©Journal of Sports Science and Medicine (2012) **11,** 624-631
http://www.jssm.org

Research article

The impact of a sports vision training program in youth field hockey players

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Abstract
The aim of this study was to investigate whether a sports vision training program improves the visual performance of youth male field hockey players, ages 12 to 16 years, after an intervention of six weeks compared to a control group with no specific sports vision training. The choice reaction time task at the D2 board (Learning Task I), the functional field of view task (Learning Task II) and the multiple object tracking (MOT) task (Transfer Task) were assessed before and after the intervention and again six weeks after the second test. Analyzes showed significant differences between the two groups for the choice reaction time task at the D2 board and the functional field of view task, with significant improvements for the intervention group and none for the control group. For the transfer task, we could not find statistically significant improvements for either group. The results of this study are discussed in terms of theoretical and practical implications.

Key words: Sports vision, perception, choice reaction time.

Introduction

There is no doubt that performance in sport is linked to cognitive and perceptual skills as well as motor and physical abilities. Over the last years, perceptual skills have received considerable research interest within the sports domain, especially the comparison between expert and novice performances (Memmert et al., 2009). Research in the area of attention suggests that expert and novices across various domains of expertise differ in their basic attention abilities (Allen et al., 2004; 2006; Bellenkes et al., 1997). In addition, there is recent evidence for enhanced basic attentional abilities among video-game experts (Green and Bavelier, 2003). Relatively less research has been conducted on improving perceptual skills amongst athletes. Revien and Gabor (1981) argued visual abilities can be trained and that visual perception training programs have a great impact on the improvement of visual abilities: "visual training […] may well make the difference between winning and losing, between revelling in keen competition or shrinking from it" (1981, p. 21). As previous research has seriously challenged this claim (Abernethy and Wood, 2001), this study attempted to shed further light on the use of generalized visual training programs in sports using a newly created intervention.

Besides the common static acuity of vision, there are a lot of visual abilities that might potentially facilitate performance in a range of fast-paced sports. These include peripheral vision, choice reaction time and dynamic vision. While central vision provides closure and identification, peripheral vision provides visual impressions of space, orientation and movement (Brandt et al., 1973; Bursill, 1958; Schnell, 1999). The differences between central and peripheral vision are mirrored in subtle physiological and anatomical differences in the visual cortex. Peripheral vision is a part of vision that emerges outside the very center of gaze. It is quite weak at keeping color and shape apart but good at catching motion and relatively strong at night or in the dark (Palmer and Rosa, 2006). For all team ball sports, it is indispensable to see and observe teammates as well as opponents in order to play effectively and efficiently (Williams and Davids, 1997) and the players as well do not have the time to interpret all of the information available (Bard and Fleury, 1976). No competition can be mastered successfully without the players' capability to use their peripheral vision. If a player had to constantly move his head to see what is going on around him, he would immediately lose sight of his running direction and not be aware of whatever important action is happening right in front of him (Campher, 2008). Here, the human capacity of a 190° peripheral vision provides a big advantage (Anderson, 1987). The player does not have to move his head and can still capture action that takes place slightly behind him. The farther behind a person is located, the more the perceiver would have to move his head to perceive the person. This good spatial resolution of the periphery is extremely important in the majority of sports (Sivak and Mackenzie, 1992). For completing a pass in field hockey, it is often very helpful having a good peripheral vision to increase the possibility of identifying an unmarked teammate.

With regard to choice reaction time, there are only very few sports that do not depend on choice reaction time. Choice reaction time is a measure of the time from the arrival of a suddenly presented stimulus (visual reaction time) until the beginning of the actual action (motor response). Therefore, one needs to examine how long it takes the brain to recognize a visual stimulus and how long it takes the respective part of the body to adequately respond to this stimulus. Most sports depend on an excellent eye-hand or eye-foot coordination which in turn is directly linked to the speed of visual reaction and motor response. The capability of becoming aware of a movement or a situation a split second faster than an opponent is important in ball sports as well as many other sports as it may offer athletes the decisive advantage. Or think of a goalkeeper in field hockey in a penalty corner situation. The opponent striker has a very close distance to the goal and so the goal-keeper needs a great reaction time to save the shot. A fast choice reaction time depends on multiple factors such as the sense of hearing and sight, special

Received: 20 March 2012 / Accepted: 28 July 2012 / Published (online): 01 December 2012

athletic capabilities (Delignières et al., 1994) as well as experience and gender (Adam et al., 1999).

In sports, a crucial factor is that the athlete has to capture complex game situations as well as movements of objects, teammates and opponents while being in motion himself - often under extreme time pressure. One parameter to quantify and evaluate the performance of motion vision is called dynamic visual acuity. Ludvigh and Miller (1953) defined the dynamic visual acuity as the ability to correctly identify the smallest possible “critical detail” in a moving visual object at a steady angular velocity. Therefore, due to the fast-paced actions and high ball speeds in racquet sports, it appears pertinent to evaluate the capacity of the visual system to “localize” an object of a determined size, (e.g. a hockey ball) with a constant “critical detail” and at the highest possible angular velocity. For example, in a match-play a hockey ball can reach speeds of up to 147 km/h. Thus, the motion vision, also known as ‘saccadic locating speed’, comes to the forefront in hockey.

Previous research

Several intervention studies using generalized visual training programs have been conducted in the sports domain. Presently the evidence concerning their effectiveness is mixed although, the majority of studies suggest no beneficial effect of generalized visual training programs (see for a review, Abernathy, 1996). Nevertheless, we argue that this might be due to specific interventions chosen in the respective studies or the impact of modifiable factors. Harper et al. (1985) for example investigated groups of rifle and pistol shooters in terms of motor and visual performance after two weeks of visual training. They did not find significant differences in the shooting performance and the visual parameters between the intervention group and the control group. Wood and Abernethy (1997) demonstrated that a four week visual training program for racquet sports, consisting of 4x20min/wk sessions of sports vision exercises and a single 20min motor practice session, improved performance on several exercises that were part of a training test battery. The battery of tests consisted of general vision and sport-specific motor and perceptual tests. The subjects in the visual training group, who had no specific competitive experience in any of the racquet sports of tennis, squash or badminton, did not improve their motor performance and were also not able to translate it into enhanced performance on any of the sport-specific perceptual measurements known to be directly linked to expert sports performance. In another study involving a four week racquet sports’ visual training program, Abernethy and Wood (2001) reported no evidences for improvements in motor vision performance. The study design consisted of two experimental groups with one group using the sports vision program of eye exercises for athletes from Revien and Gabor (1981) and the another group training with the eyerobics video-based training program from Revien (1987).

On the other hand, other research groups reported benefits from generalized visual training programs. Calder (1997) revealed that elite female field hockey players improved their performance during four weeks in 16 of 22 field-hockey skills when they received a visual awareness program (took part one hour, three times a week) on top of the visual skills (about ten minutes, five days a week) and normal training. Quevedo et al. (1999) found that the experimental group showed improvements in the four tested variables (shooting, concentration, saccades and visual acuity) after a nine session training program of shooting with specific visual exercises. This training program took part once a week for 50 minutes. The control group improved as well, but not with reference in the visual acuity. Another study from Maman et al. (2011) found similar results as well: the experimental group improved their visual variables as well as their motor performance after eight weeks of additional sports vision and eye hand coordination training with three times 45 minutes per week compared to the placebo group and the control group. The study concluded that the visual training program leads to an enhancement of the basic visual skills and that this improvement is transferable into sport-specific performance. Campher (2008) showed that a visual skill training program is beneficial to cricket performance, because more than half of the variables improved over eight weeks with a training session once a week for 60 minutes. This means that the cricket players showed significant improvements in, for example, peripheral vision, ball skills, concentration, focus flexibility and coordination. This study used the sports vision dynamics method (Bressan, 2003) which includes sports optometry, coaching, biomechanics, motor control and psychology of perception. Studies also demonstrated that superior visual skills are closely related to superior performance, such as the identification of pitches in baseball (Reichow et al., 2011) and better decision-making in soccer refereeing (Ghasemi et al., 2011).

From a methodological viewpoint, the presented studies reveal the use of particularly different designs with regards to the weekly frequency of training and the total duration of the intervention program. In addition, none of the studies contained either a retention or transfer test. A retention test can provide more detailed conclusions about the performance and, accordingly, to the learning progress after a sports vision training program. That means that when using a vision training intervention, short-term developments in performance may occur that should not be confused with increases in learning.

A principal aim of the present study was to further improve on previous research by a) a newly created complex intervention training basic perceptual skills, b) a more intensive and demanding training program (six weeks lasting intervention with three sessions at 45 minutes per week), c) a retention task, d) comparing randomized groups selected randomly from the same sample, and e) using an additional transfer test. The training programs made use of the DynamicEye® SportsVision Training Program and it is explained later in a more detailed way. The hypothesis of this study was that a complex sports vision training program based on the DynamicEye® SportsVision Training Program with five different training tasks can produce stable improvements in the central perception and the choice reaction time in a group of adolescent hockey players. For an exploratory purpose we conducted a transfer task (multiple object tracking task).

Methods

Participants

Thirty-four male youth field hockey players from two local hockey clubs in Cologne aged 12 to 16 years (M = 14.2) participated voluntarily in this experiment. They had practiced the sport for an average of 6.8 years (SD = 1.8). Twenty-two of them were allocated randomly to the intervention group (M = 14.3) whereas 12 participants were assigned to the control group (M = 13.9). It was ensured that all participants of the intervention group had binocular vision. Two participants of the intervention group wore spectacles with marginal ametropia. Furthermore, it was an important precondition for every participant that no one in their family had ever suffered from epilepsy. During the intervention, stroboscopic effects were used, which are said to potentially evoke cramp attacks in few cases under certain conditions. The players of the intervention group received 200 € for their participation and the members of the control group received 30 €. Informed written consent was obtained from one parent and assent from all participants before they took part at the experiment.

Materials and design

The experiment was a 3 (measuring point) x 2 (group) design. Participants either had a special training program to improve their visual ability over six weeks (intervention group) or just took part in the three different measuring points (control group). These three different measuring points consisted of a pre test, a post test and a retention test at intervals of six weeks. The training program was designed with the following equipment: Dynavision D2® Trainer, Eyeport, Vision Performance Enhancement Program, Hart Charts and P-Rotator.

Station one (D2 Dynavision Board): The D2 is a visuomotor training device intended to enhance eye-hand coordination, visual and motor reaction abilities, and perception in the periphery (Figure 1). Every training session is designed, performed, analyzed and stored by software. The D2-board uses 64 light emitting buttons on a 1.20 meters x 1.20 meters grey board and is height adjustable.

Figure 1. Dynavision D2® trainer.

Station two (Eyeport): The Eyeport Vision Training System is used to train all aspects of the gaze motor activity (Figure 2). The eyes have to follow flashed red and blue light emitting diodes. This causes the eye muscles to stretch in every possible direction, at different speeds and in predictable or random order. Furthermore, fixation as well as convergence- and divergence skills are trained.

Figure 2. Eyeport.

Station three (Vision Performance Enhancement Program): The Vision Performance Enhancement Program is a special vision training software for athletes which trains various visual skills like central and peripheral awareness, saccadic fixation, reaction time, scanning, tracking, stereopsis, etc.. (Figure 3). From the available exercises, five units were chosen for the DynamicEye®Sports Vision Training.

Figure 3. Vision performance enhancement program.

Station four (Hart Charts): Hart Charts are tables with letters in different sizes that are fixed to the wall (Figure 4). The distance between the charts was steadily increased from training session to training session. The task was to localize as many letters on the charts as possible in a given order on the different tables in use.

Figure 4. Hart charts

Station five (P-Rotator): The P-Rotator is a computer controlled rotating disk with alternating rotating direction and gradual speed regulation (Figure 5). On the disk, letters in different sizes are applied which have to be localized and followed from a distance of 1.50 meters in multiple requirement profiles corresponding to the daily training plan.

Figure 5. P-Rotator.

Procedure

The intervention was performed in the "VisuLab" as DynamicEye® SportsVision Training at the German Sport University Cologne. The intervention period lasted for six weeks with a pretest in the first session, a posttest in the last session of the intervention period and a retention test six weeks after the second test. During these six weeks, the participants of the experimental group exercised three times a week for 45 minutes according to the DynamicEye®SportsVision Training Program whereas the control group only took part in the three test sessions and did not have any additional training. During the three test sessions, participants had to solve two learning and one transfer task, which are explained in the sub-item dependent variables. Each training session was based on circuit training so that every participant of the intervention group exercised all of the five different stations in one 45 minutes period. The order of the training was randomized and every station had seven minutes of practice.

At the beginning of every training session, the participants of the experimental group were given a training schedule with the specific training activities for the respective day. Identical training plans for all participants were used for a specific training day irrespective of the participants' proficiency level. The daily training results were captured by means of specific training sheets, on which all the specific exercises were defined and on which the participants' scores and time were recorded. All athletes were asked for maximum performances during these training sessions. For the period of a competition, the physical, mental and visual performance had to be kept on a steady high level. It is noticeable that the maximum performance can be generated, but stressful factors such as stadium sounds, adrenalin fluctuations, exhaustion (Hodge et al., 1999; Griffiths, 1994), etc. can negatively influence the athletic performance.

According to the loading-principle of the DynamicEye®SportsVision Training, the athletes were confronted with varying stress factors during the training. After two weeks of basic training of visual skills, additional coordinative or cognitive exercises were presented to the participants. In order to have all participants on a homogeneous performance level and so not starting with these additional exercises at the beginning, the basic exercises were repeated for a couple of times. The assumption is that training on a higher energy level helps to withstand symptoms of fatigue and to build valuable reserves that can be activated during competitions. Different loading elements used during the six week intervention were for example a balance board, Impulse Shutter glasses, juggling, or cognitive tasks. All the participants used the same specific elements in the same order and with identical time periods.

The balance board, for example, was integrated at the P-Rotator. At the beginning, every participant was standing in a steady position with both feet hip-width apart and parallel. In the first two weeks, the balance was also practiced. The participant had to stand on one leg and close the eyes. Losing the balance first after one minute meant starting to use a balance board while practicing with the P-Rotator.

The impulse shutter glasses used the strobe effect (Reichow et al., 2010). A strobe light gives off flashes in very constant temporal intervals. On the one hand you can define the gating time with duty ratio (d) from 50% to 99% and on the other hand one can regulate the frequency (f) of the shutter from 99 to 1 per second; the higher the frequency, the less irritating. In the experiment it started with d=50 and f=5, that means that 50% of the time, the shutter was open and was activated for five times during one second ending with d=25 and f=3. The visual system can process optical stimuli in 100 to 200 milliseconds (Long, 1980). A baseball which is batted with a speed of 150 kilometers per hour, for example, needs less than 500 milliseconds until it reaches the catcher. Without training, the catcher would not see the ball due to "motion blur", because the brain is not able to process cloudy images. The fact that we can process things in the brain and not in the eye leads to the assumption that this process is worth practicing. A further assumption is that watching a high speed ball through strobe shutter glasses trains eye-brain coordination and anticipation as well in order to predict the path of the ball and to achieve a faster visual processing with fewer images (Shammas, 2011). Reichow et al. (2010), for example, indicated that the experimental group that trained with functional stroboscopic eyewear, showed a significant improvement concerning the anticipation timing at the fastest speed (30 mph) – as opposed to the control group who did not reveal any improvement.

Dependent variables: Two learning and one transfer task were selected. The choice reaction time (Learning task I) was measured with the D2 board. This D2 board generated a visual, a motor and a physical reaction time. The physical reaction time is the sum of the visual and the motor reaction time and was used for the evaluation. The functional field of view task (Green and Bavelier, 2003) enables the testing of spatial distribution of visual attention and accordingly, the peripheral vision (Learning task II). The multiple object tracking task (Alvarez and Franconeri, 2007) shows the ability of tracking moving objects

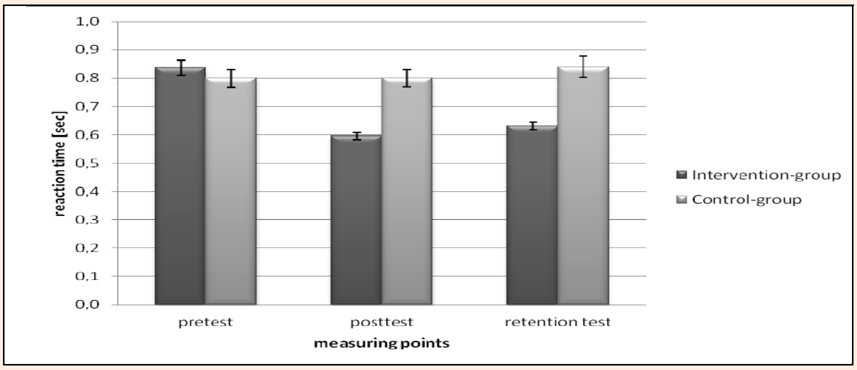

Figure 6. **Reaction time at the D2 board during all three measuring points of both groups.**

over space and time, which is an important fact in our dynamic visual world, especially in sport (Transfer task).

Data analysis

A series of 3 two-factor univariate analysis of variance (ANOVA) with repeated measures on both within subject independent variables (group; measuring point) were run to examine the effects on central perception, peripheral perception and choice reaction time. Where, the assumption of sphericity was violated, the *p*-values for main effects were computed using the conservative Greenhouse – Geisser method with corrected degrees of freedom so that a valid F-ratio can be obtained and the Type I error rate can be reduced.

Results

Figure 6 shows the descriptive data for the choice reaction time at the D2 board. A 3 (measuring point) x 2 (group) ANOVA on reaction time revealed a significant interaction effect between measuring point and group $F(2, 62) = 12.244$, $p < 0.001$, $\eta_p^2 = 0.283$, a significant main effect on measuring point $F(1.517, 47.033) = 9.714$, $p < 0.001$, $\eta_p^2 = 0.239$ and a significant main effect on group $F(1, 31) = 12.832$, $p < 0.001$, $\eta_p^2 = 0.293$. Follow-up t-test on choice reaction time of the intervention group showed a significant improvement from pretest to posttest $t(21) = 8.689$, $p < 0.001$ and from pretest to retention test $t(21) = 8.763$, $p < 0.001$. The participants became faster at reacting on the illuminated buttons at the D2 board in comparison to the baseline measurement (pretest). A t-test on choice reaction time of the control group showed no significant differences from pretest to posttest $t(10) = -1.608$, $p = 0.139$ and from pretest to retention test $t(10) = -1.150$, $p = 0.277$. The participants remained similar across all three measuring points with regard to the reaction time.

The descriptive data for the functional field of view task are shown in Figure 7. A 3 (measuring point) x 2 (group) ANOVA on correct answers revealed no significant interaction between measuring point and group in the far condition $F(2, 60) = 1.140$, $p = 0.327$, $\eta_p^2 = 0.037$, no significant interaction between measuring point and group in the mid condition $F(1.675, 50.258) = 0.825$, $p = 0.425$, $\eta_p^2 = 0.027$ and no significant interaction between measuring point and group in the near condition $F(1.316, 39.481) = 2.737$, $p = 0.096$, $\eta_p^2 = 0.084$. But it showed a significant main effect on measuring point in the three conditions *F*s > 12.4, *ps* < 0.001 and once again no significant main effect on group over all three conditions *F*s < 1.7, *ps* > 0.2. A t-test on the correct answers of the intervention group showed a significant improvement from pretest to posttest in the far condition $t(21) = -3.073$, $p < 0.05$, from pretest to posttest in the mid condition $t(21) = -4.047$, $p < 0.05$, from pretest to posttest in the near condition $t(21) = -4.749$, $p < 0.001$, from pretest to retention test in the far condition $t(21) = -6.341$, $p < 0.001$, from pretest to retention test in the mid condition $t(21) = -5.025$, $p < 0.001$ and from pretest to retention test in the near condition $t(21) = -4.676$, $p < 0.001$. The participants made significantly fewer mistakes in the

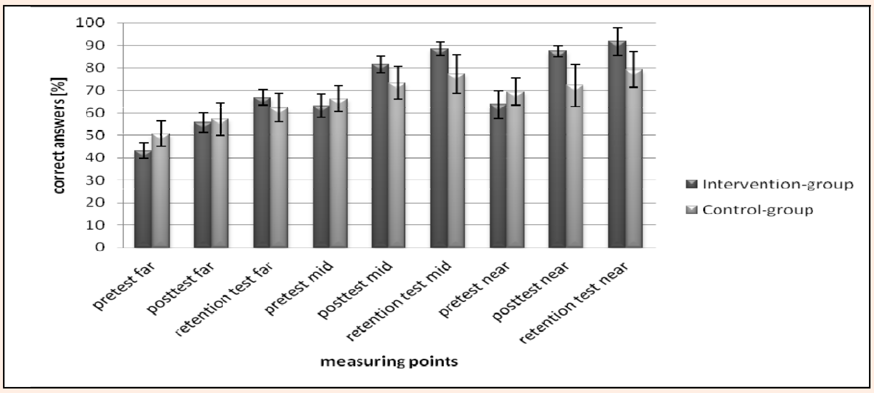

Figure 7. **Correct answers in percent in the functional field of view task during all three measuring points of both groups.**

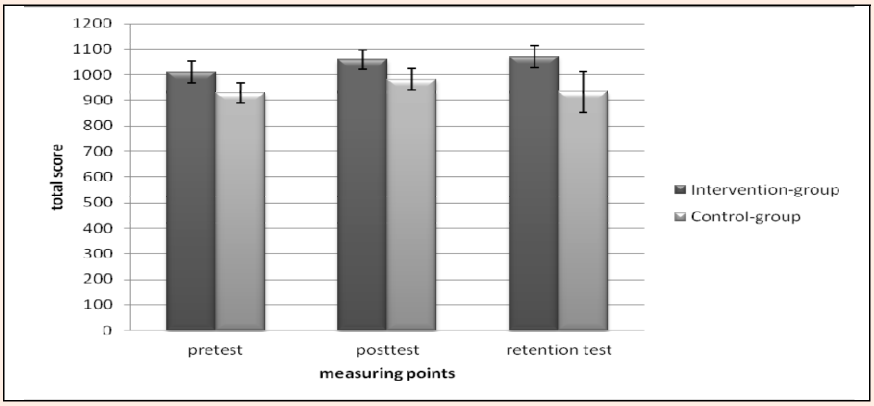

Figure 8. Total score in the multiple object tracking task during all three measuring points of both groups.

functional field of view task in comparison to the baseline measurement. A t-test on the correct answers of the control group showed no significant differences *t*s < -1.7, *p*s > 0.13 in the same conditions. The participants in the control group made descriptively more mistakes at the functional field of view task during all conditions and measuring points.

The descriptive data for the MOT are displayed in Figure 8. A 3 (measuring point) x 2 (group) ANOVA on total score in the multiple object tracking task showed no significant interaction between measuring point and group $F(2, 56) = 0.234$, $p = 0.792$, $\eta_p^2 = 0.008$, no significant main effect on measuring point $F(2, 56) = 1.473$, $p = 0.238$, $\eta_p^2 = 0.050$ and no significant main effect for group $F(1, 28) = 2.636$, $p = 0.116$, $\eta_p^2 = 0.086$. A t-test on total score of the intervention group revealed no significant improvement from pretest to posttest $t(19) = -1.500$, $p = 0.150$ and from pretest to retention test $t(20) = -1.173$, $p = 0.255$. Descriptively, however, the trend observed suggests that there were an improvement compared to the baseline level. A t-test on total score of the control group also showed no significant differences from pretest to posttest $t(10) = -1.585$, $p = 0.144$ and from pretest to retention test $t(10) = -.445$, $p = 0.666$. The participants performed more or less on the same level during all three measuring points.

Discussion

The present study shows an improvement of certain visual abilities with the help of a sports vision training program. These results are in line with previous research demonstrating that cognitive training may influence basic cognitive skills (Allen et al., 2004; 2006; Bellenkes et al., 1997; Green and Bavelier, 2003). Our results suggest that the vision training program referred to both learning tasks, the choice reaction time and to the peripheral vision, but it is not related to the transfer task.

The D2 board task measured the visual and motor reaction time and revealed an improvement for the intervention group's choice reaction time while the control group demonstrated a small slowdown with regard to the choice reaction time. It is clear that the intervention group practiced some tasks at the learning task I in their training sessions but this is unlikely to be the single reason for their improvement because the test was designed differently in comparison to the training sessions. Furthermore, the control group did not show a positive effect by a triple repetition. In general, it is difficult to ascertain whether pre- to post-training improvements in basic visual function are a consequence of a genuine improvement in visual function or merely the effect of extended practice on the test instrument. Although, in our experiment the positive effect of the intervention group was shown to be maintained six weeks later in the retention test as well.

Nevertheless, from a methodological point of view, future research designs should take into consideration to install placebo groups to avoid “familiarity effects” (cf. Abernethy et al., 1999; Farrow and Abernethy, 2002; cf. Farrow et al., 1998). Familiarity effects make a particular problem when there are strong overlaps between the task and the intervention.

The functional field of view task revealed no interaction effect between both groups. However, the intervention group, in contrast to the control group, revealed an improvement of their peripheral vision. Perhaps the learning task II was not the most effective test for measuring the peripheral vision in the way it was trained. The functional field of view task was performed in front of a computer screen with a distance of 0.70 meters whereas the distance in the training sessions was only about 0.50 meters (arm length of the participants). Thus, it should be mentioned that the attained results, in particular the improvement of the intervention group, only has validity in the measured area of the functional field of view task.

Future research should attempt to extend the training intervention period to find out whether this can increase differences found between the intervention and control group. In this study, the sports vision training program lasted for a period of six weeks. One can say that six weeks might be the minimum period required to find differences in these types of intervention studies when in comparison with results of other researchers (Campher, 2008; Maman et al., 2011; Quevedo et al., 1999). In addition, further research should try to investigate whether this sports vision training program shows benefits for the players in the sport specific field.

The aim of this study was to find out, if certain visual skills could be affected by a specific training program over six weeks in a laboratory situation. The assignability on sport performance in the field would be the next step and should be verified in a further study. A good example for a possible avenue is the study by Williams et al. (2003). They investigate the transfer of improvements in a video-based perceptual training program to more applied field-based measurements in hockey. Such research is important to show if improvements observed in laboratory tasks transfer to sport performance in field environment.

Conclusion

In summary, the study suggests that certain visual abilities, e.g. the peripheral perception or the choice reaction time are trainable and can be improved by means of an appropriate visual training. An automatic improvement of other visual abilities (transfer effects) as a result of training, such as the ability to track simultaneously different objects in the central and peripheral visual field and to identify and distinguish individual objects, as it is in the multiple object tracking task, could not be verified in this particular study.

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Key points

- Perceptual training with youth field hockey players
- Can a sports vision training program improve the visual performance of youth male field hockey players, ages 12 to 16 years, after an intervention of six weeks compared to a control group with no specific sports vision training?
- The intervention was performed in the “VisuLab” as DynamicEye® SportsVision Training at the German Sport University Cologne.
- We ran a series of 3 two-factor univariate analysis of variance (ANOVA) with repeated measures on both within subject independent variables (group; measuring point) to examine the effects on central perception, peripheral perception and choice reaction time.
- The present study shows an improvement of certain visual abilities with the help of the sports vision training program.

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