooting percentages would be higher after training with the screen and they would be the same after training without the screen.

Method

Overview

Comparable to Oudejans et al. (2005), the visual control program consisted minimally of six training sessions in 4 weeks during which participants performed a shooting drill with a visual constraint specifically designed for wheelchair basketball players. The constraint was a large screen that blocked a view of the basket until participants had driven underneath it. As soon as they cleared the screen and saw the basket, they took their shot.

Control participants received the same training without the screen. Training with and without the screen was counterbalanced (i.e., in the first training period several participants trained with the screen and others trained without it, while roles were reversed in a second training period). Also, the study consisted of three tests, one *prior to* the first training period, one *after* the first training period, and one after the second training period. Each consisted of full vision (FV) and late vision (LV) conditions. We included the LV condition to determine whether screen training affected shooting with a comparable visual constraint. We included the FV condition to investigate whether any screen training effects transferred to a "normal" FV shooting condition. Participants always executed the FV condition before the LV to prevent possible interference of the LV visual constraint on FV shooting.

Participants

Ten male expert wheelchair basketball players (*M* age = 25.5 years, *SD* = 6.1) volunteered to participate in the study. All were members of the Dutch National team and had an average of 9.4 years (*SD* = 5.2) of experience in competition wheelchair basketball. Prior to the study, the institutional ethics committee approved the protocol. All participants provided informed consent following a brief explanation of the experimental purpose and procedure.

Experimental Set-up

Tests. In a large room (7.5 m high) a standard basket with multiplex backboard (1.80 x 1.05 m) and rim (0.45 m diameter; height 3.05 m) was set-up. We used International Basketball Federation regulation-size basketballs. Players sat in their own basketball wheelchair and wore LC goggles (Plato, Translucent Technologies, Toronto, Canada) to manipulate vision. To open the goggles in the LV condition, an optical switch was placed 80 cm in front of the shot area (see Figure 1). When the wheelchair passed the switch (in driving to the shot area), the signal from the switch opened the goggles. The wires of the goggles and optical switch were connected to a host PC.

Screen Training. The screen trainings took place with two standard baskets in the basketball players' regular training facilities. The screen was a tarpaulin between two poles. The screen was 2 m high, 3 m wide, and adjustable from a minimum height of 1.30 m to a maximum of 1.65 m from the floor to the bottom of the screen. The screen was placed parallel to the free throw line 0.5 m further away from the basket. Training results were monitored to gain insight into the development of shooting percentages from training session to training session.

Procedure

Tests. Participants warmed up with 5-min of practice shots. When each was comfortable with the task, he executed 25 shots in the FV condition. Experimenter 1 indicated when the participant could start each shot. Experimenter 2 moved the wires back and forth behind the wheelchair to prevent wire damage or wheelchair obstruction. The participant started 3–5 m away from the free throw line with two pushes in a straight line facing the basket, with the ball in his lap. After the two pushes, the participant picked up the ball and shot immediately. The shooting area ranged from 50 cm in front of to 50 cm behind the free throw line. Hits and misses were registered.

After the 25 FV shots, each participant rested briefly (a few minutes) before starting the LV condition. Then each participant performed three driving motions to the basket without the ball to get used to the closing and opening of the goggles. Subsequently, they took several practice shots (< 10) followed by the 25 experimental shots. Before each shot, the participant saw the basket from the starting line. After a signal from Experimenter 1, the goggles closed and the participant started with two forward pushes. On passing the optical switch, the goggles opened, and he shot immediately.

Training Sessions. During each training session, players performed a shooting drill of 25 shots with or without the screen. Due to variation in attendance, there were also differences in the number of training sessions performed. On average, participants trained 9.7 times (*SD* = 2.3) with the screen, and 8.4 times (*SD* = 1.8) without the screen.

Players began from the starting spot, 4 m behind the screen. The screen was placed so that players faced the basket and did not need to turn their wheelchair to get a good shot. As long as they were behind the screen,
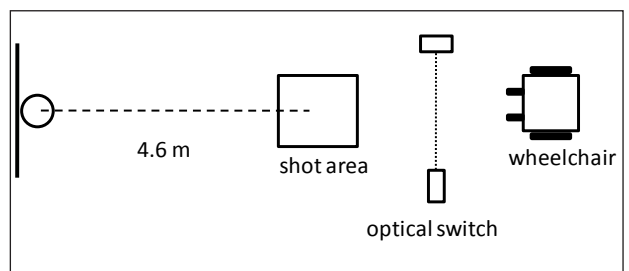

Figure 1. Top-view of experimental set-up during the tests.

they were not able to see the rim. Players used two pushes to build up speed and drive underneath the screen. As soon as the screen was cleared and the rim was visible, the participant shot. With a separate test, we determined from videos that participants shot as soon as possible. On average it took only 0.60 s from clearing the screen until ball release ($SD = 0.13$). Players took shots from close to the free throw line. After each shot, the player curled back around the screen and returned to the starting position. Other players rebounded the ball and returned it to the shooter. The experimenters scored shot outcomes (hit or miss). Apart from the absence of the screen, shooting drill procedures without the screen were identical to the drill with the screen.

Data Reduction

Shooting percentage was determined by the numbers of hits and misses during the tests and training sessions. Statistical testing of percentages during the tests, including order of the training periods as a factor, did not yield relevant effects of order. Therefore, shooting percentages were analyzed using two 2 (test: pretest-posttest) × 2 (visual condition: FV, LV) analyses of variance (ANOVAs) with repeated measures on both factors. Appropriate follow-up tests were executed whenever necessary. Effect sizes were calculated using Cohen's f with ≤ 0.10, about 0.25, and ≥ 0.40, representing small, moderate, and large effects, respectively (Cohen, 1988). Furthermore, average percentages for training with and without the screen were submitted to regression analyses.

Results

Shooting Percentage

Screen Training: Pretest-Posttest. The Test (pretest, posttest) x Visual Condition (FV, LV) repeated measures ANOVA on shooting percentages before and after training with the screen revealed a significant main effect of test, $F(1, 9) = 53.37$, $p < .001$, Cohen's $f = 2.48$, showing higher shooting percentages after training with the screen compared to before training (see Table 1). There were no other significant differences, $F < 1.97$, *ns*, Cohen's $f < 0.47$.

No Screen Training: Pretest-Posttest. The Test (pretest, posttest) x Visual Condition (FV, LV) repeated measures ANOVA on shooting percentages before and after training without the screen yielded a significant main effect of vi-

Table 1. Shooting percentages before and after training

Training	Condition	Pretest		Posttest	
		M	*SD*	*M*	*SD*
Screen	Full vision	39.6	16.2	52.0	12.1
	Late vision	36.0	12.2	44.4	11.8
	Mean	37.8	14.1	48.2	12.3*
No Screen	Full vision	50.4	13.5	50.8	10.5
	Late vision	44.0	11.8	44.0	8.6
	Mean	47.2	12.8	47.4	10.0

Note: M = mean; *SD* = standard deviation.
*$p < .05$.
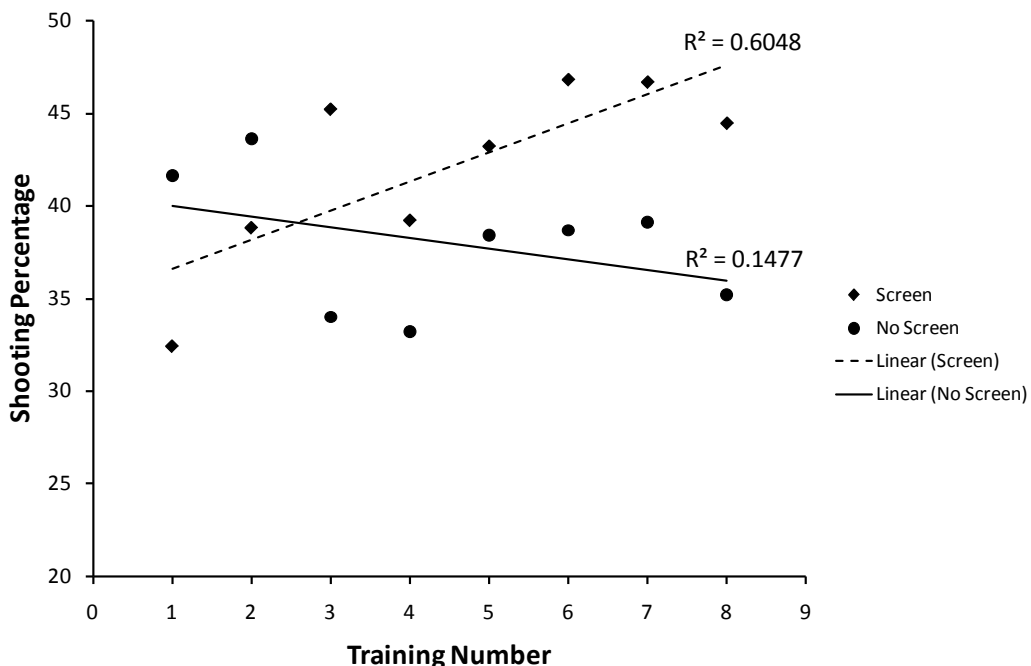
Figure 2. Shooting percentages and linear regression lines for the training sessions with and without the screen.

sion, $F(1, 9) = 6.20$, $p = .034$, Cohen's $f = 0.83$, revealing that shooting percentages were significantly higher with full vision compared to late vision (see Table 1). There were no other significant differences, $F < 1$, ns, Cohen's $f < 0.03$.

Training Results

Figure 2 displays results per training period. Linear regression analyses were conducted on the mean shooting percentages over the training sessions. During training with the screen, performance showed a positive slope of 1.58, $p = .023$, $R^2 = .60$, while performance without the screen showed a nonsignificant negative slope of -0.57, $p = .348$, $R^2 = .15$. Thus, there were small but systematic increases in shooting percentage during training with the screen but not when training without the screen.

Discussion

Our aim was to investigate whether specially designed visual control training can improve expert wheelchair basketball players' shooting performance and visual information pick-up. During training, a screen constrained vision of the basket. Participants drove underneath the screen and shot as soon as they could see the rim. Control participants received a similar training intervention without the screen. Screen training had a positive effect on shooting performance after only about eight training sessions in 4 weeks. In addition, a positive correlation between session number and performance was evidence of systematic increases during the screen training sessions. These increases provide additional confidence in test results. Thus, improved shooting percentages following screen training, systematic increases during screen training, and lack of improvement when training without the screen lead us to conclude that visual control training enhanced wheelchair basketball players' shooting performance.

The results are consistent with the study by Oudejans et al. (2005), who found that junior basketball players' jump shooting performance improved after a similar, specifically designed visual control training program. The fact that we also found positive results with wheelchair basketball players is clear support for the constraints-led approach (Davids et al., 2008; Renshaw et al., 2010) and one of its main principles that forcing players to use the most useful information for the task by manipulating relevant (visual) constraints, facilitates perceptual-motor learning (cf. Oudejans & Koedijker, 2010), even in experts. Because we measured shooting percentages only, we can merely speculate about the precise mechanisms underlying performance improvements following screen training. We would argue, just as Oudejans et al. (2005), that by training with the screen participants were forced to use the latest visual information possible, which was shown

in earlier studies showing to be necessary and sufficient for accurate shooting (De Oliveria et al., 2006; Oudejans et al., 2002). Because only late information was available, participants learned to tune their movements to this information (cf. Jacobs & Michaels, 2002; Oudejans et al., 2005; Withagen & Michaels, 2002), leading to better shooting.

More research is needed to gain insight into the mechanisms underlying visual control training (e.g., the effects on gaze behavior). Savelsbergh, Van Gastel, and Van Kampen (2010) found changes in gaze behavior following perceptual training of goalkeepers anticipating penalty kick direction. It is not unlikely that in the learning process just described the timing and duration of the final fixation on the target was enhanced (cf. Vine & Wilson, 2011; Wood & Wilson, 2011). A well timed, relatively long final fixation on the target is characteristic of higher skill levels and accuracy in sport (e.g., Binsch, Oudejans, Bakker, & Savelsbergh, 2010; Vickers, 2007; Vickers, Rodrigues, & Edworthy, 2000). Further research is needed to learn whether positive effects would transfer to actual competition, as Oudejans et al. (2005) found for able-bodied basketball players. Finally, the visual constraint used in this study was not as stringent as the one used by Oudejans et al. In their study, participants could see the rim only briefly at the top of the jump. In the current study, participants were instructed to shoot immediately after passing the screen, which is a much looser constraint on the time available for information detection. Still, our check revealed that players shot within 600 ms after clearing the screen, implying that they shot without hesitation. As a comparison, an able-bodied player's jump shot lasts about 600 ms from jump landing until ball release. Thus, even with a less stringent visual constraint, positive results can be obtained (cf. Oudejans, in press; Oudejans & Koedijker, 2010).

To conclude, when information is constrained during visual control training, it may facilitate perceptual-motor learning in sports. In the current study, the screen provided a simple tool that could easily be implemented in regular basketball training sessions. Probably, there is considerable scope for innovative and creative implications of visual control training in other sports as well. In general, visual control training may be relatively easy to implement in practice, depending on the sport in question. Using specific visual constraints, athletes could be forced to rely on information that is crucial for task execution (cf. Oudejans & Koedijker, 2010), thereby improving performance.

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Authors' Notes