LASE Journal of Sport Science
2018 Vol 9, No. 2, Pages 3 – 16
DOI: 10.2478/ljss-2018-0007
p-ISSN: 1691-7669/e-ISSN: 1691-9912/ISO 3297
http://journal.lspa.lv/

**ORIGINAL RESEARCH PAPER**

# DEVELOPMENT OF NONVISUAL SENSORY SKILL IN FOOTBALL

**Johnny Nilsson[1,2], Adam Gürsoy[2], Anders Hermanson[2]**

[1]Dalarna University
Address: 791 88 Falun, Sweden
Phone: +46 23-77 80 00
E-mail: jns@du.se
[2]The Swedish School of Sport and Health Sciences
Stockholm, Sweden

**Abstract**

*The purpose was to study if young football players can develop their nonvisual sensory performance, here defined as control of the ball without visual feedback. In total 20 elite male football players participated in the study. Their mean age (±SD) was 12.1 (±0.5) years. The participants were divided into an intervention group (n=12) and a control group (n=8). The selection of players was based on performance in the non-visual slalom pre-test. The study followed a pre- post-test design in which the intervention group practiced ball control without visual feedback (nonvisual sensory training) three times 30 minutes per week over four weeks as part of their normal training. The control group exercised conventional football training with full vision for the same amount of time. The pre- and post-test consisted of two sub-tests performed with and without visual control: 1) a stationary ball control test and 2) a slalom course ball drive test. The results show a significant improvement in the intervention group in both the stationary ball control test (p<0.001 and Effect Size (ES)=1.59) and in the slalom ball drive test (p<0.004 and ES=1.09). The control group showed no significant changes in performance between the pre- and post-test.*

*Conclusion. Nonvisual sensory skill can be significantly improved in 12 training sessions of 30 minutes each in young elite male football players.*

**Keywords**: *nonvisual sensory skill, football, ball control, performance*

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

## Introduction

Typical in football is the perceptual dominance of the visual system used in the control of the ball and in the interaction with the other players. Skilled players collect relevant visual information about the ongoing play to a large extent during a typical football match (Williams et al. 1994, Williams & Davids 1998, Williams 2000, Jordet 2004, Eldridge et al. 2013). Thus, the visual system is dominant in football and due to this, it is plausible that other sensory systems are relatively less stimulated in football training. When the player moves on the pitch without the ball, the perceptual demands may seem fairly easy; however, if a player drives the ball and is challenged by opponent players, the demands increase a great deal, forcing the player that controlling the ball to utilise non-visual sensory systems to control the ball while seeking environmental visual information. Due to the visual dominance in conventional football training, it is reasonable to assume that nonvisual sensory systems may not be developed enough to fully control the ball and to sample information simultaneously with environmental visual information. Therefore, it is important to evaluate the potential of the nonvisual sensory system to adapt to and cope with a greater involvement in the control of the ball in football.

Nonvisual sensory perception enables awareness of whole body and segmental positions and orientations in space by means of the vestibular system, muscle spindles and joint receptors as well as sensation of how hard and fast contact with external objects is by means of receptors located in the skin and projection to distinct areas on the sensory cortex (Latash 2008). Thus, the nonvisual sensory system allows us to sense balance, joint angles, and position of body segments, pressure and speed of impact when we are in contact with the ball. The nonvisual sensory system functions in collaboration with the visual system but can to a certain extent also function alone in the control of the body, which is obvious when someone tries to walk blindfolded in a furnished room. The afferent sensory receptors' sub-serving nonvisual sensory perception includes receptor systems with afferent spinal input to the reticular formation, cerebellum, thalamic relay nuclei and sensory cortex (Martin & Jessel 1991). Both conscious and subconscious perception exists. Condo and Nashner (1982) found that the latency of postural responses recorded as muscle activation was shorter than what could be expected when higher cortical centers were involved. This indicates that subconscious automatic processing occurs at the spinal, cerebellar and brainstem levels. There is reason to believe that afferent signals are used for both closed loop and open loop control of movements (Ghez & Sainburg 1995, Sjölander & Johansson 1997). Processes at a central level can use afferent information to preset stiffness in muscles in

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

feed-forward control of movements (Johansson 1993) and not only in feed-back processes. Thus, the above indicate that there is a substantial sensory and neural apparatus that can serve in a restricted visual context and in proprioceptive motor control.

There is a central adaptation that indicates a substantial neuro-cortical plasticity in the form of reorganisation, reactivation and increased number of synaptic connections associated with changes in peripheral afferent input (Merzenich et al. 1983, Bach-y-Rita 1986, Jenkins et al. 1990). In a study by Kapreli and co-workers (2009), patients with unilateral anterior cruciate ligament (ACL) deficiency from a previous injury were compared with matched controls concerning brain activation examined by functional magnetic resonance imaging technique (1.5-T scanner). The results showed that the patients with ACL dysfunction had diminished activation in several senso-motor cortical areas and increased activation in three areas compared with the controls. Thus, injuries affecting different tissues such as ACL can cause reorganisation in the central nervous system including higher brain areas. Another possible central adaptation is called "attention switching", which is thought to change the nonvisual sensory focus in accordance with performance demands (Wickens 1980). Hypothetically, such mechanisms may improve a nonvisual sensory response to a given movement demand and thus contribute to improved performance. To our knowledge, there is no information to support the assumption that sensor density increases with training, but it may be reasonable to assume that the fusi-motor drive and systematically increased gain in received afferent signals as well as nonvisual sensory attention may respond to training and improve performance (Wickens 1980). Thus, development of the nonvisual sensory system will allow for ball control simultaneously with a visual search of relevant information about the ongoing play. Thus, far less time needs to be devoted to look at the ball in the control of it. This places the nonvisual sensory system in the foreground as being an important interacting system with the visual system in football. The above information about neuronal sensory system and brain plasticity (Merzenich et al. 1983, Bach-y-Rita 1986, Jenkins et al. 1990, Kapreli et al. 2009) indicates that this could be developed.

Surprisingly little research has focused on the nonvisual sensory system and its function in football. Barfield and Fischman (1990) studied the interaction between vision and proprioception in terms of ball control and positioning of the foot in a simple soccer moves. Skilled and novice football players participated in an experiment with full vision and restricted vision. The skilled players made fewer errors compared with novice players, and all players made fewer control errors with full vision compared with

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

restricted vision. Williams and colleagues (2002) conducted two experiments on lower limb action with full vision and restricted vision. In the second experiment, 12-year-old players practised under full vision or in a condition where sight of the foot was occluded. The results showed that players who practised under occluded viewing conditions showed greater relative improvement in performance compared with a full vision control group. Thus, the research of Barfield and Fischman (1990) as well as of Williams et al. (2002) indicates that skill level and training under occluded viewing conditions influenced performance. Another indication of the possible importance of nonvisual sensory skill in football was improvement in technical football skills after a period of nonvisual sensory skill and balance training (Evangelos et al. 2012). Paillard and Noé (2006) compared football players of different rank with respect to body posture and stature while they balanced on one leg. The highest ranked players used different movement strategies compared with the lower ranked players. This may be due to a difference in nonvisual sensory system development. In a study by Han and co-workers (2013), so-called proprioceptive sensitivity was analysed among 100 athletes from different sports and skill levels. The results showed no significant differences between sports; however, they did show significant differences between athletes at different skill levels. A similar study was conducted by Muaidi et al. (2008), but here the focus was on sensitivity in knee angular displacement. The aim was to find out how the level of football performance was statistically associated with knee joint sensitivity. Their results in the study confirmed a significant positive association. Together, these studies indirectly confirm that nonvisual sensory skill might be a factor of importance in football performance and as such it is of interest to explore further in a specific study if this factor develops with training. Therefore, the purpose was to study if young football players with specific training can develop their nonvisual sensory performance in terms of their ball control without visual feedback.

## Materials and Methods

In total, 20 young players from an elite male football team participated in the study. Their mean (±SD) age was 12.1 (±0.5) years. The participants were divided into an intervention group (n=12) and a control group (n=8) with an average age of 12.2 and 12.0 years, respectively. The selection of players to the intervention group and control group was based on the performance in one of the tests (non-visual slalom test, see below). The aim of this selection was to have two groups with similar performance levels in the intervention parameter non-visual ball drive control.

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

The test procedures and training were approved by the players and their guardians. The design and procedures in the study were approved by the Regional Ethical Review Board in Uppsala, Sweden.

*Test design and procedures*. The study followed a pre- and post-test design in which the intervention group trained 30 minutes specific nonvisual sensory skill training within their normal training sessions three times a week over four weeks: thus, in total six hours of specific nonvisual sensory skill training with specially constructed glasses, which, when used correctly, prevented the players from seeing the ball while controlling it. Simultaneously, the control group received the same amount of training, but theirs was conventional football training, with full vision. The players in the control group agreed not to train with visual constraints between the pre- and post-test.

Three days before the pre-test, all participants were instructed in the test procedures and were acquainted with the test exercises and test glasses in one specific training session of approximately 30 minutes.

The participants performed conventional warm-up exercises before the pre- and post-test and in addition they were given five minutes to warm up for the test exercises. Each test exercise was first performed with full vision and subsequently with visual restriction. All tests were filmed with a video camera at 50 Hz time resolution, and the video recordings were stored for subsequent analysis.

The pre- and post-tests consisted of two exercises:

1) *Stationary ball control*. The participants performed a sole and ball backward draw followed by a forward inside-foot diagonal kick to the contralateral foot, repeating the same procedure as the ipsi-lateral foot completing one cycle. The whole test procedure was performed inside a wooden frame (1.04 · 0.88 · 0.07 m) (see Figure 1A). All players were instructed to perform as many cycles (rounds) as possible in 60 seconds. The test was first performed with full visual control and subsequently with full visual restriction by means of a blindfold to obstruct vision completely (Figure 1A). During the test, the participants were easily able to regain the ball in the frame by probing with their feet. If the ball was dropped outside the frame, it was put back by one of the experimenters, and the participant was able to continue with the test. The number of dropouts was recorded. Whenever the ball was found outside the frame, the time was paused from the moment the ball left the participant´s foot until an experimenter returned it to the same foot of the participant. When the participant was able to continue the movement, the time-recording started again.

2) *Slalom course ball drive* (Figure 1B). The participants were instructed to drive the ball through a slalom course (total length = 16.5m,

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

1.5 m between each gate) as fast as possible. This was first performed with full visual control and subsequently with special “glasses” made of foam rubber (Figure 1C) that allowed the participants to see only the direction of the course when used correctly. The participants with the glasses were instructed to tilt their head forward while standing 0.3 m from the ball until they saw the top of it (Figure 1D and E).

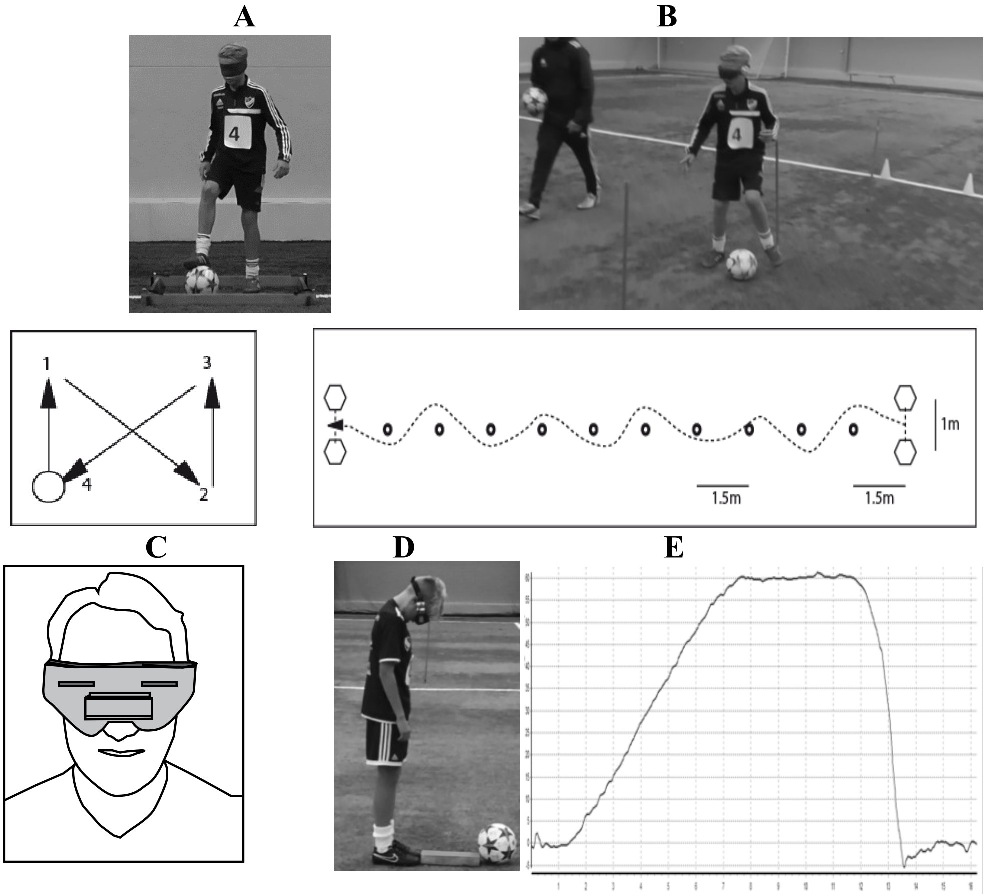


**Figure 1**. A) Stationary ball control inside a wooden frame (size inside the frame: 1.04 · 0.88 · 0.07 m). The arrows in the top view lower inset figure show the order and ball direction for one cycle. The number of cycles over 60 seconds was recorded. B) The slalom ball drive. The total distance was 16.5 m from start to finish interspaced with ten gates. C) Foam rubber test “glasses” used in the slalom ball drive test. D) Test setup that allows for detection of the forward tilt of the head needed for a player to see the ball using the test glasses controlled by a gyrodevice. E) Typical angular displacement output from the gyroscope and software during the calibration procedure. The units on the abscissa is seconds and on the ordinate show arbitrary values for angle in degrees. The same ball brand (Adidas, Champion’s League Top Training), ball size (size: 4) and pressure inside the ball (0.8 Bar) were used in all tests.

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

This was filmed in the sagittal plane and simultaneously recorded with a gyroscope (X-IMU, x-io Technologies, UK) that communicated with a PC by means of Bluetooth signals that together with software automatically calculated the pitch angle when the ball was seen. The mean (±SD) pitch angle for the participants was 62.3 (± 4.2) degrees from the horizontal level

This procedure made it easy for the experimenters to subsequently detect when the participants looked at the ball during the test in the analysis of the video recordings. If the participants dropped the ball away from the slalom course, they normally looked down to find the ball. The number of gazes for each participant was recorded. When the ball was dropped outside the course, the experimenter put it back to the place where it was dropped, and the participants continued from there. The time for this procedure was subtracted from the test time by means of the subsequent video analysis. The number of dropouts from the course was also recorded.

The reliability of the stationary ball control and the slalom course ball drive tests was analysed in the intervention group by means of a test-retest procedure performed by 10 players within 48 hours. The correlation coefficient was 0.87 and 0.81, respectively. The reliability in the judgement of the two researchers who conducted the video analysis was established through a comparison of the judgements of gazes in the non-visual stationary test and slalom course, and the correlation coefficient between the judgements of the two experimenters was 1.0 in both cases.

All the tests in the pre- and post-test protocol were conducted on artificial plastic turf and indoors in the same football hall.

*Training design for the intervention and control group*. All players in the intervention group wore the specially designed vision restricting glasses throughout the training session of 30 minutes. Each training session of nonvisual sensory skill in football started with a warm-up part of 6-7 minutes in which the 12 players started with one ball each that they moved around and controlled. Subsequently, the same players used 8 balls, which were passed around among them. Each time a player received a ball, then performed 1-3 ball touches with his feet before passing it to another player (6 minutes). All players in the intervention group were then subdivided into three sub-groups and performed three exercises, each one taking about 6 minutes. In one exercise, the players had to drive the ball through a slalom course. In another exercise, the players had to play a small-scale game (2 vs 2 players) on a small area (11 · 7 m) with small pop-up goals. In another exercise, the players soled and kicked the ball in a frame. Approximately 3 minutes were used to move between and to begin new exercises. The training was filmed in order to estimate the number of repetitions for each exercise, which was based on three randomly chosen players. In the

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

stationary ball control exercise, the players were activated on average 85 % of the time. In the slalom course ball drive exercise, the players completed on average 16.7 laps. Finally, the players in the small-scale games completed on average 68 touches, passed the ball 10.7 times and drove the ball 34.1 seconds. The control group's training comprised conventional football with full vision over the same amount of time as the intervention group practiced their nonvisual ball handling. Subsequently, all players in the team (intervention and control group) continued with conventional team training.

*Statistics*. Conventional descriptive statistics was used to calculate the mean and standard deviation (SD). The statistical calculations were performed with the Statistica 12.0 software package (StatSoft Inc. US). All distributions were tested for normality before parametric statistical calculations were made. The statistical significance between the pre- and post-test results was calculated by means of Student´s t-test and the alpha level for assumed statistical significance was set at 0.01. In addition, effect size (ES) was used to evaluate changes between pre- and post-test results (Cohen 1977), where 0.5 is regarded as a significant learning effect and 0.8 as a significant high learning effect.

**Results**

In the non-visual stationary ball control test, the results show a significant improvement for the intervention group (p= 0.001, ES=1.59) of 50.9% between pre- and post-test. Corresponding changes for the control group were not significant (p=0.306, ES=0.19), with a 4.7% reduction in performance in the post-test. The average number of ball drops for the intervention group in the pre- and post-test was 0.2 and 0.4, respectively. The corresponding number of ball drops for the control group was 0.3 and 0.5, respectively.

When the stationary ball control test was performed under visual control pre- and post-tests, the intervention group showed an improvement of 22.5% (p=0.00004, ES=2.13), while the control group showed a non-significant reduction in performance of 0.5% (p=0.845, ES=0.04). The number of ball drops for the intervention group and control group pre- and post-tests averaged 0.1 and 0.1, respectively.

In the slalom ball drive test with visual restriction, the intervention group significantly improved the results in the post-test compared with the pre-test by 24.9% (p=0.004, ES=1.09). The control group showed a reduction in performance of 12.6% in the same test situation, which was not significant (p=0.105, ES=0.55). The number of ball gazes in the ball drive test was on average 1.5 and 0.8 for the intervention group in the pre- and

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

post-tests, respectively. The corresponding number of gazes for the control group was 1.3 and 0.4 in the pre- and post-tests, respectively.

In the slalom ball drive test with no visual restrictions, the intervention group showed a non-significant improvement of 0.9% (p=0.825, ES=0.08), while the control group showed a non-significant reduction in performance of 3.1% (p=0.575, ES=0.4). The number of ball drops in the full visual pre- and post-test for the intervention group was on average 0.2 and 0, which corresponded to 0 and 0 for the control group.

In the stationary ball control test, the ratio between the number of cycles in non-visual versus visual conditions increased significantly from 0.60 to 0.72 (20%) for the intervention group (p= 0.049).

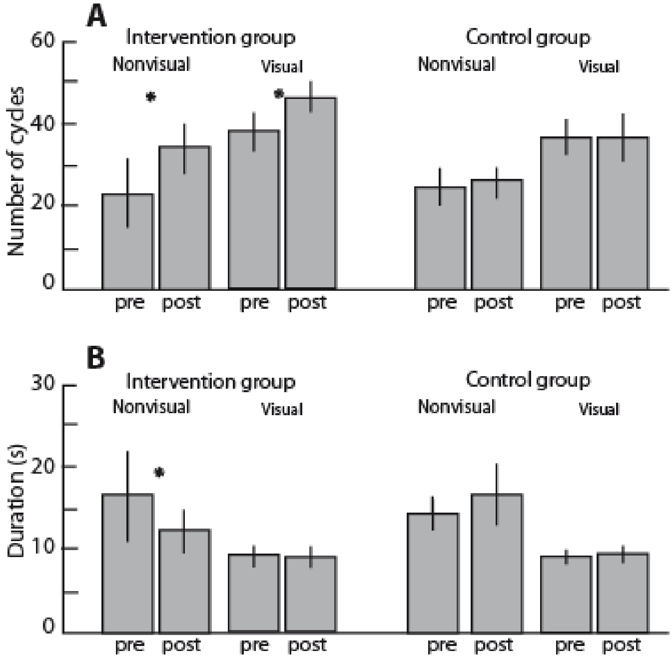


**Figure 2**. Pre- and post-test results of (A) stationary ball drive control number of cycles in the wooden frame over 60 seconds and (B) Slalom course ball drive for the intervention group and control group. *=Significant difference (p<0.01).

The ratio for the control group increased from 0.64 to 0.67 (5%) but was not significant (p=0.583). In the slalom drive ball test, the ratio between time to finish the slalom course in non-visual versus visual conditions decreased significantly from 1.91 to 1.45 (24%) for the intervention group (p=0.015) between pre- and post-test. The corresponding ratio for the control group showed a non-significant increase of 6% from 1.49 to 1.58 (p=0.794).

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

## Discussion

The present study showed significant improvements among players in the intervention group concerning nonvisual stationary ball control and slalom ball drive of approximately 50 and 25%, respectively. No significant changes occurred in the control group, indicating that nonvisual sensory skill training influenced the ability to perform in the present non-visual test exercises, which was specific for the intervention group and showed that the research question can be answered affirmatively.

In our study, the intervention group showed significant improvements in the development of nonvisual sensory skill in stationary ball control and ball drive in a slalom course. The training in the intervention group included the test exercises (20 plus 20% of the training time) due to their relevance for ball control in football. However, the improvements in these two exercises shown by the tests may be influenced by the specific training the footballers received in the test exercises. If this were the case, an improvement in the tests with no visual restrictions would probably occur. A significant improvement was seen in the visual stationary ball control test, but not in the visual ball drive test. The significant improvement seen in visual performance in stationary ball control, but not in the slalom course, for the intervention group indicates that the transfer of learning improvement process is at least not uniform. One reason for this may be that the specific training of stationary ball control and slalom course ball drive was together only 40% of the training time. Furthermore, the control group's lack of improvement demonstrates that they did not develop between the pre-test and the post-test, indicating that the testing did not result in learning.

The ultimate training result for the intervention group is that the performance during non-visual conditions is as good as during full visual feedback conditions. Thus, it should not matter whether or not the player sees the ball while controlling it. This means that the nonvisual sensory system has reached an extreme level of development, which may be useful in football as it would allow visual information to be collected to a large extent simultaneously with nonvisual sensory control of the ball. In the test exercises, this ratio between full vision and nonvision improved with training as the participants in the intervention group performed the slalom course without visual feedback in a shorter time during the post-test compared with the pre-test and in the stationary ball control test, the performance in the intervention group improved under both visual and non-visual conditions.

Previous research indicates that there seems to be an association between skill in football and postural control (Paillard & Noé 2006, Biec´

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

and Kuczynski 2010) as well as in performance level and so-called proprioceptive sensitivity (Han et al. 2013, Muaidi et al. 2008). This justified the aim of this study to investigate nonvisual sensory response to training. In addition, the study by Barfield and Fischman (1990) shows that skilled players made fewer errors while controlling the football. This study also showed a reduced performance when the ball was controlled under restricted viewing conditions, which was also observable in the present study. Williams and co-workers (2002) showed that training under restricted viewing conditions resulted in a larger relative improvement compared with training under full vision. A significant improvement was also shown in the present study after nonvisual sensory training.

A hypothesis, forwarded by Proteau et al. (1998), states that a decrement in performance will occur when a specific important source of afferent information (e.g. sight of the foot), available during training, is removed. According to Proteau´s hypothesis, the decrement in performance will occur with practice under restricted viewing conditions. This hypothesis was not supported by Williams et al. (2002). In addition, the results in the present study showed that training under nonvisual conditions left performance under visual conditions unchanged or improved (see Figure 2 A and B). The latter is supported by the data of Bennett et al. (1999) and Williams et al. (2002). In contrast to Proteau´s hypothesis, it seems that restriction in visual feedback may have enabled an exploitation of alternative sources of afferent information. This supports the hypothesis presented in the present study that restriction in viewing conditions will allow the nonvisual sensory system – for example, proprioception – to develop. Furthermore, it is reasonable to assume that a development of nonvisual sensory skill will be beneficial to ball control during full visual conditions as well, which is evident at least with the stationary ball control in the present study.

The impact on improvement in motor performance under nonvisual conditions shown by Bennett et al. (1999), Williams et al. (2002) and the present study indicates the importance of the sensory information in motor performance, which was previously also claimed by, for example, Henriques and Cressman (2012). They pointed out that sensory plasticity and particularly proprioceptive recalibration play a unique and important role in motor learning. The improved performance in full-vision stationary ball control in the intervention group indicates that manipulation with visual restriction can improve motor performance. At this stage, it is not possible to exactly pinpoint where the changes are in the neuro-motor system or what they are.

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

In a match situation, a player's increased ability to control the ball without visual control has the potential to increase the time that is available for the visual system to obtain information about ongoing play. However, there is no guarantee that an increase in nonvisual sensory competence will automatically change the visual scanning patterns in football. This study shows only that training of stationary control and drive of the ball on the pitch can be improved by nonvisual sensory training. This will only indirectly show that there is a potential for this to happen during an authentic match. Further research is needed to study if the real visual scanning pattern changed during a match or match-like situations after nonvisual sensory training.

Previous information about sensory manipulation (Barfield and Fischman 1990, Bennett et al. 1999, Williams et al. 2002), as well as the results from the present study, is important for practitioners in the design of this type of training and in the periodisation of it. Future studies where the intervention period is longer and is also repeated may reveal new features in the nonvisual sensory skill adaptation to training.

## Conclusion

Nonvisual sensory skill in stationary ball control and driving the ball in a slalom course can be significantly improved in 12 training sessions of 30 minutes each.

*What does this article add?*

The results in this study clearly show that the control of the ball in typical football movements without visual control can be improved significantly in a relatively short period of time. This knowledge indicates that sensory information other than information through the visual system can contribute to the control of the ball in football. Perhaps players with high nonvisual sensory competence will be able to control the ball in a match situation and simultaneously be able to seek valuable visual information about the ongoing play. The latter requires further research.

## References

1. Bach-y-Rita, P. (1986). *Recovery of function: theoretical considerations for brain injury rehabilitation*. Huber, Toronto.
2. Barfield, B. & Fischman, M.G. (1990). Control of Ground-Level Ball as a Function of Skill Level and of the Foot. *Journal of Human movement Studies*, 19(4), pp. 181-188.
3. Bennett, S.J., Button, C., Kingsbury, D. & Davids, K. (1999). Manipulating visual informational constraints during practice enhances the acquisition of catching skill in children. *Research Quarterly for Exercise and Sport*, 70, 220-232.

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

4. Biec, E. & Kuczynski, M. (2010). Postural control in 13-year-old soccer players. *European Journal of Applied Physiology*, 110(4), pp. 703-708.
5. Cohen, J. (1977). *Statistical power analysis for behavioral sciences (revised Ed.)* New York: Academic Press.
6. Condo, P.J. & Nashner, L.M. (1982). Properties of postural adjustments associated with rapid arm movements. Journal *Neurophysiology*, 47:287-302.
7. Eldridge, D., Pulling, C., Robins, M. (2013) Visual exploratory activity and resultant behavioural analysis of youth midfield soccer players. *Journal of Human Sport & Exercise*, Vol. 8, No. Proc. 3, S560-S577.
8. Evangelos, B., Kahrimanis, G., Konstantinos, A., Gissis, J. Papadopoulos, C., Aristomenis, S. (2012). Proprioception and balance training can improve amateur soccer players´technical skills. *Journal of Physical Education and Sport*, 12(1), 13. 81-89.
9. Ghez, C. & Sainburg, R. (1995). Proprioceptive control of inter joint coordination. *Canadian Journal Physiology Pharmacology,* 73:273-284.
10. Han, J., Anson, J., Waddington, A. & Adams, R. (2013). Level of competitive success achieved by elite athletes and multi-joint proprioceptive ability. *Journal of Science and Medicine in Sport,* 18(1), pp. 1-5.
11. Henriques, D. Y. P. & Cressman, E. K. (2012). Visuomotor Adaptation and Proprioceptive Recalibration. *Journal of Motor Behavior*, 44(6), pp. 435-444.
12. Jenkins, W.M., Merzenich, M.M., Ochs, M.T., Allard, T., Guic-Robles, E. (1990). Functional reorganization of primary somatosensory cortex in adult owl monkeys after behaviorally controlled tactile stimulation, *Journal Neurophysiology,* 63:82-104.
13. Johansson, H. (1993). *Neurophysiology of joints*. In: Wright, V., Radin, E. (Eds) Mechanics of human joints, physiology and treatment. Dekker, New York, pp 243-284.
14. Jordet, G. (2004). *Perceptual expertise in dynamic and complex competitive team contexts.* Diss. Norges idrottshögskola. Oslo: NIH.
15. Kapreli, E., Athanasopoulos, S. Gliatis, J., Papathanasiou, M., Peeters, R., Strimpakos, N., Van Henke, P. Gouliamos, A. & Sunaert, S. (2009). Anterior cruciate ligament deficiency causes brain plasticity: a functional MRI study. *American Journal of Sports Medicine*, 37:2419, DOI: 10.1177/0363546509343201.
16. Latash, M.L. (2008) *Neurophysiological basis of movement*. Human Kinetis, Champaigne IL. US. 2nd Ed., 40pp, 258pp.
17. Martin, J. & Jessell, T. (1991) *Modality coding in the somatic sensory system*. In: Kandell, E.R., Schwartz, J., Jessel, T.M. (Eds) Principles of neuroscience. Appleton & Lange, Norwalk.
18. Merzenich, M.M., Kaas, J.H., Wall, J., Nelson, R.J., Sur,M., Felleman, D. (1983) Topographical reorganization of somatosensory cortical areas 3b and 1 in adult monkeys following restricted deafferentation. *Neuroscience*, 8:44-55.

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia

19. Muaidi, Q. I., Nicholson, L. L. & Refshauge, K. M. (2008). Do elite athletes exhibit enhanced proprioceptive acuity, range and strength of knee rotation compared with non-athletes? *Scandinavian Journal of Medicine & Science in Sports,* 19 (1), pp. 103-112.
20. Paillard, Th., Noé, F. (2006). Effect of exercise and visual contribution on postural control in soccer. *Scandinavian Journal of Medicine & Science in Sports,* 16, pp. 345-348.
21. Proteau, l., Tremblay, L. & DeJaeger, D. (1998). Practice does not diminish the role of visual information in on-line control of precision walking task: Support for the specificity of practice hypothesis. *Journal of Motor Behaviour,* 30(2), pp. 143-150.
22. Sjölander, P. & Johansson, H. (1997). *Sensory endings in ligaments: response properties and effects on proprioception and motor control*. In: Yahia, L. (Ed). Ligaments and ligamentoplastics. Springer, Berlin, Heidelberg, New York, pp. 39-83.
23. Wickens, C.D. (1981). *The structure of processing resources*. In: Nickerson, R., Pew, R. (Eds). Attention and performance, VIII. Erlbaum, Hillsdale.
24. Williams, A.M., Weigelt, C., Harris, M. & Scott, M. A. (2002). Age-related differences in vision and proprioception in a lower limb Interceptive task: The effects of skill level and practice. *Research Institute for Sport and Exercise Sciences,* 73(4), pp. 386-395, DOI:10.1080/02701367.2002.10609038.
25. Williams, A.M., Davids, K., Burwitz, L. & Williams, J.G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport*, 65(2), 127-135.
26. Williams, A.M. & Davids, K. (1998). Visual search strategy, selective attention, and expertise in soccer. *Research Quarterly for Exercise and Sport*, 65, 111-128.
27. Williams, A.M. (2000). Perceptual skill in soccer: Implications for talent identification and development. *Journal of Sport Science*, 18, 737-750.


Submitted: May 17, 2018
Accepted: December 14, 2018

Copyright © by the Latvian Academy of Sport Education in Riga, Latvia