DOES OFF-COURT GENERIC PERIPHERAL PERCEPTION TRAINING IMPROVE BASKETBALL SPORTS PERFORMANCE?

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ABSTRACT

Löppönen, S. 2022. Does off-court generic peripheral perception training improve basketball sports performance? University of Jyväskylä, Master's thesis, 73 pp., 2 appendices.

Peripheral perception is crucial in team sports where multiple players are simultaneously observed. Former research of sports vision has focussed on investigating the role of the central vision and the gaze behaviour whereas peripheral vision has been left in the shadow. Ecological dynamics and the information processing theories have fundamental differences in how perception and action are coupled. Elite athletes can extract sport-specific useful peripheral information more accurately and efficiently than lesser-skilled athletes or novices. Perceptual-cognitive interventions have successfully improved athletes' peripheral perception, but it has not been connected to improved sports performance. There is no common understanding of how peripheral perception should be trained to gain transfer effects in sports performance. Thus, the purpose of the study was to investigate the useability of the information processing approach to train peripheral perception off-court using non-sport-specific stimuli.

Nine intermediate basketball players were recruited to participate in the study. The study included pre-tests, placebo control period, mid-tests, peripheral training intervention and post-tests. Both study periods lasted for four weeks. Four peripheral reaction tests, visual field size tests, basketball skill tests and from the basketball transfer test (Pick and Roll), gaze location and decision accuracy were collected before and after intervention periods. Participants went first through the placebo control period followed by the peripheral training intervention. Peripheral training intervention, twice 30 minutes per week, included peripheral stimuli identification, attention allocation and multiple object tracking combined with correct motor response and/or sport-specific task.

After the placebo control period significant increase ($p<0,001$) occurred in the horizontal visual field size and performance significantly improved ($p<0,05$) in two basketball skill tests. After peripheral training intervention, total simple reaction times decreased significantly ($p<0,05$) and a decrease in reaction time also occurred in the other two reaction tests, but insignificantly. The number of peripheral decisions made compared to foveal decisions increased in post-test, but insignificantly.

The off-court generic peripheral training used in the present study does not seem to improve basketball offence performance. Reaction time results suggest peripheral training might improve reaction speed to non-sport-specific peripheral stimuli. Peripheral training potentially shifted participants to use peripheral perception in the decision-making process with no decrements in overall basketball on-court performance. More intervention studies investigating peripheral perception training's effects on sports performance are needed.

Keywords: perceptual-cognitive training, sports vision, visual attention

TIIVISTELMÄ

Löppönen, S. 2022. Kehittääkö koripallokentän ulkopuolella tapahtuva yleinen perifeerinen havainnointiharjoittelu koripallon lajisuoritusta? Jyväskylän yliopisto, valmennus- ja testausopin pro gradu -tutkielma, 73 s., liitteitä 2.

Perifeerinen havainnointi on ratkaisevan tärkeää joukkuelajeissa, joissa tarkkaillaan useita pelaajia samanaikaisesti. Aiempi havainnointitutkimus urheilun parissa on keskittynyt tarkan näön alueen rooliin ja sen käyttäytymisen tutkimiseen, kun taas perifeeristä on tutkittu selkeästi vähemmän. Ecological dynamics ja Information processing -mallit ovat esittäneet erilaisia näkökulmia havainnoinnin ja toiminnan välisistä vuorovaikutussuhteista. On myös esitetty, että huippu-urheilijat hyödyntävät lajikohtaista perifeeristä tietoa paremmin kuin alemmalla tasolla harrastavat. Havaintokognitiiviset interventiot voivat kehittää urheilijoiden perifeeristä havainnointia, mutta siirtovaikutusta lajiin ei ole todistettu. Perifeerisen harjoittelun suoritustavoista ei ole selkeää ymmärrystä, jotta mahdollisia siirtovaikutuksia urheilusuorituksiin havaittaisiin. Tämä tutkimus pyrki valoittamaan Information processing -teorian lähestymistavalla toteutetun perifeerisen havaintoharjoittelun vaikutuksia koripallon lajisuoritukseen.

Yhdeksän keskitason koripalloilijaa värvättiin koehenkilöiksi. Tutkimus sisälsi alkutestit, plasebokontrollijakson, välitestit, perifeerisen havainnoinnin harjoittelujakson ja jälkitestit. Molemmat interventiojaksot kestivät neljä viikkoa. Neljä perifeeristä reaktiotestiä, näkökentän laajuustestit, koripallon taitotestit ja koripallon hyökkäystilanteesta (Pick and Roll) katseen sijainti ja päätöksien laadut mitattiin ennen ja jälkeen interventiojaksoja. Osallistujat suorittivat ensin placebokontrollijakson, jota seurasi perifeerinen havainnoinnin harjoittelujakso. Perifeerinen harjoittelujakso, kahdesti 30 minuuttia viikossa, sisälsi perifeeristen ärsykkeiden tunnistamista, huomion kohdistamista sekä useiden esineiden seurantaa yhdistettynä oikeanlaiseen toimintaan ja/tai urheilulajikohtaiseen tehtävään.

Plasebokontrollijakson jälkeen horisontaalisen näkökentän laajuus kasvoi merkittävästi ($p<0,001$) ja suorituskyky parani merkittävästi ($p<0,05$) kahdessa koripallon taitotestissä. Perifeerisen harjoittelun jälkeen tilastollisesti merkittävää nopeutumista ($p<0,05$) tapahtui reaktiotestissä yksinkertaiseen visuaaliseen ärsykkeeseen. Reaktioajat pienenivät myös kahdessa muussa reaktiotestissä, mutta eivät merkitsevästi. Perifeeristen päätösten määrä foveaalisiin päätöksiin verrattuna kasvoi jälkitestissä, mutta merkityksettömästi.

Tässä tutkimuksessa käytetty perifeerisen havainnoinnin harjoittelutapa ei näytä parantavan koripallon hyökkäyssuoritusta. Perifeerinen harjoittelu saattaa kehittää reaktionopeutta yleisiin visuaalisiin ärsykkeisiin. Osallistujat saattoivat hyödyntää perifeeristä havainnointia enemmän koripallon hyökkäystilanteessa ilman, että koripallon yleissuoritus kentällä heikkenisi. Muita siirtovaikutuksia lajiin ei löytynyt. Lisää interventiotutkimuksia tarvitaan, joissa tutkitaan perifeerisen havaintoharjoittelun vaikutuksia urheilusuoritukseen.

Asiasanat: havaintokognitiivinen harjoittelu, urheilunäkö, visuaalinen huomiointi

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ABSTRACT

APPENDICES

1 INTRODUCTION

Athletes use vision in sports to monitor surrounding areas and keep track of moving players and objects (Schumacher et. al. 2020). Foveal/central gaze is used to accurately observe areas of interest (Guyton & Hall, 2011, 604), for example, basketball hoop before initializing the final shooting movement. Research has been focused on how the gaze work and where athletes look at certain times (Vater et. al. 2019 A). Outside of the foveal gaze, which contains only approximately 1,7° of the visual field (Rosenholtz, 2016), is peripheral vision which research has almost forgotten to the shadow due to vast research focus on the central vision (Burnat, 2015). Especially in sports, research has taken major interest in peripheral vision only recently (Vater et. al. 2019 A).

Information from the peripheral visual field is perceived differently in many ways than information from central vision (Guyton & Hall, 2011, 619; Whitney & Lewi, 2011; Shapiro et. al. 2010). Also, the location of the information in the periphery affects how it is perceived (Brown, et. al. 2005; Khan & Lawrence, 2005; Strasburger et. al. 2011). Although, peripheral vision is crucial in team sports where multiple players need to be observed simultaneously (Erickson, 2007, 16) there does not exist much information about the role of peripheral-cognitive functions in complex situations. (Vater et. al. 2019 A).

There are two main theories which explain how visual information is used to guide movement. Information processing and ecological dynamics theories argue how visual information is processed and used. (McMorris, 2014, 240). Information processing theorists argue that visual cues and predictive information are processed in the brains to analyze optimal movement because information from the environment is not sufficient. (Klein, 2017, 24). Ecological dynamics ague that humans act according to the affordances in the environment and that visual information and movement are coupled, meaning that those things cannot be separated. For that reason, to gain improvements in sports performance, training should be sport specific. (McMorris, 2014, 40-43).

It has been shown that elite athletes possess superior peripheral perception over novice counterparts (Williams & Davids, 1998; Ruy et. al. 2013 B; Vater et. al. 2017). Studies do not clearly state weather basic peripheral visual skills, e.g. reaction speed or visual fields, are better at elite athletes (Zwierko, 2008; Stine & Arturburn, 1980; Vera et. al. 2017; Ando et. al. 2001; Zwierko et. al. 2008), but it is clear that athletes extract sport-related peripheral visual information better than novices (Vater et. al. 2017; Williams & Davids, 1998; Ryu et. al. 2013 B). For example, basketball players have been shown to gain more information from the peripheries than novice players (Ruy et. al. 2013 B) and that this information is used to basketball decision making (Van Maarseveen et. al. 2018). Intervention studies have successfully improved athletes' generic peripheral perceptual skills, for example, reaction speed (Krüger et. al. 2010; Schwab & Memmert, 2012; Feldhacker & Molitor, 2019; Schumacher et. al. 2020).

The information processing and ecological dynamics theorists still argue how movement is controlled and what is the role of the perception (Anson et. al. 2005). This affects how perceptual-cognitive skills should be trained to see benefits in sports performance (Zantgraf et. al. 2017). Peripheral perception of athletes has been successively improved (Hüttermann & Memmert, 2018; Schwab & Memmert, 2012; Feldhacker & Molitor, 2019; Schumacher et. al. 2020) but there are only a few studies (e.g. Stine & Arterburn, 1980; Wimshurst et. al. 2018; Romeas et. al. 2016), that include peripheral vision, which investigate possible transfer effects to sports performance. There is a clear need for more intervention studies before appropriate ways to train peripheral vision and gain benefits to sports performance can be stated.

2 PHYSIOLOGY OF VISION

Light from the objects enter eyes, activates cells which send the emerged visual information to visual brain areas where it is analyzed and understood. Motor responses are elicited if necessary. The human visual system has major visual information processing differences from foveal and peripheral retinal areas. Visual information extraction and processing are different when peripheral visual information is used rather than foveal visual information. (Guyton & Hall, 2011, 600-602; Whitney & Lewi, 2011).

2.1 Eyes

The eye refracts light to the retina by four refractive interfaces: cornea, aqueous humor, lens and vitreous humor. The anterior surface of the cornea has the most refractive power, approximately two-thirds of the total 59 diopter refraction power. The lens, which possesses a refraction power of 20 diopters is practically important because it's curvature can be increased to focus on nearby objects. The ciliary muscle along with suspensory ligaments enable the lens to be contracted. When ciliary muscle contracts, controlled by parasympathetic nerves, it releases tension from suspensory ligaments and lens can assume more spherical shape due to its natural elasticity. The iris controls the amount of light penetrating to the eye. Parasympathetic and sympathetic nerves decrease or dilate the pupil diameter, respectively. As light travels through the eye, the image of an object is flipped at the retina. (Guyton & Hall, 2011, 600, 601, 632, 599).

Fovea, only 0,5 millimetres in diameter and approximately two degrees of the visual field, has physical properties that allow high acuity vision over peripheral retinal locations. (Guyton & Hall, 2011, 604). Photoreceptor cells, which are rod and cone cells contain pigments that interact with light in different ways. Dim light activates rod cells and different wavelengths of colour activate cone cells, hence making rod cells responsible for night vision and cone cell active in bright light by portraying different colours of light. (Burnat & Compton, 2018, 138, 139). There are three different types of cones, each sensitive to one of the following colour of light, green, blue or red. Colour blindness is present when one of the three cones are missing from the retina. Red-green colour blindness, the most usual scenario especially amongst men, disturbs severely colour detection between red and green light. (Guyton & Hall, 2011, 616). Photoreceptor cells are distributed differently across the retina. Central of fovea consist almost solely of cone cells and outside the fovea, rod cells outnumber cone cells. (Burnat & Compton, 2018, 139). Individual differences exist in the distribution of rod and cone cells across the retina. (Kalat, 2016, 154, 155). Cone cells in the fovea have thinner bodies compared to cones in other parts of the retina, which increases visual acuity. In figure 1, is presented how light penetrates to rod and cone cells by going through additional layers of the retina. This penetration through layers decreases visual acuity. In the fovea covering layers are pulled aside, increasing visual acuity. (Guyton & Hall, 2011, 609)

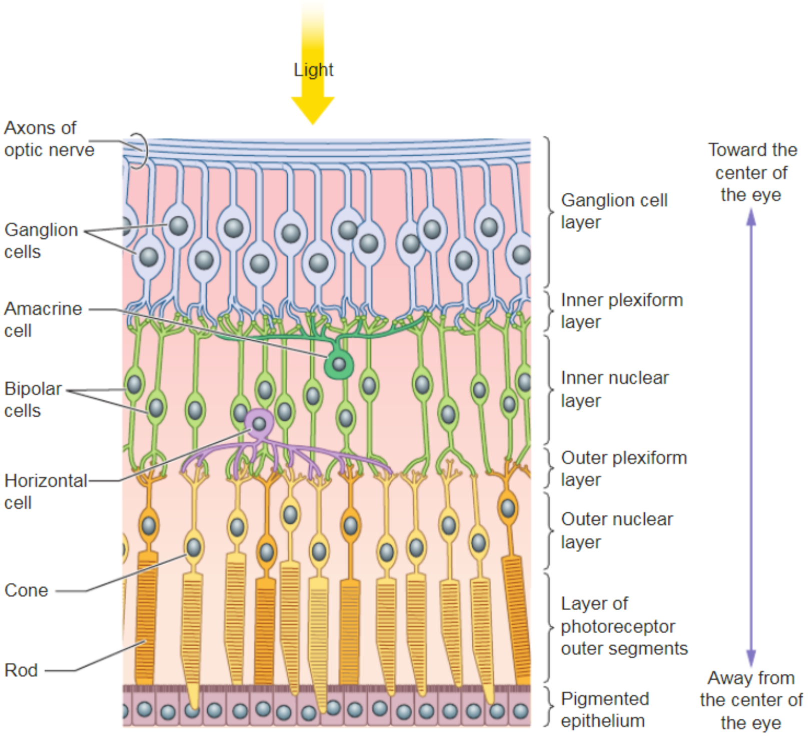

FIGURE 1. Different layers of the retina. (Banich & Compton, 2018, 138).

When rod and cone cells activate, they transmit information towards the brain via multiple neural circuits. Information signal passes through horizontal cells, bipolar cells and amacrine cells to the ganglion cells which transport signal to the brain. From rod and cone cells, information transmits by electrotonic conduction to the ganglion cells which is important because it allows graded conduction of the signal strength, meaning signal can also be between none and all-out unlike in action potential. A visual signal from cone cells is transferred to the brain two to five times faster due to larger body and more straight forward orientation of the transmission nerve cells. Horizontal cells work as lateral inhibitors. When one area of the retina gets excited horizontal cells inhibit the surrounding area. This system enables contrast borders of visual images and so, works as an important factor in high visual acuity. Also, bipolar cells operate as inhibitors of the surrounding area and they provide optional contrast border detection system. Many rod and cone cells are attached to a single ganglion cell. In the peripheral retina, the number of attached cells is vastly greater compared to the fovea. In the central fovea, almost every cone cell has its own ganglion cell, which enables higher visual acuity. (Guyton & Hall, 2011, 616-619). Upper retinal hemisphere contains more ganglion cells than the lower retinal hemisphere (Curcio & Allen, 1990.) Although, because numerous rod cells connect to a single ganglion cell, it provides peripheral retina to be much more sensitive to weak light than central vision, but in the tradeoff, it loses visual acuity (Guyton & Hall, 2011, 619).

There are three types of ganglion cells: W-types, which detects directional movement in the field of vision and rod signals, X-types, which transmit colour and high acuity vision and Y-types. Y-type ganglion cells transmit signal fastest and respond to rapid changes in the visual field. They cannot accurately state the location of the stimuli but can give cues to relocate the gaze. Ganglion cells are mostly capable to detect changes in light intensity. When intensity increases influenced cells get more excited and surrounding cells less excited. This is demonstrated in figure 2. This capability is as well functional in the periphery as in the central vision. Change of light intensity can be caused by, for example, a bird flying against the sky. (Guyton & Hall, 2011, 619, 620).

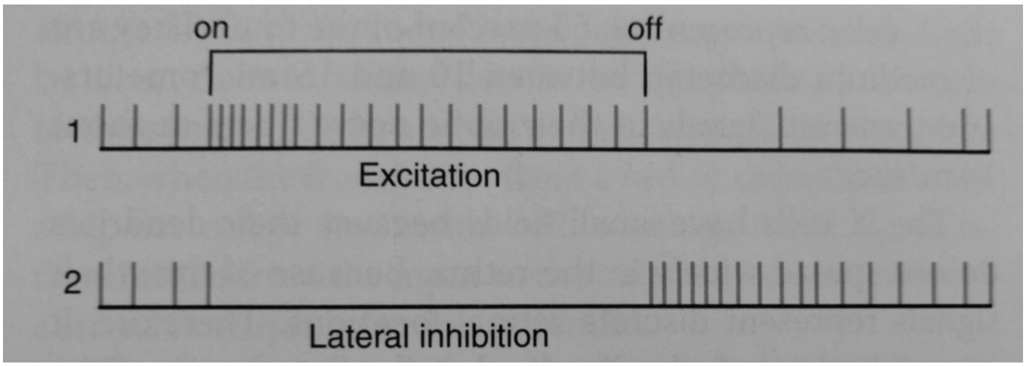

FIGURE 2. Lateral inhibition of retinal ganglion cells. Stimulated cells get more excited and surrounding cells less excited (Guyton & Hall, 2011, 620).

Vision in peripheral retina is decreased because of the heterogeneous layers light penetrates to reach rod and cone cells, cone bodies are fatter compared to cones at the fovea, less rod and cone cells are attached to one ganglion cell than in fovea, in primary visual cortex foveal information is highly presented compared to information from peripheral retina. (Guyton & Hall, 2011, 609, 619).

2.2 Visual pathways

Visual information travels via optic fibres to the optic chiasm, where signals from nasal retinal areas cross to the other side of the brain and temporal signals travel ipsilaterally, as presented in figure 3. (Guyton & Hall, 2011, 623). Optic nerves and blood vessels exit the retina causing a blind spot where there are no cone or rod cells. When observed monocularly perception gap appears 10° of temporal eccentricity. (Burneau, 2015). There are two main pathways with different purposes for visual stimuli to be transmitted to the brain. The tectopulvinar pathway transmits information to the superior colliculus and is responsible for directing gaze and attention to important stimuli. The information about a novel object appearing in the periphery or an unknown movement is quickly transmitted via this pathway. The other pathway, the geniculostriate pathway contains approximately 90% of optic nerve fibres and is responsible for high detailed colour vision. This pathway is used to recognize objects with high acuity. The geniculostriate pathway terminates in the lateral geniculate nucleus and continues to the primary visual cortex. (Banich & Compton, 2018, 141-143).

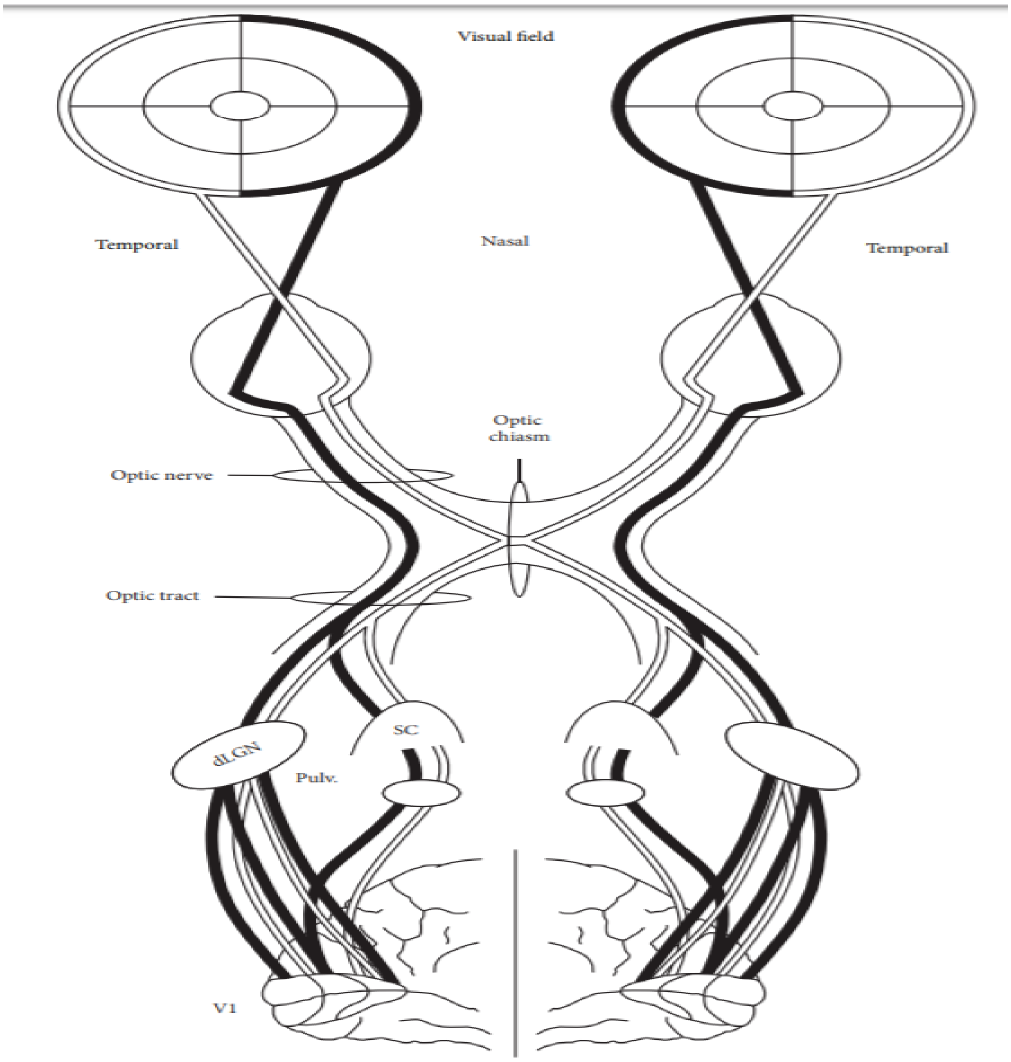

FIGURE 3. The visual system. (Burnat, 2015).

The visual cortex is divided to the primary and secondary visual cortex. In primary visual cortex information from the retina terminates. Foveal information is represented several hundred times more than most peripheral retinal areas. Secondary visual cortex surrounds primary visual cortex. Information from the primary visual cortex is sent to the secondary visual cortex where information is dissected and analysed in many different processing areas. (Guyton & Hall, 2011, 624, 625). The primary visual cortex is much more dedicated to central vision than the periphery, which the number of afferents departing from respective areas suggests. There is a general bias towards perception from the central vision in visual cortex. High acuity objects, for example, faces, are processed in central locations and big and bulky objects in more distant locations. (Burnat, 2015). The primary visual cortex is developed to detect differences in contrast. Unlike contrast detection in the retina, brains can detect the amount of contrast difference in a visual scene. Colour is also detected by contrast. Certain colour is contrasted against a different type of colour enabling contrast to happen. Contrasting colours excite specific cells in the brain. (Guyton & Hall, 2011, 626, 627). The visual cortex has plasticity capabilities. Deaf peoples' visual cortex activates stronger to visual stimulus than normally hearing peoples' does. Adaptations in cortical level have been documented in adulthood without loss of senses. (Burnat, 2015).

Studies have shown that ventral and dorsal pathways have special abilities in analyzing visual information. The ventral pathway runs through the temporal cortex and is called the "what" pathway. Dorsal runs through the parietal cortex and is called the "how" pathway (Kalat 2016, 177). It analyses gross physical form and motion of the objects (Guyton & Hall, 2011, 626) and information relative to the observer and object (Schmidt & Lee, 2014, 76). The ventral pathway is used to identify and recognize objects and dorsal is used to visually guided movements. (Kalat 2016, 177). Also, the dorsal pathway is believed to be tightly associated with unconscious fine control of the movement. The ventral pathway has a certain role in movement control because high acuity demanding objects are analyzed with the ventral pathway. For example, hitter observes baseballs spin and acts upon it. (Schmidt & Lee, 2014, 74, 80, 81). These pathways show their importance when the other pathway is impaired. For example, patients with impaired temporal cortex cannot identify objects but can use vision to guide movements. They cannot locate objects but can avoid them when walking. This demonstrates well how information processing is spread among different parts of the brain. If one damage, the other continue functioning without major impairment. (Kalat 2016, 177, 178).

3 PERIPHERAL PERCEPTION

Peripheral perception works differently than perception in foveal vision (Whitney & Lewi, 2011). Anatomical and physiological differences of the fovea and periphery are clear but how those differences affect perception are not completely uncovered (Shapiro et. al. 2010). Many studies have reported situations where peripheral stimulus is observed differently than when the gaze is aimed towards it (Shapiro et. al. 2010; Whitney & Lewi, 2011). Perception processes are influenced by mechanisms of image filtration, attention, memory, and decision making. Their relative influence on different perceptual tasks varies. (Bondarko et. al. 2014). Peripheral vision is used to guide the foveal gaze to perform efficient saccadic eye movements to crucial visual information areas. (Erickson, 2007, 213; Burnat, 2015).

3.1 Visual information and movement control

Peripheral information is used in everyday situations to movement control, for example walking on different terrains and avoiding obstacles (Marigold, 2008). Ecological psychology theories and the information processing theory explain how visual information is used to movement control. There are several ecological psychology theories, but the ecological dynamics theory has become the most popular to explain behaviour of ecological psychology. Ecological dynamics is based on human-environment interaction through affordances. A person sees the surrounding world and acts in it according to the affordances he/she has. Perceiving in ecological dynamics is based on active search, meaning affordances to do something, for example, pass the ball to a free teammate, are needed to be searched. The role of the brains is to vaguely decide what to do, but according to ecological dynamics' memory has no function in any process. In information processing theory short and long-term memories are in the main role. Perceived visual stimuli are stored in short term memory and compared to long term memory which informs which stimuli are important and consciously seen. (McMorris, 2014, 40-43). Visual cues and predictive information are used to parameterize internal models or motor programs of desired movement to achieve the task goal. (Klein, 2017, 24-30).

Model of the information processing theory, the closed-loop control system, presented in the figure 4, describes how sensory information is used to analyse information, perform actions, and then compared the actual outcome to the desired outcome. Closed-loop system has four distinctive parts: executive for decision making and order giving, effector to make executives orders happen, comparator which as it is named, compares orders to the outcome, and error signal, which gives information to the executive to make more precise orders. Information arrives at the executive, where the stimulus is identified, a suitable response is selected, and movement is programmed. This information is forwarded to effector where motor programs are used to deliver information to muscles via the spinal cord. Information arrives at comparator from exteroceptors, muscles' proprioceptors and from executive which sends anticipated feedback of the movement. After and during the movement, the comparator analyses anticipated sensory feedback and compares it to actual proprioceptive and exteroceptive feedback. If differences appear, the error signal is sent to the executive to achieve better movement control and outcome. For example, during driving, a person observes the road ahead and adjusts the car's position on the road if error feedback is given. Error feedback can arise for example when the car starts to drift to the middle of the road. Vision, especially dorsal pathway vision, affects movement control also on a subconscious level. Visual feedback is used to, for example, alter bat swing to successful hit in baseball. (Schmidt & Lee, 2014, 83).

There are problems concerning the information processing theory and movement control from the ecological dynamics standpoint. Novelty and storage problems concern the information processing theory. If motor programs are always used to perform an action, how completely novel movements could happen? Also, if there would be a motor program for every variation of every movement, the storage capacity of the brains would not be enough. (McMorris, 2014, 45). Theory of the closed-loop system is suitable for relatively slow and long-lasting actions, but sudden, quick, or discrete movements do not fit in. Visual processing using feedback needs time and hence do not seem capable to control the execution of fast movements. In tracking tasks approximately three corrections per second seem to be the upper limit of using visual feedback. If the task demands more, performance usually deteriorates. Before every correcting movement information goes through the executive, effector and comparator which simply takes time. Fast movements are performed without correction or modification, using pre-planned movements, motor programs. (Schmidt & Lee, 2014, 70-71). Problems in ecological dynamics are related to the strict view of cognitive processes. The human ability to learn and improve through practise is contradictory to the view that memory plays no role in movement control. Ecological dynamics' avoid the problem by stating that people get attuned to the same affordances and thus improve. The second problem is the inability to recognize the role of cognitive processes for example decision making. It is not clearly explained how the most important affordance is decided. (McMorris, 2014, 48).

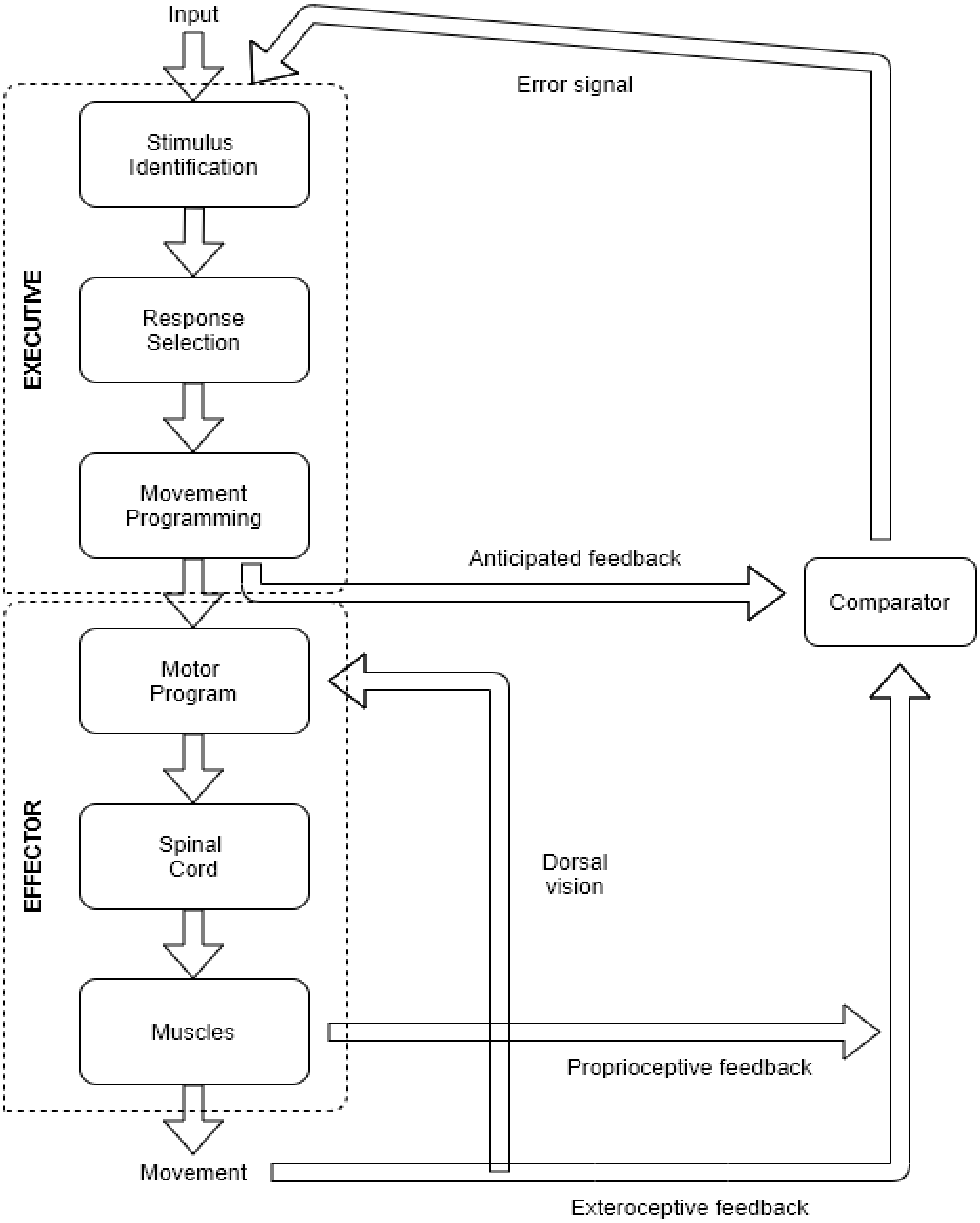

FIGURE 4. The closed-loop motor control system. (Adapted from Schmidt & Lee, 2014, 83).

This dichotomy of movement control theories influences how visual information is used to guide movement. Two main theories exist: model-based control and information-based control. Model-based approach suggests that movement is controlled by internal models of the body and environment. The role of the perception is to create an 3D-model of the environment where person can act. Advantage of this model is that it explains how person can move even without visual information, for example when his/her eyes are shut. Information-based control, supported by ecological dynamics, supports the tight coupling of perception and action. Perception detects information, optic variables from optic flow, which guides the movement. Optic variables are task specific, meaning optic variables in one task differ from variables in other tasks. (Fajen, 2007). Zhao & Warren (2015) reviewed research on the topic and came to conclusion that model-based control does not sufficiently explain movement control and that only in rare conditions weak internal models might guide movement. Fajen (2007) introduced the affordance-based approach, developed from the information-based model, to explain how vision guides the movement. The affordance-based approach explains that athletes move based on affordances in the environment. For example, baseball outfielder runs to catch the ball only if it is perceived as catchable. Information-based approach explains how athlete moves his/her body regarding to environment but not how the athlete achieves the goal within the limits of his/her action capabilities. Affordance-based approach takes this into account by including actor's movement capabilities and enables athletes to separate possible and impossible actions with visual information. (Fajen, 2007).

Another argument about perception in sports is the role of general visual skills. Ecological dynamics argue that perception is sport specific which is why general skills do not transfer to other sports. (Anson et. al. 2005). Some researchers argue that general visual skills are important in sports performance (Hitzeman & Beckerman, 1993) and improving them will aid sports performance (Clark et. al. 2012). Support for this comes from studies where athletes have shown better visual performance than non-ahtletes. (Vera et. al. 2020; Laby et. al. 1996). It is debated whether the superiority of visual skills arrive from nature or nurture. Does sport specific training develop visual skills or do persons with good vision seek to be athletes? (Barrett, 2008). Whether or not visual skills are improved in athletic populations some researchers debate that there are no clear benefits of improved visual functions to the sports performance. (Hitzeman & Beckerman, 1993). For example, Mann et. al. (2007) had to blur baseball batters' vision to the level of almost legally blind before any decrease in performance was observed. Recent research about eye-hand coordination skill supports the sport-specificity. Eye-hand coordination is said to give person a general skill to move hand accordingly to what is perceived, for example to catch a fast-bouncing ball. This ability was thought to offer a general ability to many situations to coordinate eye-hand teamwork but increasing information shows that this kind of general, works in many situations, ability might not exist. Intercorrelations between different eye-hand coordination tests have been mostly small. This evidence arguments about the importance of sport specific tasks. (Ellison et. al. 2018). Supportive findings about the importance of general visual skills in sports performance has been found when 252 professional baseball players' sensorimotor abilities were compared to baseball game statistics. Sensorimotor abilities were significant predictors for on-base percentage, walk-rate and strikeout rate. This finding supports the role of generic visual skills for on-field sports performance. (Burris et. al. 2018).

3.2 Stimulus perception

Signal detection theory explains how visual stimuli are perceived. Eyes gain a huge number of signals per second from the surrounding environment, but only some are consciously perceived. This depends on the stimuli's intensity compared to the intensity of the background noise (e.g. all the other visual information). Individual's sensitivity and bias to the stimuli affect how high the intensity of one stimulus is. Sensitivity means how the sensory information is gained, for example visually, and it is affected by stimuli familiarity. Bias to stimulus is highly affected by arousal, which can decrease or increase stimuli intensity. If arousal is too low, some stimuli are not noticed, and if arousal is too high stimuli that do not exist can be perceived or arousal increases background noise drowning important stimuli. (McMorris, 2014, 58-59).

A visual stimulus can be perceived within the visual field, i.e. visible area without change of fixation (Ferreira, 2002). The visual field of one eye extends depending on the source approximately 90° degrees temporally (Regan et. al. 2011; Mańkowska et. al. 2015) and approximately 50° nasally (Burnat, 2015) as presented in figure 5. Stimulus identification degenerates the further in the periphery it is observed (Kalat, 2016, 153) due to a decrease in retinal ganglion density (Kwon & Liu, 2019). Overall, due to these changes' periphery has some basic identification capabilities. (Kalat 2016, 153). It responds well to motion detection (Regan et. al. 2011) due to a great number of Y-ganglion cells (Burnat, 2015), multiple object tracking (Vater et. al. 2017) and dim light but visual acuity, colour detection and identification among bright lights are poor. Individual differences exist in the ability to detect changing visual stimuli. (Kalat 2016, 153). Humans seem to be more efficient at interacting with items in the lower than in the upper visual field (Brown, et. al. 2005; Khan & Lawrence, 2005). For example, reactions to visual stimuli are faster in the lower than the upper visual field (Stone et. al. 2019). Although, Campbell et. al. (2019) investigated grasping objects at the lower or upper visual field and found no differences in movement control.

Peripheral information is important for motion detection and objects recognition. On the outer region, 70 degrees from the fovea, motion contrast is higher than colour contrast and at the extreme periphery, only movement can be detected. This does not mean that these extreme retinal areas excel in these capabilities. Contrast and movement detection degenerate as eccentricity increases. It also appears that motion detection is highest near the vertical and the horizontal axis and for objects moving towards the observer rather than to other directions. (Regan et. al. 2011). Object recognition is time dependant, meaning recognition accuracy increases as observation time increases (Heitz & Engle, 2007). Objects perceived in periphery seem, for an unknown reason, smaller than when gazed. Even at eccentricities 3°-12°, this perception error is in effect. Distributing attention towards the peripheral object eliminates the effect. (Kirsch et. al. 2019). All in all, attention shift towards peripheral targets improves peripheral perception (Burnat, 2015) which will be discussed more in chapter visual attention.

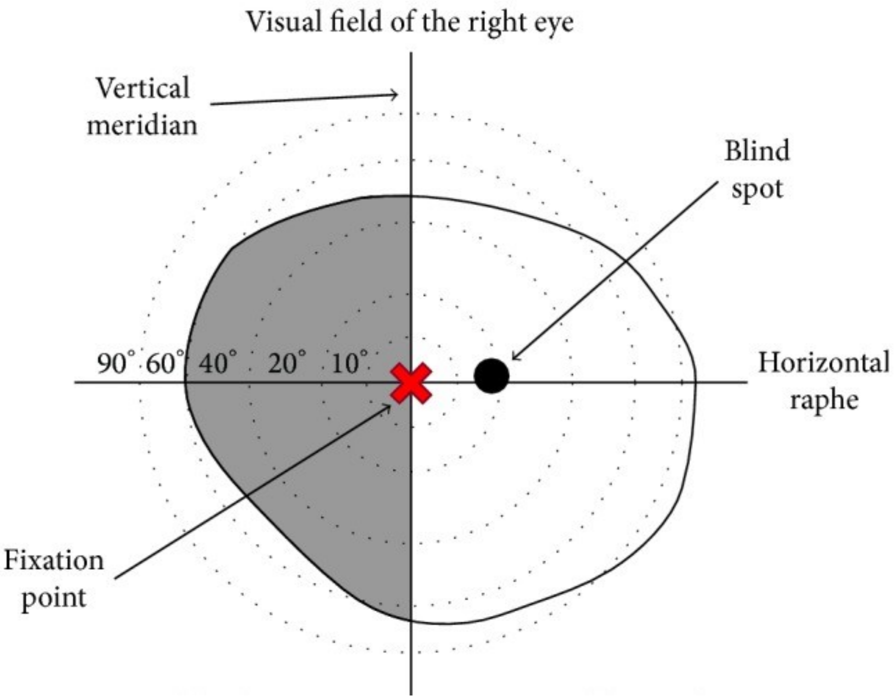

FIGURE 5. Visual field of the right eye. (Burnat, 2015).

Peripheral reaction speed has great intra- and interindividual variability. Following aspects have significant but small effects: eccentricity, luminance, target size, target duration, monocular/binocular observing, and nasal vs temporal side of stimulus. (Strasburger et. al. 2011). Also, sex might have an effect because it has been found that men are slightly faster in reaction tests with central stimuli (Silwerman, 2006). Peripheral reaction speed is generally slower than a reaction to a central stimulus (Soichi et. al. 2001). Reaction time increases the further in the periphery the stimulus is observed (Yang et. al. 2012; Helseni & Starkes, 1999). Reactions to visual stimuli on the temporal visual field are slower than reaction times to stimuli appearing on the nasal visual field. Reaction time increases approximately 1.08-1.56 ms/degree on the temporal visual field and 0.84-1.42 ms/degree on the nasal visual field. (Strasburger et. al. 2011). Reaction time varies between 220-260ms at a central location and 255-340ms at peripheral locations depending on size and eccentricity of the stimulus (Ando et. al. 2001; Clark et. al. 2017). Reaction time to visual stimulus is faster when the stimulus appears to a cued location compared to an unexpected location (Posner et. al. 1980). When the location of stimuli appearance is not known, reaction time increases to 268-286ms at 30° degrees of eccentricity depending on the size of the stimulus. (Soichi et. al. 2001).

Depth perception occurs by both foveal and peripheral vision in many ways. Binocular disparity gives cues to how far objects are. As an object’s disparity increases, it is analysed to be further away. (Banich & Compton, 2018, 202). By knowing the size of a certain object, brains automatically calculate the distance from that objects retinal image. Peripheral vision to depth perception is used in moving parallax which happens when the head is moved. Objects close to the observer move further in the retina than objects that are further away. (Guyton & Hall 2011, 605).

Colour detection. Even though there are major inter-individual differences in distribution and number of different cones in the retina, they produce only small differences in colour perception. In peripheral retina, there are scarcely cone cells that is why colour detection in the periphery is inefficient. (Kalat 2016, 155). Noorlander et. al. (1983) investigated how colour is perceived at horizontal eccentricities. They found that colour detection discriminates as the stimulus moves to bigger eccentricities but if stimulus size increases can colour detection be same as in foveal gaze. They found that colour can be detected up to at least 90 degrees of nasal retinal eccentricity. Even though cells in the nasal peripheral retina are suitable to detect motion much better than colour (Burnat, 2015), Noorlander et. al. (1983) did not find a retinal location along horizontal meridian which could not detect colours between yellow-blue or red-green colour types. Also, Ghasemi et. al. (2009) found colour perception in multiple peripheral field locations. Due to Noorlander et. al. (1983), Ghasemi et. al. (2009) and Kalat (2016, 155) To conclude, it seems that colour perception in peripheral retina is rather inefficient, but identification gets easier as the stimulus is perceived closer to the fovea and as the stimulus size increases (Noorlander et. al. 1983; Ghasemi et. al. 2009; Kalat, 2016).

Extreme periphery is used in maintaining balance. Even when a person is standing still, the peripheral vision has major importance to keep the body steady. (Horiuchi et. al. 2017). Peripheral vision seems to be more important to balance control than central vision, but controversy exists (Raffi & Piras, 2019). At stance, the lack of peripheral visual information produces more body sway than the absence of foveal information, highlighting the role of peripheral visual information to balance. Peripheral information for balance is controlled by head-gaze orientation rather than body-gaze orientation, meaning both head and gaze need to be pointed to the same direction to utilize peripheral information to control balance. (Berencsi et.al. 2005). When walking and maintaining focus where one is going, flow patterns to eyes are fastest at 90 degrees from the gaze. Vection, the illusion of experiencing motion while being stable, is the most easily generated in this visual area. (Reagan et. al. 2011). Temporal crescent fields affect postural balance as they adjust head and body position with the latency of approximately 1 second (Bessou et. al. 1999.) Peripheral vision is in an assistant role to perceive optical flow-induced heading, but still has an important effect in total heading perception. These statements stand in natural movement situations, for example in running. (Warren & Kurtz, 1992).

Stimuli misanalysis. There are two general situations when peripheral information processing is lacking (Whitney & Lewis, 2011; Shapiro et. al. 2010). The crowding effect is a major impediment to object recognition in the periphery. Crowding effect, shown in figure 6, is present in everyday life, for example in driving and reading. Individually objects are identified easily but when objects are in a cluster, failure to incorrect recognition increases greatly. Analysing peripheral objects' size, shape, alignment or recognition deteriorates if the targeted object is in a cluster. (Whitney & Lewi, 2011). The density of the cluster affect recognition. The denser the cluster is, the harder it is to recognize. (Bondarko et. al. 2014). Also, the crowding effect decreases the ability to react correctly to peripheral stimulus. Crowding does not make objects disappear from vision it only affects identification. Objects appear to have high contrast, but they can be mixed or indistinct. The proximity of other objects and the eccentricity of a targeted object affect recognition. At a given eccentricity, recognition of the targeted object improves as surrounding objects are further away. Crowding can occur to moving objects, for example, the target is more crowded when flanker is moving in front of the target rather than behind it. The crowding effect does not destroy all the receivable information, it is believed to be pooled and averaged. The crowding effect can be destroyed by making the crowded object as different as possible from the flankers. Also, directing attention towards the crowded object decreases the effect. (Whitney & Lewi, 2011).

If attention in directed to multiple locations, recognition of the crowded object deteriorates (Bondarko et. al. 2014).

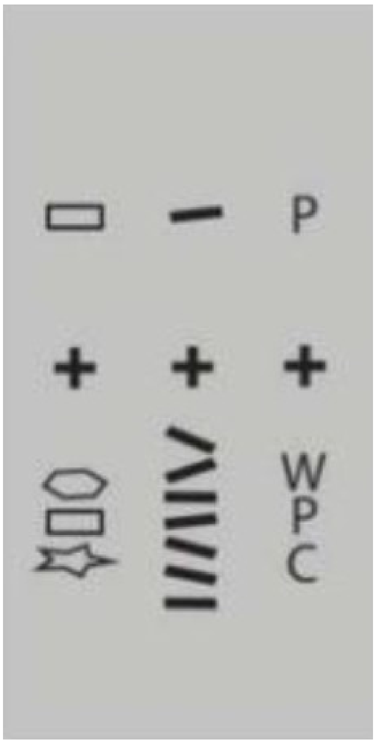

FIGURE 6. The Crowding effect. Gaze on a cross mark, figures in the middle of the cluster below the mark are harder to recognize than figures above the cross mark, although distance remains the same. (Whitney & Lewi, 2011).

Gabor illusion. An important perception misanalysis occurs when a moving object has local movement (e.g. ball has a spin during flight). Baseball batters have often reported that thrown curveballs move unpredictably, even though observations using a camera state otherwise. This might be due to the inability of perceptual mechanisms to process information when an object moves from fovea to periphery or globally moving object has also local movement. (Shapiro et. al. 2010).

Shapiro et. al. (2010) examined how vertically moving object with local horizontal movement to the left or right (i.e. a Gabor) is perceived when the gaze is fixed at 0, 15 or 30 degrees off the descending trajectory. They found that when an object was perceived peripherally, the object was observed to descend to the same direction as the object's local movement and the effect increased as the eccentricity of the gaze and local movement of the Gabor increased. At eccentricity 0, objects descend was perceived without faults. This led to the conclusion that foveal vision can perceive and separate global and local movement, but peripheral vision lacks this skill and combines the two movement signals. This may explain why batters perceive abnormalities in curveballs trajectory and fail to hit the ball accurately. (Shapiro et. al. 2010).

Massendari et. al. (2018) investigated visually guided and memory-guided saccades' differences in similar vertically descending Gabor. The saccade was performed towards Gabor while it was descending or 0, 0,25, 0,5 and 1 second after the Gabor had disappeared. Results showed that memory-guided saccades were highly influenced by the perceived illusion by approximately 48%. Error in memory-guided saccades increased as the time from Gabor's disappearing increased. These results showed that oculomotor memory (eye movement memory) decays over time and is unreliable. (Massendari et. al. 2018). Whether visually guided saccades are influenced by the Gabor illusion is not clear. Small error with visually guided saccades may occur but visually guided saccades are much more accurate than saccades based on oculomotor memory. (Massendari et. al. 2018; Lisi & Cavanagh, 2015).

3.3 Athletes' perception

Athletes perceive in the same way and has the same theoretical dilemmas as discussed in the visual information and the movement control chapter. Many studies have investigated athletes' perception to generic stimuli and some differences compared to the novices have been found (Zwierko et. al. 2010; Stone et. al. 2019). Ecological dynamics and information processing theory have different perspectives of the relevance of generic stimuli in sports (Fajen, 2007).

Peripheral stimulus perception in sport is not as widely investigated area as central perception and gaze behaviour. There is not much information about the role of peripheral-cognitive functions in sport situations. (Vater et. al. 2019 A). Peripheral perception and the extent of the visual field are important in sports because a lot of information is gained from the visual peripheries (Ciuffreda & Wang, 2004; Ryu et. al. 2013). For example, in basketball, players balance their visual attention between central and peripheral attention and often, information from the periphery is more important than information from the gaze. (Erickson, 2007, 16). Different aspects, for example, gaze behaviour, reaction speed and visual attention affect peripheral perception in sport and sports performance (Vater et. al. 2019 A; Mashige 2014). Superior peripheral perception in elite athletes has been found, for example, elite football players acquire more information from the periphery than novice players (Vater et. al. 2017). Also, basketball players' decision-making accuracy does not decrease as much as novices' when only peripheral information is available (Ruy et. al. 2013 B). There are contradictory studies whether visual fields are larger in athletes than non-athletes (Zwierko, 2008; Stine & Arturburn, 1980).

Athletes seem to have a shorter reaction time to a non-sport-specific peripheral stimulus than non-athletes, but controversy exists. (Helseni & Starkes, 1999; Soichi et. al. 2001; Ward & Williams, 2003; Zwierko, 2008; Vera et. al. 2017; Stone et. al. 2019). Some studies have not found differences between athletes and non-athletes in peripheral reaction time (Vera et. al. 2017; Ando et. al. 2001). But, studies have been made where differences exist. Faster reaction speed to peripheral stimulus has been found among handball (Zwierko et. al. 2008), volleyball (Zwieko et. al. 2010) and basketball players (Stone et. al. 2019). In Zwierko et. al. (2008) and (2010) studies simple central task was used during peripheral reaction test which could mean that athletes can process more demanding visual scenario better than non-athletes (Zwerko et al. 2010). This is supported by athletes' faster premotor times to central and peripheral stimulus (Ando et. al. 2001; Zwierko et. al. 2010) and above-average brain responses to visual stimuli. Faster brain responses are found only among athletes who compete in quick reaction sports, like fencing or tennis. (Kalat 2016, 153). Older athletes' peripheral reaction speed may be influenced by age which has been showing to be detrimental for reaction speed (Ward & Williams, 2003; Jaworski et. al. 2011). Stone et. al. (2019) investigated whether basketball players have a lower difference between upper and lower visual fields in the motor task. Basketball players were used because a significant amount of training consists of the upper visual field. They found out that athletes were faster and had smaller difference at reaction speed between visual fields than non-athletes, meaning information from the upper visual field was used better in movement control. (Stone et. al. 2019). Peripheral reaction speed does not seem to separate different skill level football players (Helseni & Starkes, 1999; Ward & Williams, 2003). Colour detection has been shown to be improved with expert soccer referees compared to novice referees demonstrating a positive correlation with colour detection and skill. (Ghasemi et. al. 2009).

Moderate exercise seems to have an acute negative influence on peripheral reaction speed. Reactions to peripheral stimulus during cycling at 65% of peak oxygen uptake were significantly slower (195.9 ± 7.9ms) than reaction times during rest (183.7 ± 6.8ms). Exercise did not affect foveal vision reaction time. Increase in the reaction time may be caused by exercise-induced increase in arousal and narrowing of attentional focus. (Ando et. al. 2008). Recent research suggests another explanation. During strenuous activity, peripheral perception is impaired due to a decrease in cerebral oxygenation. Under hyperoxia conditions, peripheral perception does not decrease even during heavy exercise. (Ando, 2013). There appears to be a limit where visual perception is influenced by exercise. Ando et. al. (2012) tested perception during cycling and found that perception was not influenced at 40% of VO2max but at 70% from VO2max decrease in both peripheral and foveal perception occurred. Detrimental effect on peripheral performance was no longer present immediately after exercise. High aerobic capacity seems to at some level attenuate the decrease of peripheral perception during strenuous exercise. (Ando, 2013). The perception was tested using a simple visual reaction time. These findings are important in sports where activity level increases over 70% from VO2max. (Ando et. al. 2012). More common-sense impairment to peripheral vision is caused by goggles. Frames of the goggles block vision and diminish the visual field. (Kayffman et. al. 2015).

3.3.1 Visual attention

Visual attention is tightly linked to peripheral vision because directing attention appropriately enhances peripheral capabilities. (Vater et. al. 2017.) Visual attention is important because the location of attention defines what an individual is currently perceiving. The person can watch something but if attention is elsewhere, information is not consciously perceived. (Dehaene et.

al. 2006). Thus, visual attention and visual perception are relatively similar but have differences as explained. Visual attention is a subprocess of visual perception which can be defined as the basis of human recognition, experience, and action. (Memmert, 2009). Covert attention, i.e. directing attention towards peripheral locations (Ryu et. al. 2013), can increase peripheral perception accuracy, for example, contrast sensitivity and information processing speed (Vater et. al. 2017.) Reaction time decreases when attention is directed to the same location where the stimulus appears (Posner et. al. 1980).

There are two models of how visual attention guides stimulus perception: bottom-up and top-down attentional selection. Attention is directed to a visual stimulus in a bottom-up manner when the visual stimulus is distinctive as its own, for example, due to a contrast difference. Top-down selection occurs when an individual decides to move attention. This could happen for example when a task is performed, and attention is needed to shift according to the task. These models are said to be linked to dorsal and ventral pathways. Bottom-up attention and ventral pathway both are related to salient stimulus identification whereas dorsal pathway and top-down attention selection are related to goal-directed processing. (Banich & Compton, 2018, 300, 301, 317). Irrelevant visual stimuli can be suppressed if person guides attention in top-down fashion and moves gaze to the task specific locations. To know which locations are relevant comes from experience of previous similar situations making highly experienced performers act with only little conscious control. (Brams et. al. 2019).

There are multiple various objects in team sports which need to be observed at the same time. Players' ability to focus on what he/she looks at and at the same time observe surrounding events, together with anticipatory skills are crucial for elite performance. (Mashige, 2014; Mańkowska, 2015). Elite basketball players have been shown to possess superior multiple object tracking skills than novices or intermediate players (Qiu et. al. 2018). Because attention affects how many and how difficult stimuli can be perceived during the action (Cavanagh & Alvarez, 2005), it must be taken into account in every situation. Visual attention can be directed towards multiple objects but with limitations and considerations (Cavanagh & Alvarez, 2005.) Vater (2019) studied how movement changes in attended or unattended objects are observed. Participants tracked four objects which moved along with six additional objects. Button was pressed when any object's disappearing was perceived. When attention was directed to an object almost all disappearances were perceived but only half of the unattended objects' disappearances were noticed. This means that when attention is directed elsewhere other objects cannot be perceived successively. All the objects moved inside 25° of visual field so the widespread attention was not needed. (Vater, 2019)

Foveal and peripheral visual scene processing happens in parallel in the visual cortex, having a reciprocal influence on each other (Schwartz et. al. 2005.) For example, when attention and gaze are directed to high demanding task, processing of the surrounding stimuli is decreased. But when the task is low demanding, surrounding stimuli are processed simultaneously. (Banich & Compton, 2018, 312). In visually challenging scenarios, where there are multiple objects to observe (e.g. basketball game), a common pool of attentional resources is used to maintain attention. If the attention demand of the scenario exceeds attention resources in the pool, performance will deteriorate. (Wickens, 2008.) Also, perception performance can decline when another task is performed simultaneously even though neither exceeds attentional resource pool. (Bondarko et. al. 2014). In team sports, athletes gain a lot of information from the periphery which highlights the importance of divided attention skill for athletes (Ryu et. al. 2013.)

Attention and memory systems are linked together because they show similar properties (e.g. capacity limits, brain activation) when brains have been analysed during tracking and visual short-term memory tasks. Attention can be defined as visual memory at point zero because of its relation to episodic memory. (Cavanagh & Alvarez, 2005). Visual memory holds information about objects detected in visual space (Pratte & Tong, 2014). The salience map introduces a topographical map of visual space where every object competes to be the most salient one. Usually, the most distinctive object compared to other surrounding objects wins foveal attention. (Fecteau & Munoz, 2006). Also, previously told signal detection theory explains object recognition similarly (McMorris, 2014, 58-59). Visual attention is used to select the most important stimuli and peripheral vision coordinates the attention shift (Hüttermann & Memmert, 2017; Kowler, 2011). In multiple objects tracking visual memory is used to track objects (Cavanagh & Alvarez, 2005). Two objects appearing at the same time define the size of the attention-window. Individuals can spread attention to only one fifth or sixth of the visual field size. Attention-window is defined with small geometrical shapes so bulkier objects could be observed from a wider area. (Hüttermann & Memmert, 2017).

People have different abilities to direct their visual attention. Individuals' working-memory capacity and environmental issues (e.g. motivation) affect how attention can be distributed. (Heitz & Engle, 2007). Object recognition and scene understanding influence visual attention. Familiar objects are recognized easier and do not need that much attentional resources. (Itti & Koch, 2001). Athletes seem to be better at shifting attention between different locations (Memmert, 2009; Williams et. al. 1999) and being able to spread their attention to a wider area than novices. Also, attentional demands of one object can be less in athletes which enables wider attentional distribution. (Williams et. al. 1999, 49). Team sport athletes show wider attention spreading skills than closed-skill athletes or non-athletes, demonstrating the importance of visual attention in team sports when the movement on the whole court must be analyzed (Hüttermann & Memmert, 2018).

3.3.2 Gaze behaviour

The foveal gaze is used to analyze objects with high acuity, but because the gaze is only a few degrees wide lots of information is positioned in the periphery (Guyton & Hall, 2011, 604). Saccadic eye movements are used to move gaze towards these areas (Vater et. al. 2019 B). During saccades visual attention is directed towards the target of the saccade, leaving other areas unperceived, (Kowler et. al. 1995) and visual information processing is suppressed (saccadic suppression) which can lead to detrimental effects in sports where extremely fast reactions are necessary (Klingenhoefer & Bremmer, 2011).

Peripheral vision can be used to observe multiple objects at the same time (Cavanagh & Alvarez, 2005). This ability is used when the gaze is anchored between important objects to enable the simultaneous perception of both objects. This point of gaze is called as a pivot or an anchor and is beneficial for decision-making because saccadic suppression does not occur. These pivot points have been found to be made by karatekas, goalkeepers, batters in baseball and blockers in beach volley. (Vater et. al. 2017). Depends on the task, anchors are made to optimally extract peripheral information. For example, kung fu fighters fix their gaze higher on opponents' torso than Thai boxers, who mostly only kick. Kung fu fighters do not use legs so they are not so important to observe. (Hausegger et. al. 2019). Several functional advantages for stabilizing the foveal gaze have been introduced which have also benefits to peripheral perception performance. Visual information can be processed from the fovea and peripheries while covert attention scans for changes in the environment. Peripheral information is used to locate the most salient target to be observed with the foveal gaze. Gaze location is most efficiently targeted between relevant cues, i.e. an anchor of gaze is made, to extract most cost-efficiently peripheral information. Simultaneously, suppressing saccades are avoided. (Vater et. al. 2019 B.)

Two findings demonstrate elite athletes' superior peripheral perception over novices; when peripheral vision is blocked elite athletes' performance deteriorates more than novice players (Williams & Davids, 1998), and when central vision is blocked elite basketball players make more accurate decisions than novice players (Ryu et. al. 2013 B). In Van Maarseveen et. al. (2018) study they examined basketball players gaze behaviour in an offence scenario. They found that usually players located their gaze to the player they passed the ball to but in 19,5% of the trials the last fixation was elsewhere, meaning they passed the ball relying on peripheral information. In shooting and driving to the basket, the final fixation was always on the basket. Near significant positive correlation was found with successful performance and time spent fixating between players. This means players used an anchor point between players to better utilize information from peripheral vision and that it could result in better decision making. When gaze paths of successful and unsuccessful decisions were compared, it was found that focusing on central targets rather than moving gaze to and from distal locations resulted in better decisions. (Van Maarseveen et. al. 2018). In Ruy et. al. (2013 B) study novice and skilled basketball players were shown basketball situations in three conditions; central vision blocked, peripheral vision blocked and full vision. Skilled players were better at recognizing the best action in every viewing situation than novices. This means that when central vision was blocked skilled players were better at extracting information from visual peripheries. (Ruy et. al. 2013 B).

4 PERIPHERAL PERCEPTION TRAINING

The different views about visual cue utilization and how visual information is used in sports affects how training should be organized. (Hitzeman & Beckerman, 1993; Anson et. al. 2005; Clark et. al. 2012). Ecological dynamics argue that the environment where movement is performed is crucial because perception and action are coupled and so, training with generic stimuli cannot improve sports performance. Athlete reacts to affordances in the environment and acts upon them with current constraints she/he has. These affordances do not exist with general visual training and so, athlete cannot improve sports performance with such training. (Fajen, 2007). Meaning, the environment where training is performed plays a key role in perception and action (Formenti et. al. 2019). Training should be performed in a sport-specific way (Anson et. al. 2005). Eye-hand coordination studies demonstrate that this ability does not transfer efficiently across sport domains and so, training eye-hand coordination should be sport-specific (Ellison et. al. 2018). Also, Formenti et. al. (2019) found no significant differences between groups in volleyball sports performance after 6 weeks of visual or volleyball training. Training did improve volleyball players cognitive performance measured as executive performance, reaction speed and perceptual speed (Formenti et. al. 2019). Wimshurst et. al. (2018) found support to the general visual training. They divided cricket players into three different visual training groups and to one control group. After 6 weeks of training all vision training groups improved significantly in cricketing tasks compared to the control group. (Wimshurst et. al. 2018). Yet, there does not seem to be a clear consensus what could be the most optimal way to train perception in sports (Anson et. al. 2005; Formenti et. al. 2019).

Many different perception training programs involve peripheral perception training (Hadlow, 2018). Perceptual-cognitive training seems to improve athletes’ perception, but a statement, whether perceptual training improves sports performance cannot be made due to a lack of studies investigating this (Zentgraf et. al. 2017). Improving the attentional resources should improve the capability to observe objects with higher accuracy or increase the number of observed objects (Cavanagh & Alvarez, 2005). Burnat (2015) hypothesized that peripheral vision system is immature and creates a beneficial condition for the maintenance of a great level of plasticity which could allow peripheral vision system to develop due to training.

Vision training has been given guidelines to optimize transfer effects. Training should be highly specific, goal-directed, behaviourally based with adequate feedback to diverse responses. Also, a large number of repetitions and task-specificity to the sport are necessary. (Chiueffreda & Wang, 2004, 24, 25). Task specificity means that the perception-action coupling in exercises should mimic perception-action coupling in key sport situations (Broadbent et. al. 2014; Zentgraf et. al. 2017). At the beginning of the visual training, visual stimulus and response should be introduced and after some trials, speed of response should be demanded. Exercises should progressively advance as the athlete improves. Visual training should include additional sensory load during exercises to accurately match sports scenarios and lead towards automaticity of response. Balancing, auditory tasks and distractors are used to increase the sensory load. Training effects may be increased when an additional sensory load is added. (Erickson 2007, 186, 194, 195). Training can be designed by analysing the attention demands of the sport and then train these perceptual-cognitive skills with the sport like technique and physical activity level. This should closely resemble the competitions' perceptual-cognitive demands. (Zentgraf et. al. 2017). Combining visual training with aerobic exercise is not suggested as an exercise prior to visual training could impair training results. On the other hand, exercise after visual training does not seem to any effects. (Connell et. al. 2018).

4.1 Improvements in Peripheral Perception

Sports vision training aims to improve athletes vision skills (e.g. dynamic acuity, depth perception, peripheral awareness) which may help athlete detect and identify visual information. In sports vision training generic stimuli for example symbols, colours or patterns are constantly used. Training tasks are specified according to the visual skills used in the sport. Perceptual-cognitive training typically uses videos of sport scenarios to improve athletes' anticipation and decision-making skills. (Hadlow, 2018). Physiological improvements in peripheral vision have been suggested. There is a theoretical possibility to improve physiological peripheral acuity. In animal studies, a lesion in central vision may have improved static acuity of peripheral vision. In humans, peripheral receptive cells are large and could have the potential to decrease which could lead to visual acuity changes that were observed in animals. (Burnat, 2015).

Peripheral stimulus perception and reaction speed can be improved with numerous hours of practice (Krüger et. al. 2010; Schwab & Memmert, 2012; Feldhacker & Molitor, 2019; Schumacher et. al. 2020). People with hearing disabilities have been found to possess a vaster visual field, especially the lower field. (Burnat 2015; Buckley et. al. 2010). Action video game players have overall larger peripheral visual fields and higher detection acuity at 30º eccentricity than non-players. This is probably because of numerous hours of playing video games. (Buckley et. al. 2010).

Peripheral reaction speed has been improved with sport-specific on-field peripheral training. Young football players' peripheral reaction speed significantly improved after eight weeks 20 minutes per week training. Training consisted of reactions to football that came out of view with and without additional juggling task. (Schumacher et. al. 2020). Peripheral perception of field hockey players was successfully increased with six weeks, three 45 minutes sessions per week, of generic vision training. Sport-specific transfer test was not used so influence on field hockey performance cannot be evaluated. (Schwab & Memmert, 2012). Improvements in cricket players' peripheral perception have been found after eight weeks of training. Training intervention included many ball catching exercises with different visual skill improvement aims. The study did not have a control group so actual training effects cannot be clearly separated from possible familiarization to the tests. (Krüger et. al. 2010). Feldhacker & Molitor (2019) improved softball players peripheral reaction speed with six weeks of visual skill training. In a reaction test, participants pressed randomly illuminated red light button as fast as possible. The training was not directed to enhance peripheral vision. It included attention, reaction speed, eye movement and central peripheral integration training. Reaction times decreased significantly from 0.81±0.04s to 0.73±0.06s. (Feldhacker & Molitor, 2019).

The Crowding effect. Chung (2007) investigated whether the crowding effect can be decreased by training. She tested reading speed and letter recognition with flanker letters using five different distances between the target letter and flankers before and after training intervention where participants practised recognizing flanked letters. She found out that letter recognition improved substantially at the trained flanker separation distance and at distances which were not trained. Peripheral reading speed improved 7,8 % but was not significant (Chung, 2007). In a previous study from Chung et. al. (2004) found more positive results when peripheral reading speed after flanked letter training period improved 41%. Also, Treleaven & Yu (2019) found significant improvements, 50% in untrained and 49% in trained peripheral location, in peripheral reading speed. Similar outcomes were found in a previous study (Yu et. al. 2018).

Attention resources have been successfully increased with training multiple object tracking. (Parsons et. al. 2014). In multiple object tracking, moving targets are followed among other similar moving objects. After a while, targets are identified as accurately as possible. (Cavanagh & Alvarez, 2005). Memory, attention, and visual information processing speed along with corresponding changes in brain functions improved after five weeks of training multiple object tracking. Authors stated that transition to normal life should occur due to these improvements. (Parsons et. al. 2014). Athletes' attention-window, the maximum area to spread attention, can be increased by training attention tasks in a lab or on a field. Doing exercises where attention is directed to high acuity demanding location and to a wide area where many different objects need to be perceived seem to improve athletes' capability to direct attention to a wider area. Differences in improvement were not found between lab and field-based exercises. (Hüttermann & Memmert, 2018).

4.2 Improvements in Sports

There are not enough studies to state whether perception training improves or has no effect on sports performance (Abernathy & Wood, 2001; Zentgraf et. al. 2017), but some positive findings have been found (Stine & Arterburn, 1980; Wimshurst et. al. 2018; Romeas et. al. 2016). Studies designated to investigate peripheral perception training and connection to improvements in sport do not exist, at least to the author's knowledge, but there are studies where peripheral perception is involved.

There are opposite findings of visual skill training's effects on sports performance (Abernethy & Wood, 2001; Stine & Arterburn, 1980; Wimshurst et. al. 2018). Stine & Arterburn (1980) reviewed sports vision studies and found evidence that training vision skills might improve sports performance, although those studies had a poor design. Abernethy & Wood (2001) tested two different vision training interventions and found no effect on sports performance. They used novices as participants so training effects to higher-level athletes cannot be made. It is argued that if sports vision skills are already at an adequate level, other components of sports performance (e.g. decision making) hinder performance, making sports vision training ineffective (Abernethy, 1986). Unfortunately, previous studies did not investigate peripheral vision. Studies exist where peripheral training has some role. Wimshurst et. al. (2018) tested how online visual skill, Nintendo Wii and practical vision skill training affect general visual and cricketing skills compared to a control group. Online and practical training interventions included peripheral vision training. All three experimental groups showed similar significant improvements in visual, including peripheral perception tests and cricketing skill tests compared to the control group. Findings suggest that there are many ways peripheral perception can be trained, and that training can be beneficial to sports performance. (Wimshurst et. al. 2018).

Inconsistent results have been found when multiple object tracking has been trained (Fleddermann et. al. 2019; Romeas et. al. 2016). Romeas et. al. (2016) trained football players ten sessions of 20 minutes of training 3D-multiple objects tracking and found improved passing accuracy. No improvements were found in shooting or dribbling accuracy. Fleddermann et. al. (2019) did not find any significant improvements in far transfer tests, volleyball block prediction accuracy and jump height, when female volleyball athletes trained multiple object tracking. However, significant improvements occurred in task-specific test and in some near transfer tests after training intervention which made authors imply that cognitive capacity can be increased, and it could be useful even for professional athletes.

Formenti et. al. (2019) investigated sport vision training with and without sport specific movements and generic sport training to vision and sports performance. Their results favour the ecological approach to skill development and show how generic visual training does not improve sports performance. Visual training groups did not improve in sport specific skills after 6 weeks of visual skill training, but significant development occurred in a few generic stimuli reaction tasks. A group that responded in a sport specific way during visual training did not show different improvements. (Formenti et. al. 2019). This highlights the importance of perception-action coupling in sports, meaning that you learn to act on specific stimuli and in order to gain benefit in sports you must act in a sport specific environment (Fajen, 2007). Brams et. al. (2019) examined experts across multiple domains and found supportive evidence to ecological dynamics theory. In most studies which examined experts' perceptual-cognitive skills selectively allocating attention to important locations was the most valuable skill development. These findings support the sport-specificity in training. (Brams et. al. 2019).

5 PURPOSE OF THE STUDY

There have not been studies made which investigate the possible benefits of peripheral perception training on basketball performance. Also, existing perceptual training intervention studies often lack sport specific transfer tests which would demonstrate possible training benefits. Therefore, the aim of this study was to investigate possible off-court generic peripheral perception training benefits to basketball on-field performance. With this study, author tries to shed light to the following questions:

Question 1: Does generic off-court peripheral perception training improve general peripheral perception?

Hypothesis 1: Yes, because previous sports vision intervention studies have successfully improved athletes' general vision, including peripheral perception. (Krüger et. al. 2010; Schwab & Memmert, 2012; Feldhacker & Molitor, 2019)

Question 2: Does generic off-court peripheral perception training improve basketball performance?

Hypothesis 2: Yes. Perception training interventions that use solely peripheral perception training does not exist, but sports performances have improved after general perception training interventions. (Stine & Arterburn, 1980; Wimshurst et. al. 2018; Romeas et. al. 2016).

Or.

Hypothesis 3: No. Perception interventions have not reliably and clearly improved sports performance (Formenti et. al. 2019; Zentgraf et. al. 2017; Abernethy & Wood, 2001). Also, based on theory of ecological dynamics, general non-sport-specific perception training does not represent situations in sport scenarios and thus, improvements in basketball performance does not happen (Fajen, 2007).

Question 3: Is information from peripheral vision used more to decision-making in basketball offence scenario after peripheral perception training?

Hypothesis 4: Yes, because elite athletes can use their gaze more optimally (Vater et. al. 2017) and extract more information from periphery than novices (Williams & Davids, 1998; Ryu et. al. 2013 B)

6 METHODS

6.1 Participants

Eleven male participants with normal or corrected-to-normal vision with glasses or contact lenses volunteered to take part in this study. They were intermediate level basketball players from local teams or individuals with basketball playing experience. Two participants dropped out in the middle of the study making a total of nine participants with complete data. Remaining participants were adults (average 26 ± 4,2 years) who had on average 12,4 (± 5,4) of basketball training years and trained average 143 (± 120,6) minutes of basketball per week.

The Ethical Committee of the University of Jyväskylä has given an approval for this study. Participants signed an approval to participate in this study.

6.2 Research design

This study used participants as their own placebo control group. Placebo training was added to training because participants' expectations affect test outcome (Boot et. al 2013). Placebo control period (PCP) took place before the peripheral training intervention (PTI) period. Both PCP and PTI lasted four weeks. Participants were not informed that the first training period was not meant to improve peripheral vision skills. Participants were tested with the same tests three times, before the placebo training intervention, between placebo and PTI and after PTI. Tests included visual field measurements, four peripheral visual reaction tests, basketball skill tests and on-field transfer test. Intervention timeline is shown in figure 7. All the measurements and interventions were executed in the fall of 2019.

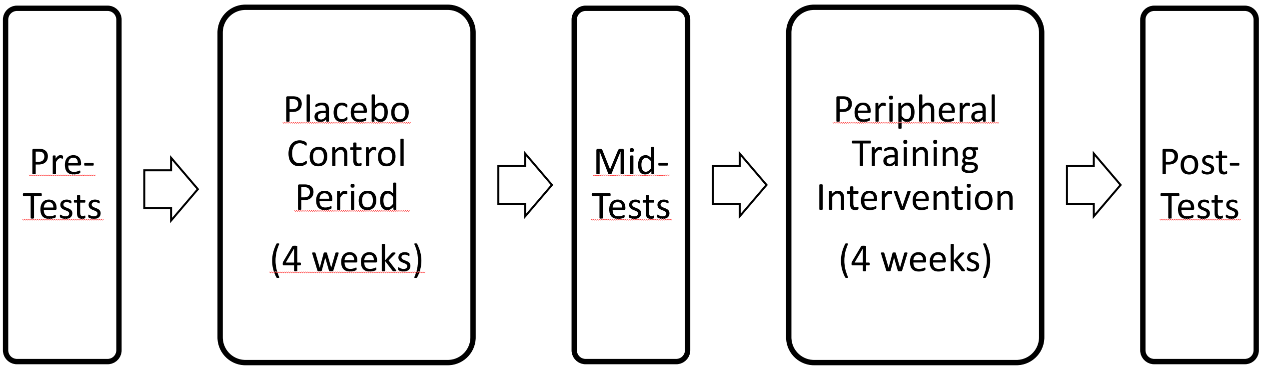

FIGURE 7. Research timeline.

6.3 Measurements

6.3.1 Visual fields

Peripheral apparatus. Horizontal and vertical visual field sizes were measured with the peripheral apparatus, shown in figure 8. It was designed and constructed with the help of the University of Applied Sciences of Jyväskylä. The device consisted of four poles to which WS2812B RGB led strips were added. Led strips ran on horizontal and vertical lines of vision when the participant was in the test position. Two headrests were used between the horizontal poles to keep participants head stable through the measurements and to control distance to the device between the tests. Fixation mark was in the middle of the device where participants focus their gaze. The device contained two handles, one button on each.

Figure 8. Custom made device for visual field and peripheral reaction speed measurements.

The device was used in a specific room with the same lighting situation. One researcher ran all the tests where the peripheral apparatus was used to minimize inter-individual errors. While the device was used in tests, no movement was allowed in the room to avoid distractions and perceptual errors. On each side of the device, there were doors with similar colour so significant contrast differences did not exist. The device was connected to a computer where a program was used to control the tests.

The middle of the apparatus was placed at participants eye level on the wall for both tests. On vertical field measurement, red led lights blinked at both directions and moved slowly along vertical led light tracks towards the middle of the device, within the participants' visual field. Participants stood close to the center of the device resting their back of the head against closest head support. Participants held handles and pressed buttons with their thumbs when a stimulus was observed. On vertical visual field test, button on the right-hand handle was pressed when stimuli were observed from upper peripheral eccentricities and the button on the left-hand handle was pressed when stimuli were observed from lower peripheral eccentricities. The right hand was placed near the chest and left hand next to left thigh to remind participants which button to press to which stimulus.

On the horizontal visual field test, the participant stood resting their forehead against the furthest head support, as presented in figure 9. Red lights started flashing in led light tracks behind participants and moved slowly at the same speed as on vertical track forward on a transverse plane. Participants held handles at their sides and pressed a button on the same side they observed stimulus.

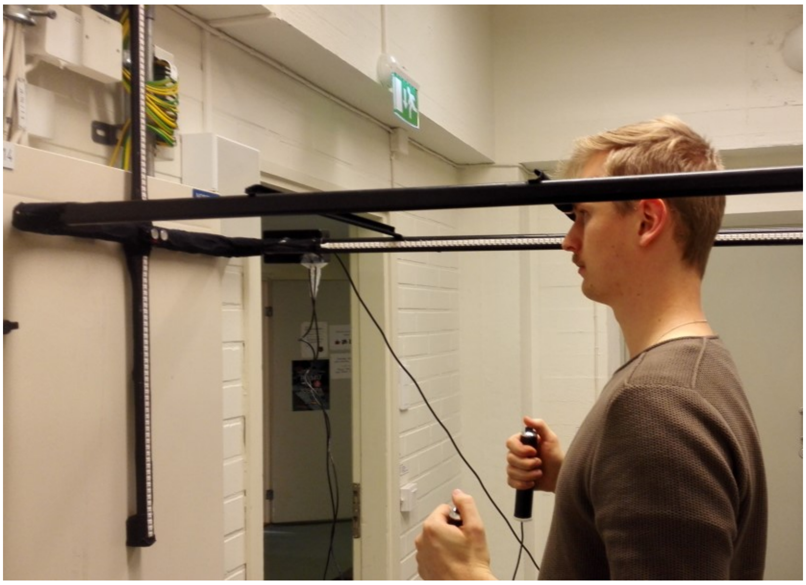

FIGURE 9. Peripheral apparatus was placed at participants eye level. Position for horizontal visual field test.

Tests were explained thoroughly to participants and one practice stimulus per direction was carried out before the actual tests. Participants were told to press the correct button when a stimulus was observed and keep their head stable and eyes fixed on the fixation mark. On both tests, five reactions per direction were reacted to and computer program calculated the average of the visual fields. Vertical visual field and horizontal visual field test was carried out in respective order. Both tests lasted 90-150 seconds and were separated by a short time when gaze was advised to roam freely. The same researcher carried out every visual field test.

6.3.2 Peripheral reaction

Peripheral reaction speed was measured with the peripheral apparatus. Four different reaction tests were carried out in the following order: simple reaction test, go/no-go reaction test, simple reaction with central task and go/no-go reaction with the central task. Participants were seated, otherwise, the position of the device and participant is similar to horizontal visual field test, as presented in figure 10. Monocular stimulus led beaming red light (RGB: 255, 0, 0), appeared at the specific led on either left or right side at approximately 61,9° lateral eccentricity depending on physical skull properties of the test subject. The eccentricity of the stimulus was measured from the same side-eye than where the stimulus appeared. Participants held one handle on their dominant hand and pressed the button when a stimulus was observed. A computer program was used to measure reaction speeds from the tests.

FIGURE 10. Position for simple reaction test with central task and go/no-go reaction test with central task.

In the simple reaction test, participants were instructed to focus their gaze at the fixation marker and react to a stimulus by pressing the button as fast as possible with their thumb. In go/no-go reaction test participants were instructed again to react to stimulus light as fast as possible but also to avoid pressing the button when diversion light appeared. Diversion lights were either blue (RGB: 0, 0, 255) or yellow (RGB: 247, 247, 10). Colour of the diversion light was randomized by a code algorithm.

In the latter two reaction tests, the central task was a simple ball following and clicking task on computer laptop (Acer, Swift 5) display. The white ball moved unpredictably around the screen at slow speed and needed to be clicked with the cursor when the ball turned black. This caused the ball to turn white. The ball remained white for one second and turned black again. This cycle was repeated through the tests which lasted 90-180 seconds. Clicks on the black balls and times the ball turned black were measured to ensure attention was kept in the task. The display was positioned in front of the fixation marker. Because the ball moved in the central task around the display and, assumably, gaze followed the ball, peripheral stimuli appeared between 56.1° to 67.5° eccentricity. Participants operated computer mouse on their dominant hand and held the handle in their non-dominant hand. Switching the button pressing hand should not affect reaction time (Gignac & Vernon, 2004). Operating mouse with non-dominant hand could have made the task too difficult. Gaze was free to follow the white ball moving around the display. Otherwise, the latter two tests were similar to the simple reaction and the go/no-go reaction tests.

The computer program was operated by the same researcher in every test. Two reactions to stimuli were carried out per side as a rehearsal before each test. Every test included ten reactions to visual stimuli per side. Additional stimuli and reactions were tested if computer program failed to read and calculate reaction speed due to untypical button press. In go/no-go reaction tests, four diversion lights appeared on each side and incorrect responses to them were counted. A number of appearing diversion lights was not told. Participants were told to keep their gaze at the fixation marker or in tests with the central task at the ball and react as fast as possible to the peripheral stimuli. Tests were separated by a short period when the following test was explained, and gaze was advised to roam free.

6.3.3 Basketball skill tests

Basketball skill tests: dribbling, shooting and ball bouncing tests were executed, respectively. Participants started from any of the tests and then moved forward in a respective manner. Health and basketball training background questionnaires (appendix 1) were answered at the beginning of each testing sessions. Before pre-tests, additional instructions and documents were filled: every test was explained thoroughly before warm-up, vaster health questionnaire was answered and participants gave their consent for the study by signing documents (appendix 2). Before skill tests, participants did ten minutes of self-organized warm-up without basketball. After the warm-up, skill tests were instructed and practiced, each for a couple of minutes in the same order as the tests were carried out. Tests were held in an indoor sports hall and participants wore indoor training equipment.

In shooting test, 25 shots were performed from a basketball free throw line at free pace. Researcher retrieved the ball for the participant and counted successful throws. 3-5 warmup throws and short rest period were allowed before the actual test began.

In the ball bouncing test, participant stood two meters from the wall holding basketball on their right hand, shown in figure 11. The test evaluated ball-handling skills. The following cycle was instructed to be repeated ten times; throw the ball to the wall and catch it with your right hand, bounce ball in front of you to your left hand, bounce ball between your legs to your right hand, bounce ball behind your back to your left hand and now repeat the cycle but with opposite hands. Small movement with legs was allowed but crossing the two-meter line was not allowed. Time to execute the cycle ten times and time for each cycle was measured with a stopwatch. The test was pulled to a halt if the ball bounced away from the participant. The ball bouncing test was done twice, but if the ball got loose, an additional trial was measured until participant performed successfully. The same researcher measured every ball bouncing test.

FIGURE 11. The ball bouncing test.

The dribbling test, developed for this study by the researcher, included dribbling the course, presented in figure 12, through thrice using the non-dominant hand, dominant hand and both hands, respectively. Participant stood behind the starting line holding the basketball. Test started by dribbling red cones around in numeric order using only the non-dominant hand. Then blue cones were dribbled around starting from the furthest from the last red cone. After that, red and blue cones were dribbled similarly but to the opposite direction using only the dominant hand and then dribbled again using both hands. All in all, the course was dribbled through three times. Light gates were used to measure the time on course. Gates were placed at both ends of the dribbling course. Participants were allowed to walk and dribble through the course to help them memorize the course. Before the test participants were instructed to dribble as fast as they could. The dribbling test was done twice, two minutes rest between trials. If the participant lost the ball, the trial was started over after a short break. At least one successful trial was mandatory. Overall test time was used to examine participants dribbling skills.

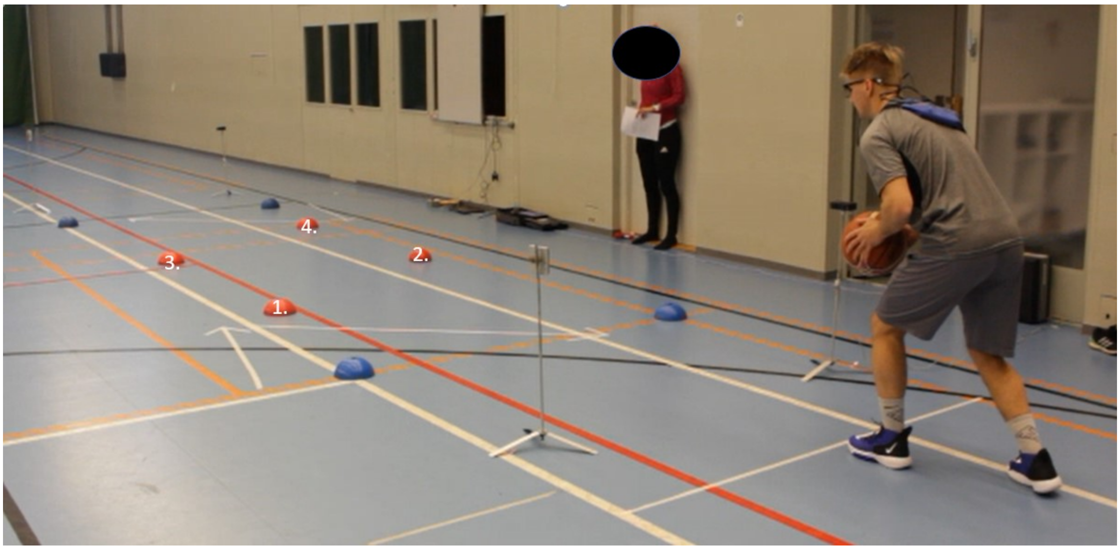

FIGURE 12. Dribbling test.

6.3.4 Transfer test

Apparatus. The Tobii Pro Glasses 2 – mobile eye-tracking device (Tobii AB, Sweden) and Tobi Pro Glasses Controller software were used to measure and record gaze movement during transfer test. Mobile eye-tracking device consisted of a head unit which was attached to a recording unit with an HDMI cable. Head unit, referred further as glasses, contained two cameras per eye, lights whom reflection cameras recorded from the eyes and a forward orientated camera that recorded participant's point of view in full HD. Recording unit was connected to tablet via wireless connection. Live video from the head unit was displayed in the tablet where gaze was automatically calculated by Tobii algorithms and displayed as a red circle, presented in figure 13. Video of gaze behaviour from the participants point of view was obtained at 25 frames per second.

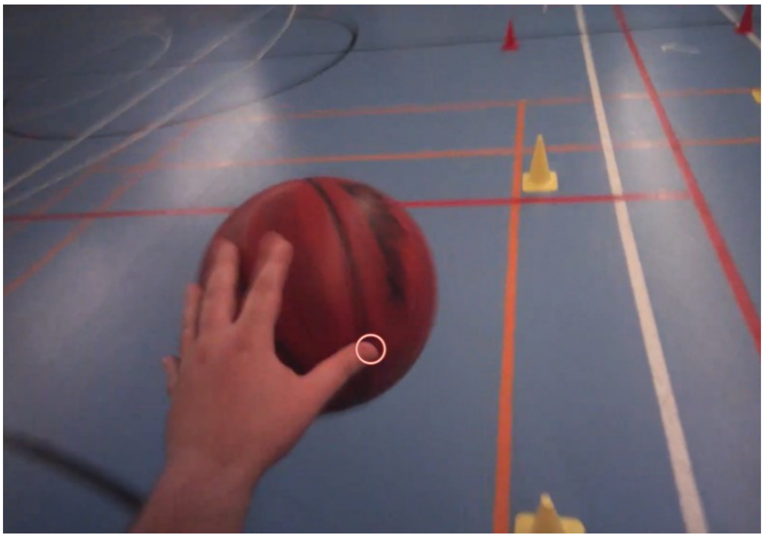

Figure 13. Live video view from the tablet, gaze displayed as red circle.

Recording unit was positioned in a running belt tightened around the torso so that it would not disturb basketball performance. Glasses were calibrated before every trial with the system's one-point calibration. Additional calibration was performed if disturbance occurred to the glasses or recording software. According to Tobii producer, Tobii Pro 2 has an accuracy of 0,62 ° (±0.23°) but for large gaze angles (e.g. outside regular movement of eyes) 3,05° (±1.13°). Tobii Pro Glasses 2 precision varies between 0,05° and 0,62°. (Tobii Pro 2017).

Transfer test examined participants gaze behaviour and decision-making during offence scenario. As a transfer test, 3 vs 3 Pick and Roll (P'nR) gameplay situation was used. Van Maarseveen et. al. (2018) used a similar set up to study gaze behaviour of skilled female basketball players. P'nR is highly used in basketball offence situations and is a general training scenario, and thus was selected as a transfer test (Van Maarseveen et. al. 2018). Before transfer test players were instructed about the test by doing example demonstrations on the court. Additionally, before pre-tests, a detailed instruction video was shown. Transfer tests were executed after basketball skill tests.

Three attackers, one who was being tested (wing-man), attacked against three defenders. Players other than wing-man were either other participants or supportive cast. In starting positions of P’nR, presented in figure 14, offenders (1, 2 and 3) faced the wall, and one of three defensive styles was shown to the defenders (4, 5 and 6). When the researcher (R) gave starting command, wing-man (1) turned and received a pass from the researcher. Player 2 made a screen to player 4 and player 1 had to use it by moving passed them. After screening player 2 rolled towards the basket and player 3 made a lift and rose to assist player 1. These actions happened in every situation and the defenders defended by the style that was shown to them. Three defending styles were: switch, hard hedge and soft hedge. In switch, defenders 4 and 5 switched whom they defended, so number 4 defended number 2 and number 5 defended number 1. In hard hedge, player 1 was trapped by defenders 4 and 5 by stopping his movement. Defender 5 stopped player 1’s horizontal movement by stepping in the way and defender 4 came to assist by stopping player 2’s vertical line. In soft hedge, defender 5 moved between player 1 and 2 and tried to stop passing. Defender 4 followed as fast as possible player 1 and tried to stop him. In hard hedge and soft hedge, defender 4 was not allowed to go behind player 2’s screen, he had to follow player 1. Defender 6 either defended player 3 or player 2. Wing-man was given four options to perform: roll to the basket, shoot to the basket, pass to the lift or pass to the roll.

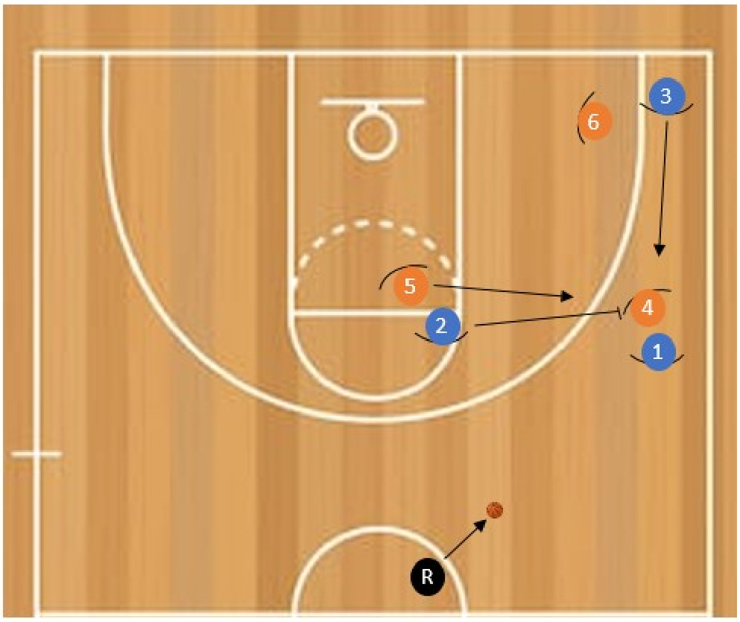

FIGURE 14. Pick’n Roll starting positions of offenders (blue) and defenders (orange) and first moving directions when starting command is given from researcher (black).

P’nR situations were recorded with a video camera (GoPro Hero 3, GoPro Inc, United States of America, in pre-tests and Canon 600D, Canon Inc, Japan, in mid- and post-tests) from an elevated perspective. Wing-man’s behaviour of gaze was measured with eye-tracking glasses (Tobii Pro 2). From glasses video the following variables were analyzed: gaze location during decision making (e.g. time the ball was leaving from the participant), additional observations to the decision target before decision making, and success percent of the decisions. A decision was regarded as peripheral if a participant did not fixate at the decision target during or before decision making. Decisions could be partly peripheral if the decision target was fixated but at the decision-making moment gaze was not at the target. A decision was regarded as a successful if the ball was accurately passed to the receiver, or the ball went through the basketball hoop. Additionally, from elevated camera’s recording, decision making quality was estimated by ball game specialist from Finnish Research Institute for Olympic Sports who also works as basketball coach and basketball coaches’ educator.

6.4 Placebo control period (PCP)

PCP exercises were designed to have no effect on visual nor motor skills evaluated in this study. Exercises are described in table 1. Exercises were instructed to be performed twice per week, 30 minutes per week, for four weeks, combining a total of 2 hours of training. Participants were given a ringette ring with three coloured tapes circling it evenly and a tennis ball to do the exercises on their own time. Also, a similar table sheet as table 1 was given to the participants but in Finnish.

TABLE 1. Exercises in the placebo control period (PCP).

Exercise	**Instructions**	**Progression after two weeks**	**Training time**
1. Tennis ball throw and catch	Stand 2-5 meter off the wall ball in your dominant hand. Throw the ball to the wall and catch it after a bounce on the floor. Keep gaze on it all the time.	After throw, move forwards or backwards until you catch the ball. Remember to keep the gaze at the ball.	1 min
2. Tennis ball throw and catch	Same as exercise 1 but spin around after you have thrown and return gaze on ball.	Spin eyes shut.	1 min
3. Tennis ball throw and catch	Pick a target in front of you. Throw the ball in the air with your dominant hand and quickly look at the chosen target and return your gaze on the ball. Follow the ball with your gaze until you catch it.	Throw the ball lower in the air.	2 min
4. Bouncing	Bounce tennis ball in front of you and keep your gaze on the ball all the time. Change your bouncing hand. Bounce the ball the whole time.	Move around while bouncing.	2 min
5. Bouncing	Bounce the tennis ball so that when ball hits the floor, shut your eyes and catch it eyes shut. Bounce with both hands.	Walk around while you bounce.	2 min
6. Ring toss and catch.	Decide one of the colours on the ring. Toss the ring slightly in the air and catch it by grabbing from that colour. Increase the toss height when you improve.	Walk around while tossing the ring.	2 min
7. Ring toss and catch.	Same as exercise 6 but after the toss look quickly to your toes and back to the ring.	After the toss, move your gaze accordingly: toes, ring, toes, ring.	2 min
8. Ring toss and catch.	Same as exercise 6 but catch the ring from the colour that is the most top of all the colours on the apex of the toss.	After you have seen the colour, close your eyes for a moment before catching the ring. Keep your eyes shut for longer as you improve.	2 min
9. Tennis ball throw and ring toss.	Stand 1-2 meters off the wall tennis ball and ring in your hands. Throw tennis ball with a floor bounce to the wall and catch it with the same hand. Then, toss the ring above your head and catch it with the same hand. Repeat this. Keep your gaze on the moving object and switch it quickly between objects after each catch. You can increase tempo when you improve.	Catch the ring from the colour that is the most top of all the colours on the apex of the toss.	1 min

6.5 Peripheral training intervention (PTI)

The PTI was designed to improve participants' peripheral stimulus identification, multifocal attention, and the ability to seek the most important information from the periphery. Also, correct motor response to a certain stimulus was an aim of improvement. Intervention exercises were performed twice per week for four weeks, combining a total of eight training sessions and four hours per participant. Each session lasted 30 minutes and sessions were separated by at least one rest day. Participants wore sports clothes and used vision correction if they normally used one. Table 2 presents exercises in the PTI. Colours of the balls and balloons and sizes of balloons varied between training sessions. Tennis balls were thrown in different ways and from different places behind participants' backs to decrease predictability.

TABLE 2. Exercises in the peripheral training intervention.

Exercise	Instructions	Progression after two weeks	Training time
Catching the balls	Participant stood two meters off the wall, facing it, gaze was told to be kept at marked spot 1,2 meters off the ground. Tennis balls were thrown underarm behind participants back to the wall so that they bounced before participant. Three variations: 1. Two balls were thrown, both needed to be caught. 2. Two balls of different colour were thrown. Participants were told which colour to catch with which hand. 3. Three balls were thrown of two different colours. Balls of the same colour were to be caught and extra ball ignored.	Exercises remained the same, but letter chart was added to the marked spot of gaze. Letters had to be read during the exercise.	1. 2 minutes 2. 2 minutes 3. 3 minutes
Balloon drop	Three balloons were thrown in the air. Balloons were to be kept in the air as long as possible using hands. If one ball dropped to the ground, all were collected and thrown again. If exercise seemed easy, balloons' size was decreased.	Fourth balloon was added. If a balloon dropped, participants were instructed to keep other balloons in the air as researcher threw fallen back to the air.	8 minutes
Catching the balls	Participant stood two meters off the wall, facing it, gaze was told to be kept at marked spot 1,2 meters off the ground. Tennis balls were thrown underarm behind participants back to the wall so that they bounced before participant. Three variations: 1. Two balls were thrown, both needed to be caught. 2. Two balls of different colour were thrown. Participants were told which colour to catch with which hand. 3. Three balls were thrown of two different colours. Balls of the same colour were to be caught and extra ball ignored.	Exercises remained the same, but letter chart was added to the marked spot of gaze. Letters had to be read during the exercise.	1. 2 minutes 2. 2 minutes 3. 3 minutes

Exercise	Instructions	Progression after two weeks	Training time
Balloon drop	Three balloons were thrown in the air. Balloons were to be kept in the air as long as possible using hands. If one ball dropped to the ground, all were collected and thrown again. If exercise seemed easy, balloons' size was decreased.	Fourth balloon was added. If one balloon dropped, participants were instructed to keep other balloons in the air as researcher threw fallen one back to the air.	8 minutes
Ball colour reaction	Participants stood 2 meters off the wall holding a ball. Tennis balls of different colours were thrown to the wall behind participants' backs. Two variations were done: 1. Participants held a basketball and were told to pass it to the wall when ball of certain colour, told before exercise, was thrown to the wall. Participants stood on a balance board. 2. Participants stood in front of white canvas to which video projector projected three balls moving around (yellow, blue and red). Tennis balls (yellow, blue and red) were thrown behind participants' backs. Black spot was in middle of the canvas where participants fixed their gaze. Participants held soft volleyball which was told to pass to projected ball of similar colour than what was thrown behind their backs without moving their gaze. Participants were told to try to be aware where projected balls moved.	1. Participants stood in front of canvas. Exercise was the same but to the spot where gaze was fixed appeared arrows (up, right, left or down) in 2 second intervals. Participants needed to step into arrows direction and back. Balance board was taken away. 2. Exercise was the same but the already mentioned arrows were added.	1. 3 minutes 2. 4 minutes
Multiple object tracking (MOT)	Participants stood and bounced a basketball 2 to 3 meters off the white canvas where MOT game was projected. Ten balls, five red and five black. Red balls turned black after 2 seconds and all the balls started moving around. After 8 seconds of moving, the balls stopped, and participants were asked to show which balls were red originally. Original balls were revealed after participants' answers. If participants got three correct answers in a row, speed of the balls was increased.	Exercise remained the same except in the next training session speed of the balls continued where last time ended.	8 minutes

6.6 Statistical analyses

Statistical analyses were done with IBM SPSS Statistics 24- software (International Business Machines Corp, New York, United States). Shapiro-Wilk test was used to test normal distribution of the data. Because data was not normally distributed, Nonparametric Friedman test was chosen to compare statistical differences in all variables between pre, mid and post-tests. Statistical levels of differences were set to be $p<0.05^*$, $p<0.01^{**}$ and $p<0.001^{***}$. Two participants could not attend every PTI session so the average number of training sessions per participant became 7,6.

7 RESULTS

7.1 Peripheral vision tests

Reaction time results from the peripheral apparatus are shown in table 3 and in figure 15. A significant difference (p<0,05) was found in simple reaction time change percent in mid-to-post compared to pre-to-mid. From go/no-go reaction and go/no-go reaction with central task test all reactions above 1500ms were excluded from analyses as they were thought to be caused by incorrect colour identification and not reacting to perceived colour. 35 out of 1080 (3,2%) reactions were excluded because of this. There were 15,3% of reactions to diversion lights (incorrect reactions) in go/no-go reaction tests. Attention was directed towards the central task in reaction tests where it was used. When the moving ball turned black in the central task, it was clicked with 99,1% accuracy.

TABLE 3. Peripheral reaction times and standard deviations from simple, go/no-go, simple with central task and go/no-go with central task tests. Significant differences between mid-post and post-pre are marked with # and ¤, respectively. (## = p<0,01; ¤ = p<0,05).

	Simple reaction (ms)			Go/no-go reaction (ms)			Simple reaction with central task (ms)			Go/no-go reaction with central task (ms)		
	Left	Right	Total	Left	Right	Total	Left	Right	Total	Left	Right	Total
Pre	276	278	277	429	428	428	414	429	422	539	519	529
SD	27	26	25	75	89	81	42	50	43	165	113	137
Mid	305	288	297	454	451	452	409	448	429	600	575	587
SD	45	16	26	87	84	85	63	63	58	189	108	143
Post	264 ##	288	276	455	454	¤454	401	427	414	564	571	567
SD	14	27	18	53	33	37	46	59	49	147	168	153
Average	**282**	**285**	**283**	**446**	**444**	**445**	**408**	**435**	**422**	**568**	**555**	**561**
SD	17	5	10	12	12	12	5	9	6	25	26	24

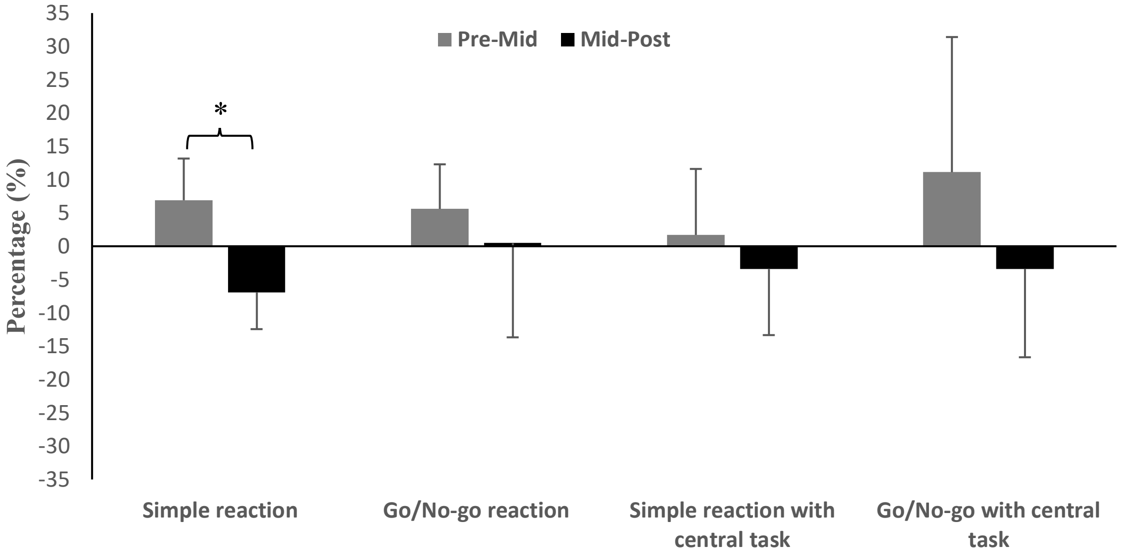

FIGURE 15. Reaction times' average change percent, standard deviations, and significance between pre to mid and mid to post measurements. (* = p<0,05).

Visual field measurements are shown in figure 16. In vertical visual field measurements, no significant changes occurred, though vertical visual field size decreased in each measuring point. Horizontal visual field size significantly decreased (p<0,01) between pre and mid measurements.

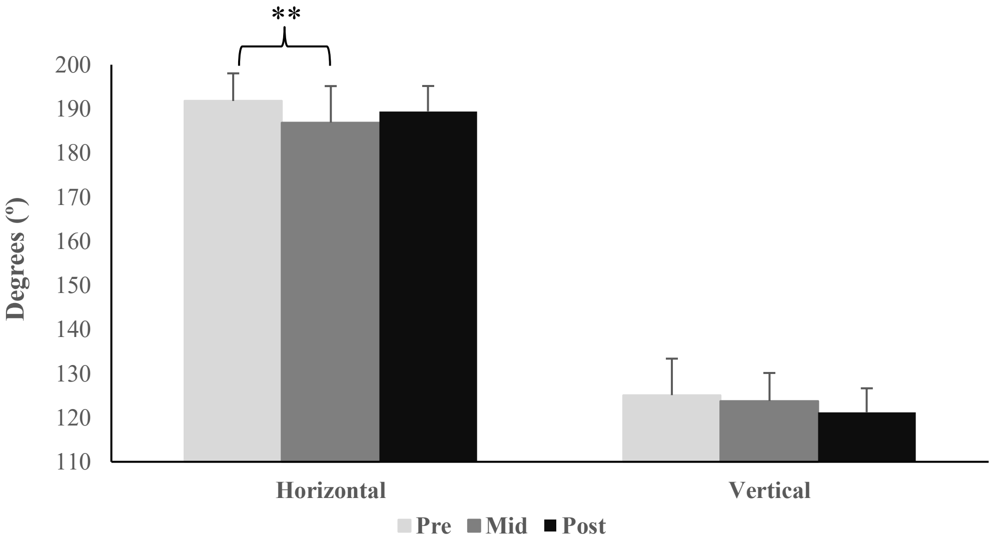

FIGURE 16. Average horizontal and vertical visual field sizes, their standard error and significance (** = p<0,01) in pre, mid and post-tests.

7.2 Basketball skill tests

Average basketball shooting accuracy, measured as successful throws out of 25, changed insignificantly (p=0,944) from 14,7 (SD ± 2,9) to 16,8 (SD ± 3,5) and to 16,0 (SD ± 3,4) in pre, mid and post-test, respectively. Dribbling and bouncing results are shown in figure 17. Significant changes (p<0,05) occurred between pre and mid measurements in both tests and between pre- and post-test in bouncing test. Also, in dribbling tests highly significant change (p<0,001) was found between pre and post-test.

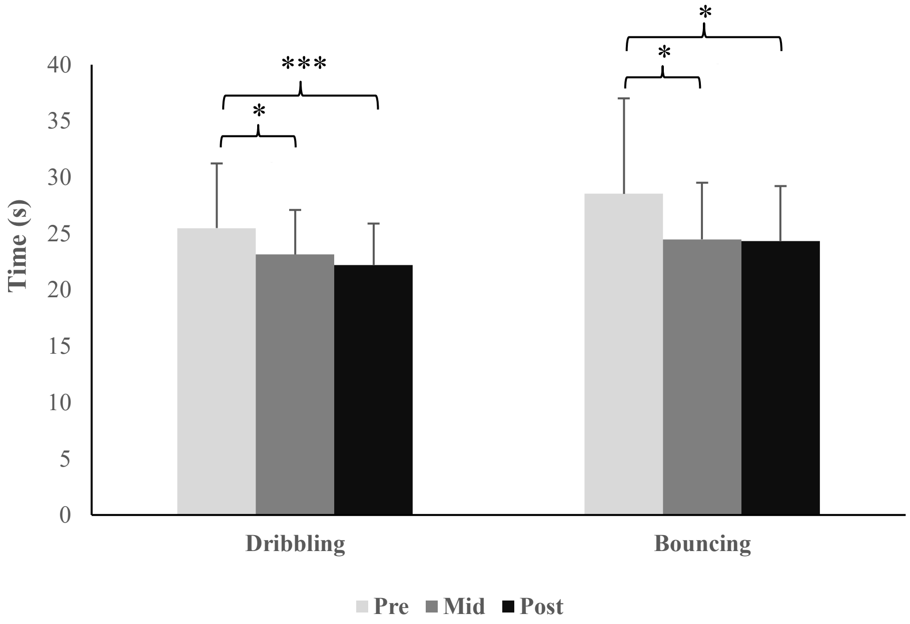

FIGURE 17. Basketball skill test results, standard deviations and significance values from pre, mid and post-tests. (* = p<0,05; *** = p<0,001).

7.3 Transfer tests

2,7% (22 out of 810) of P'nR trials were discarded from analyzes due to incorrect playstyle or mishandling of the ball. Additional 1,6% (13 out of 810) of P'nR trials were removed from gaze behaviour analyzes because of insufficient gaze tracking data. No significant changes occurred in the number of peripheral or partly peripheral decisions made, success percent of all trials, success percent of decisions made with peripheral vision only, and in decisions quality. The results are shown in figures 18, 19 and 20, respectively.

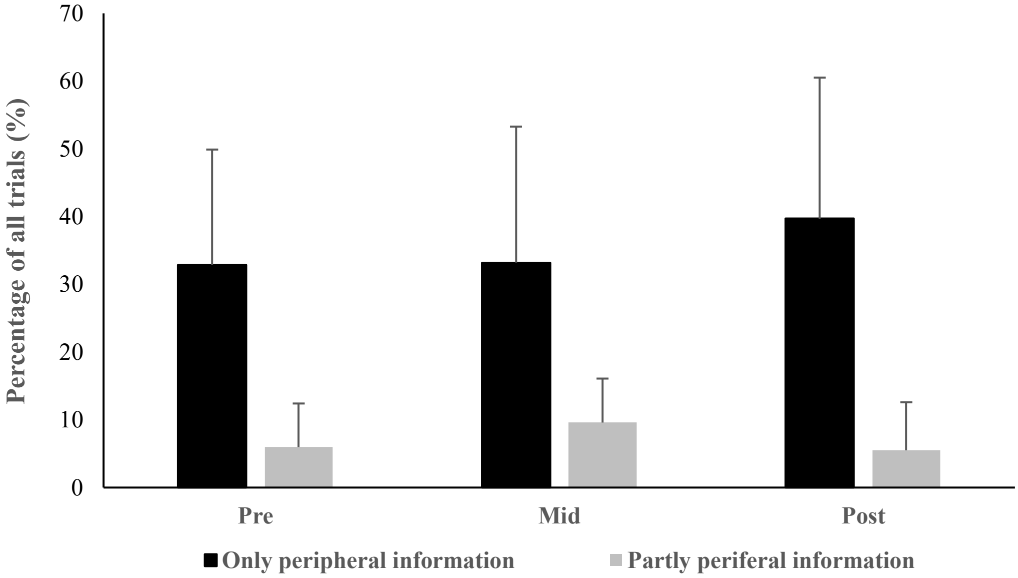

FIGURE 18. Percent of decisions made with only peripheral visual information and with partly peripheral visual information, and their standard deviations. Trial's decision was made partly with peripheral information when decision target was looked at but not at the moment of decision. Significant changes were not found.

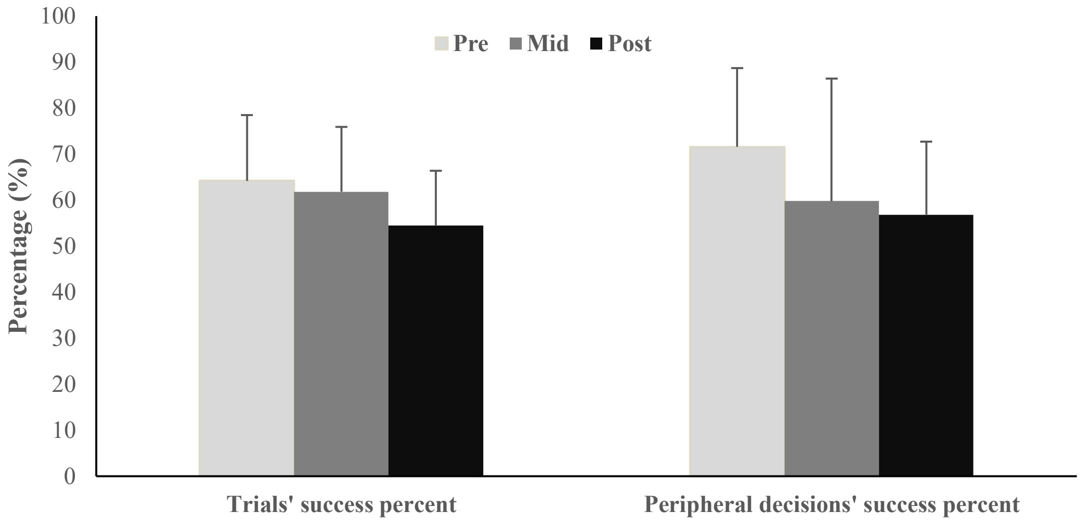

FIGURE 19. Pick’n Roll trials’ and peripheral decisions’ success percents and standard deviations from pre, mid and post-tests. Significant changes were not found.

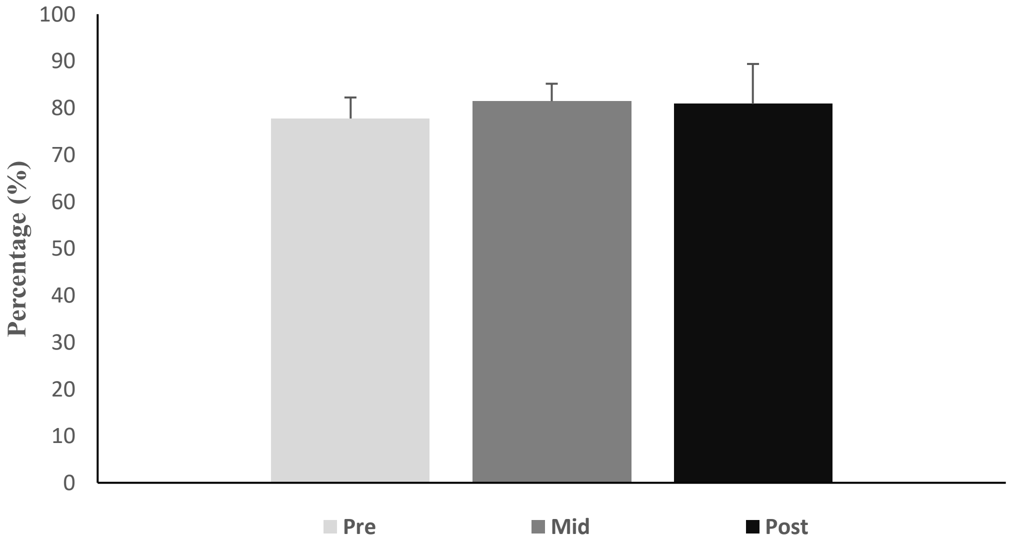

FIGURE 20. Average decision quality of Pick’n Roll trials and their standard deviations. No significant differences were found.

In figure 21, decision targets from only peripheral information trials are analysed. Majority of only peripheral visual information decisions were passing to the roller, 73%, 95% and 89% in pre, mid and post-test, respectively. In figure 22, percentage of peripheral decisions in the same decision target is shown. No significant differences were found in the percentage of peripheral decisions in any decision target.

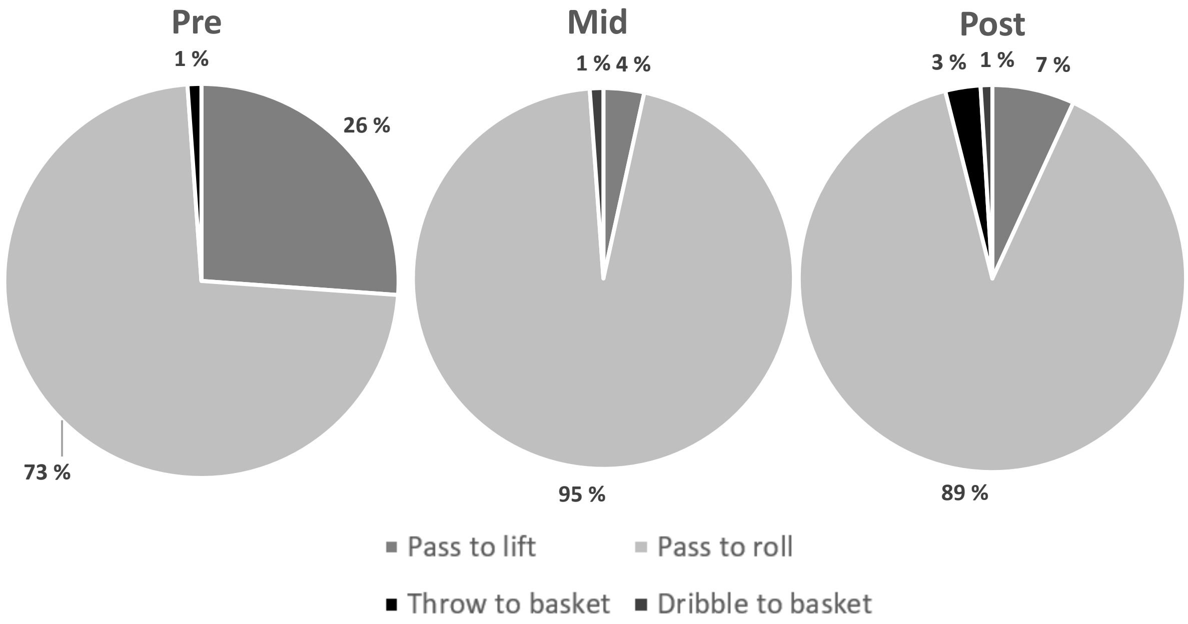

FIGURE 21. Decisions' targets from trials where peripheral information was only used.

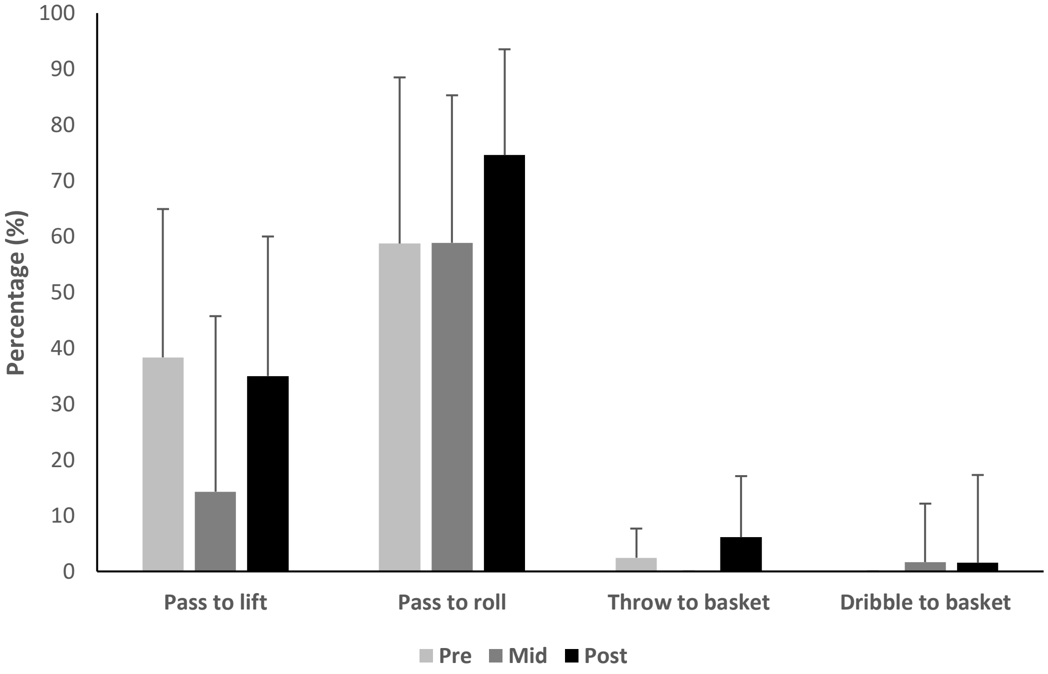

FIGURE 22. Percentage of peripheral decisions in each decision target in pre, mid and post-tests and their standard deviations. No significant changes found.

8 DISCUSSION

Not many significant changes were found after PTI. Peripheral reaction times had a decreasing trend after PTI but only simple reaction time to peripheral stimulus decreased significantly after PTI compared to PCP. PTI did not yield any significant changes to peripheral decision making in basketball transfer test.

First research question asked does generic off-court peripheral perception training improve general peripheral perception. Significant decrease in horizontal visual field size was found in the mid-tests. A trend can be seen where reaction times tended to increase after the PCP and decrease after the PTI. PTI significantly decreased participants reaction time to a simple peripheral stimulus that was observed from the left visual field. Also, total simple reaction time significantly decreased compared to the change after PCP. It seems that peripheral training could slightly improve simple reaction time to peripheral stimulus but not reactions with higher cognitive load. A decrease in simple reaction task shows possible evidence for improvement in the visual perception speed. Because simple reaction task is to perform a simple motor response to a simple visual stimulus its' cognitive load is only minimal response selection (Ando, 2013). Because in post-tests simple reaction speed significantly improved little evidence of visual perception improvement with peripheral perception training can be found. No other significant changes in peripheral apparatus tests occurred after PTI meaning research question 1 was only partially supported.

Peripheral perception results were quite well in conjunction with previous research findings. In pre-tests, simple reaction time results were found to be between 255-340ms (Ando et. al. 2001; Clark et. al. 2017). In other studies, reaction time increases from the simple test to go/no-go reaction test between 50 and 150ms (Miller & Low, 2001; Chan et. al. 2011). In this study, similar findings were found. Horizontal visual field results are close to what other studies have found. Generally, the temporal visual field extends 90 degrees laterally meaning approximately 180 degrees horizontal visual field. (Regan et. al. 2011; Mańkowska et. al. 2015). Reaction time increased when diversion lights and/or the central task was added. Cognitive load increased because either stimulus needed to be identified or attention was divided into the wider area. Because the reaction time increased more when diversion lights were added than with the central task, means that identifying task was more demanding than dual tasking. The central task was not probably very difficult because less than 1% of the clicks were missed. Identifying the colour of the lights would become easier if the lights were bigger or brighter (Strasburger et. al. 2011).

Second research question tried to solve whether generic off-court peripheral perception training improve basketball performance. Basketball dribbling and bouncing tests improved significantly from pre-to-mid and pre-to-post. Basketball shooting accuracy did not change significantly during the study. Success percent of the transfer test trials did not improve after PTI. Participants actually seemed to be less successful in their decisions in mid and post-tests compared to pre-tests. The quality of decisions made in the transfer tests did not significantly change after PCP or PTI. Results support the hypothesis 3, peripheral training does not improve basketball performance, because after PTI no significant improvements occurred in skill tests nor in transfer test trials' success percentage or decision quality.

After the PCP no changes should have been found but the emergence of significant changes during that period force to evaluate training period and possible reasons explaining the results. In basketball skill tests, learning effect possibly occurred. In mid-tests, almost all participants improved their performance in bouncing and dribbling tests. Instructions and familiarization trials before pre-tests were possibly not sufficient enough to teach participants to optimally perform tests. Also, some participants in the pre-tests reported that they had recently continued basketball practices after a break, which could explain the quick improvement in the sport skills. PCP training unlikely caused changes to the results due to short training time and, if some training effects would have occurred, they should not have influence tests. In dribbling and bouncing tests, improvements halted to post-tests which suggests that participants probably achieved their best performance in mid-tests. In transfer test, the quality of trials' decisions was higher than in Van Maarseveen et. al. (2018), where decision quality ranged between 53 and 74 percent in a similar basketball set-up. In their study, professional female basketball players were tested which could mean tested participants faced better defence performance.

Third research question tried to solve is peripheral information used more to decision-making in transfer test after PTI. Participants used peripheral information a lot in the decision making at every test point. The number of peripheral decisions made increased after PTI, but it was not significant. From mid-to-post, trials' success percent decreased more than trials' where only peripheral information was used suggesting that decisions made with peripheral information were not accountable for the trials' decrease of success percent. Failed trials were made with foveal vision. This information is noteworthy because participants slightly increased the number of peripheral decisions made, meaning they relied more on peripheral information to extract information without a notable decrease in success percent. These changes might hint a possible benefit of peripheral perception training. Still, results do not support research hypothesis 4 because significant changes did not occur after PTI. This study examined only offensive ball possessive players' peripheral behaviour so future research should examine could there be improvements to players who do not control the ball.

The number of partly peripheral decisions made was notably less than total peripheral decisions or decisions made foveally. This means participants searched the optimal decision foveally, found it and made their decision or used peripheral vision to do this. Rarely participants glimpsed at the decision target and did not act immediately. The participants are in high temporal constraints to do the decision after using the screen because the defence is moving to a better position. Peripheral perception could be used to exploit the open defence. Because the defence is not in the correct position and searching for the optimal decision using the gaze would take too much time, the peripheral perception could be used. Peripheral vision's ability to track multiple objects could find a way to make the decision (Cavanagh & Alvarez, 2005). Using the gaze would cause saccadic suppression which limits the available visual information and is detrimental in fast-paced sports (Klingenhoefer & Bremmer, 2011). Quickly made decisions could have a higher percentage of peripheral decisions because of the temporal constraints of the situation, and because of the roller's proximity. After making the screen, the roller moves and is close to the decision-making participant and so, easier to be perceived. This would be one reason for the high number of peripheral decisions made to pass the ball to the roller. Maarseveen et. al. (2018) found that basketball players kept their gaze 69,7% of the time in a possible anchor point in the area of the central players, enabling them to analyse surroundings with peripheral vision. Another explanation for using the peripheral vision to pass the ball to the roller is to use the gaze location to deceive defenders. When the head orientation and the pass direction are incongruent basketball defenders respond slower (Kunde et. al. 2011).

Van Maarseveen et. al. (2018) found smaller percent of peripheral decisions made, 19,5%, than in this study. Fatigue may play a role in the occurrence of peripheral decisions. Peripheral reaction speed decreases as activity level increases over 70% of the VO2max. As players get fatigued, they might respond to this new constraint by changing gaze behaviour. Players with higher aerobic capacity may experience less this possible negative effect. In this study's transfer tests, peripheral decision was most often to pass to the roller. When the number of peripheral decisions is compared to all the decisions of the same decision target, peripheral decisions were still the most usually made when the ball was passed to the roller. Van Maarseveen et. al. (2018) found the same finding but with a fewer number of peripheral decisions, 37%. This could be explained by the proximity of targets. Targets are closer so they are easier to recognize than the lift player who is further away (Strasburger et. al. 2011). When the participants decided to shoot, the gaze was almost always located at the basket. Stabilizing the gaze at the basket helps players to acquire the necessary information to shoot the ball in (Klostermann et. al. 2020). This kind of gaze behaviour is called quiet eye and it is defined as the final fixation before movement initialization (Vickers, 2007). Skilled basketball players use the same gaze behaviour (Van Maarseveen et. al. 2018). Reasons for the differences in the number of peripheral decisions made and decisions' quality between these studies cannot be clearly made. Because participants in this study were not professionals, intensity and difficulty levels of the trials are most likely different, so the constraints change in which the participants have to perform. For example, different visual search paths have been found from the same situation when the task or number of players in the field are changed (Vaeyens, et. al. 2007; Van Maarseveen, et. al. 2016).

Lack of improvements in transfer tests may be due to insufficient training effect of the PTI and the absence of similar perception-cognition coupling as in basketball game performance. Schumacher et. al. (2020) used similar training but in a more sport-specific way and found improvements in peripheral reaction speed. Also, Formenti et. al. (2019) got similar results with sport vision training and sport vision training with sport specific response groups compared to sport specific training group. Several cognitive functions improved after 6-weeks of training but only sport specific training group improved sports performance. Training intervention probably lacked sport specificity which is highly important if transfer to sports performance is wanted (Chiueffreda & Wang, 2004, 24, 25). PTI included object recognition, hand-eye coordination and different attentional allocations combined with choosing the correct motor response but as results show, this type of training does not seem to improve basketball skill or on-field performance of intermediate basketball participants. It has been suggested that this kind of training could be more beneficial for elite athletes' whose sport-related skills are already at the top level but learning to reallocate attention to beneficial locations could still benefit sports performance (Ciuffreda & Wang, 2004, 25).

8.1 Strengths and limitations

A major strength of this study was its ecologically valid transfer test. Most of the perceptual-cognitive training intervention studies have not evaluated how perceptual skill training transfer to highly sport specific performance (Zentgraf et. al. 2017). In this study, offensive basketball strategy with authentic defending scenarios were used. Mimicking basketball game situations should provide almost game like perceptual and attentional constraints for the participants resulting to rather naturalistic gaze behaviour and decision making. Although, real game situations rarely start from a standstill. One researcher worked as the organizer and main operator throughout the study. For example, all peripheral apparatus tests and almost all PTI sessions were led by the same person decreasing possibility for the inter-examiner mistakes. Participants of the study expressed motivation towards the training interventions which possibly elicits better learning.

There were some minor limitations with the methodology of the study. In reaction tests with diversion lights, some participants had troubles identifying diversion lights from lights which to respond. This is seen from longer reaction times and bigger standard variation from go/no-go reaction and go/no-go reaction with central task tests. This is possible due to a few reasons. Lights were lit quite far in the horizontal periphery, 60,9°, where colour vision is less functional and colour detection discriminates (Noorlander et. al. 1983). Also, red, and yellow are close in colour wavelength spectrum making them harder to distinguish from each other and, if any participant suffered from some level of red-green blindness, separation of those colours would get even harder (Guyton & Hall, 2011, 614, 616). The illuminance of the room can affect how well lights are perceived (Strasburger et. al. 2011). The illumination level of the peripheral apparatus test room was not objectively measured so possible changes could have affected the results. The PCP took place before the actual training intervention. Because the order was the same for every participant, possible learning effects of the tests are present after PCP, distorting the results. Switching the order of the PCP and PTI period for half of the participants would have reallocated possible influence of the learning effect. Transfer tests decisions' quality was evaluated from the video only by one person. Even though, the person would be a professional at analysing correct decisions, the lack of other analyser leaves room for doubt whether the made decisions were affected by subjective opinions.

8.2 Conclusions

Peripheral perception, basketball skill tests and gaze location combined with decision accuracy results were analysed before and after a placebo control period (PCP) and peripheral training intervention (PTI). Based on the results, peripheral training does not seem to improve on-field basketball performance nor general basketball skills. Peripheral information is used in the basketball offence situations, usually, to pass to the roller. Peripheral reaction speed might benefit from the training, but there were no positive effects on the visual field sizes. These findings support more the ecological dynamics theory of the movement control because general perceptual training was not found to be connected to the sports performance.

In future research, training should more accurately replicate perception-action coupling of the basketball game situations to ensure transferability to game performance. In transfer tests, possible effects that disturb gaze, for example, anxiety, must be neutralized as well as possible. Also, analysing gaze scan paths could give more information about possible training effects. More intervention studies with sport specific transfer tests are needed to state how peripheral perception training should be conducted to have positive effects on sports performance.

8.3 Practical applications

The coaches and trainers can train their athletes' peripheral perceptual skills, but exercises that follow the principles of ecological dynamics and not generic off-court exercises, as in this study, are recommended. Training should include sport specific exercises with attentional demands to observe a wide area with multiple important actors, for example many players at the same time. The task of the exercise should resemble sport scenarios, for example, pass the ball to the player who has the most space so that players learn to direct their focus of attention and perception at the optimal locations to find the relevant information. Perception should be connected to action which should always be towards sport specific goal.

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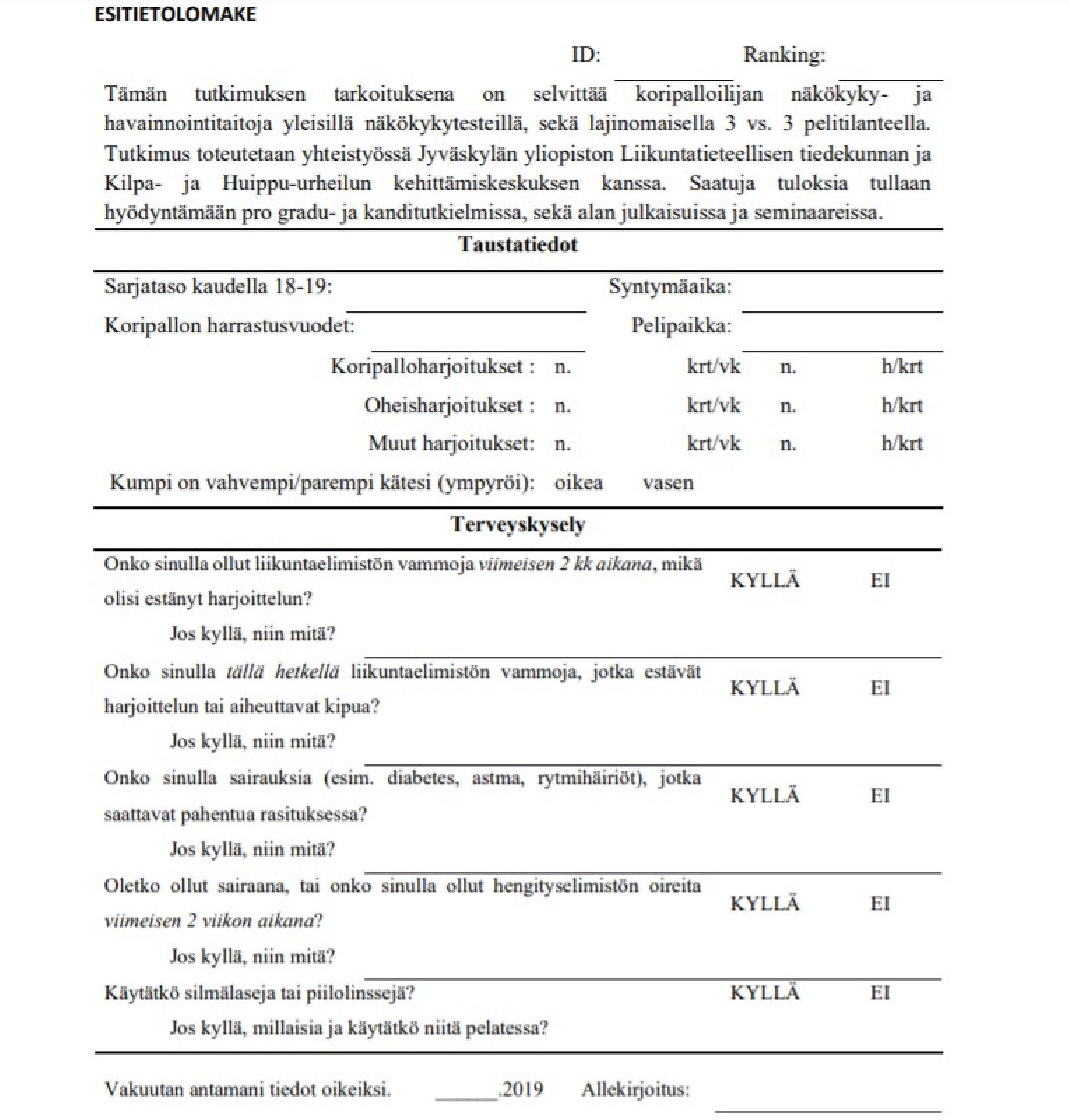
APPENDICES

APPENDIX 1. Health and basketball training background questionnaires.



ESITIETOLOMAKE

ID: ________ Ranking: ________

Tämän tutkimuksen tarkoituksena on selvittää koripalloilijan näkökyky- ja havainnointitaitoja yleisillä näkökykytesteillä, sekä lajinomaisella 3 vs. 3 pelitilanteella. Tutkimus toteutetaan yhteistyössä Jyväskylän yliopiston Liikuntatieteellisen tiedekunnan ja Kilpa- ja Huippu-urheilun kehittämiskeskuksen kanssa. Saatuja tuloksia tullaan hyödyntämään pro gradu- ja kanditutkielmissa, sekä alan julkaisuissa ja seminaareissa.

Taustatiedot

Sarjataso kaudella 18-19: ________ Syntymäaika: ________

Koripallon harrastusvuodet: ________ Pelipaikka: ________

Koripalloharjoitukset : n. krt/vk n. h/krt

Oheisharjoitukset : n. krt/vk n. h/krt

Muut harjoitukset: n. krt/vk n. h/krt

Kumpi on vahvempi/parempi kätesi (ympyröi): oikea vasen

Terveyskysely

Onko sinulla ollut liikuntaelimistön vammoja *viimeisen 2 kk aikana*, mikä olisi estänyt harjoittelun? KYLLÄ EI

Jos kyllä, niin mitä? ________

Onko sinulla *tällä hetkellä* liikuntaelimistön vammoja, jotka estävät harjoittelun tai aiheuttavat kipua? KYLLÄ EI

Jos kyllä, niin mitä? ________

Onko sinulla sairauksia (esim. diabetes, astma, rytmihäiriöt), jotka saattavat pahentua rasituksessa? KYLLÄ EI

Jos kyllä, niin mitä? ________

Oletko ollut sairaana, tai onko sinulla ollut hengityselimistön oireita *viimeisen 2 viikon aikana*? KYLLÄ EI

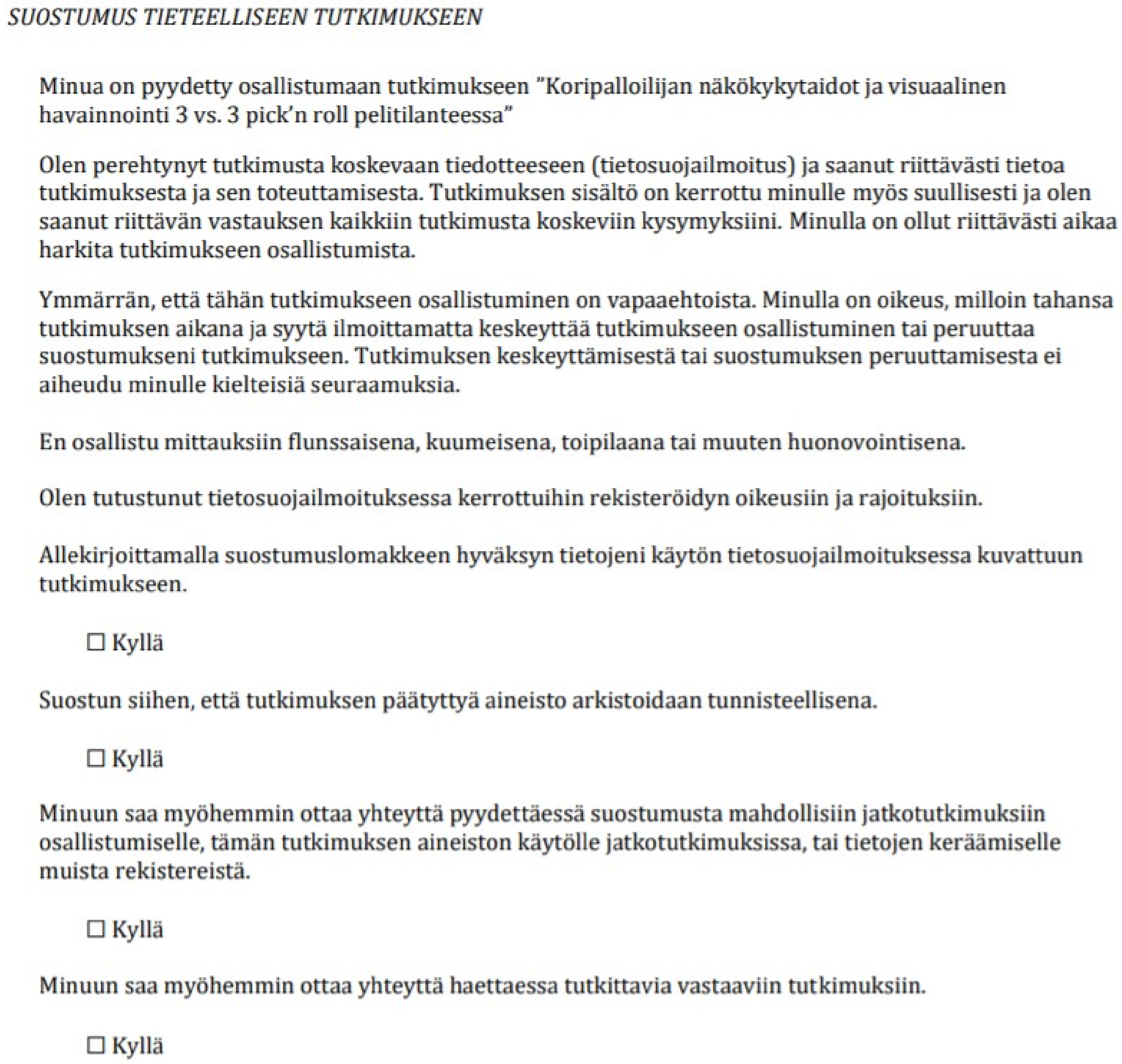
Jos kyllä, niin mitä? ________

Käytätkö silmälaseja tai piilolinssejä? KYLLÄ EI

Jos kyllä, millaisia ja käytätkö niitä pelatessa?

Vakuutan antamani tiedot oikeiksi. ______.2019 Allekirjoitus: ________

APPENDIX 2. An approval form of the study.



SUOSTUMUS TIETEELLISEEN TUTKIMUKSEEN

Minua on pyydetty osallistumaan tutkimukseen ”Koripalloilijan näkökykytaidot ja visuaalinen havainnointi 3 vs. 3 pick’n roll pelitilanteessa”

Olen perehtynyt tutkimusta koskevaan tiedotteeseen (tietosuojailmoitus) ja saanut riittävästi tietoa tutkimuksesta ja sen toteuttamisesta. Tutkimuksen sisältö on kerrottu minulle myös suullisesti ja olen saanut riittävän vastauksen kaikkiin tutkimusta koskeviin kysymyksiini. Minulla on ollut riittävästi aikaa harkita tutkimukseen osallistumista.

Ymmärrän, että tähän tutkimukseen osallistuminen on vapaaehtoista. Minulla on oikeus, milloin tahansa tutkimuksen aikana ja syytä ilmoittamatta keskeyttää tutkimukseen osallistuminen tai peruuttaa suostumukseni tutkimukseen. Tutkimuksen keskeyttämisestä tai suostumuksen peruuttamisesta ei aiheudu minulle kielteisiä seuraamuksia.

En osallistu mittauksiin flunssaisena, kuumeisena, toipilaana tai muuten huonovointisena.

Olen tutustunut tietosuojailmoituksessa kerrottuihin rekisteröidyn oikeusiin ja rajoituksiin.

Allekirjoittamalla suostumuslomakkeen hyväksyn tietojeni käytön tietosuojailmoituksessa kuvattuun tutkimukseen.

☐ Kyllä

Suostun siihen, että tutkimuksen päätyttyä aineisto arkistoidaan tunnisteellisena.

☐ Kyllä

Minuun saa myöhemmin ottaa yhteyttä pyydettäessä suostumusta mahdollisiin jatkotutkimuksiin osallistumiselle, tämän tutkimuksen aineiston käytölle jatkotutkimuksissa, tai tietojen keräämiselle muista rekistereistä.

☐ Kyllä

Minuun saa myöhemmin ottaa yhteyttä haettaessa tutkittavia vastaaviin tutkimuksiin.

☐ Kyllä

Allekirjoituksellani vahvistan, että osallistun tutkimukseen ja suostun vapaaehtoisesti tutkittavaksi sekä annan luvan edellä kerrottuihin asioihin.

______________________	______________________
Allekirjoitus	*Päiväys*
______________________	______________________
Nimenselvennys	*Syntymäaika*

____

Osoite

Suostumus vastaanotettu

______________________	______________________
Suostumuksen vastaanottajan allekirjoitus	*Päiväys*

____

Nimenselvennys