

**THE ROLE OF TASK CONSTRAINTS IN PROMOTING
DEVELOPMENT AND TRANSFER OF PERCEPTUAL-
MOTOR SKILL IN SPORT**

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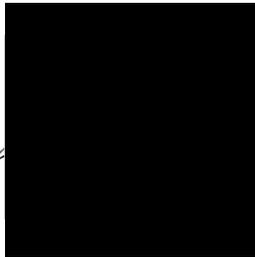
ABSTRACT

This thesis examined the role that task constraints play in promoting transfer of perceptual skill in sport tasks (futsal and soccer). Transfer of learning is the process of adapting a learned behaviour to a new context. Transfer occurs due to the similarity between a learned behaviour and the behaviour required to achieve the task goal. The similarity of information that guides action between the learning and criterion (transfer) tasks facilitates the transfer process. An individual's ability to perceive information that specifies opportunities for action (affordances), which underpins skilled performance, has been shown to transfer between similar sport tasks. However, it is unknown how task constraints (e.g., rules, equipment and task goal) influence the development and transfer of perceptual skill between similar tasks. While previous research has been limited to examining acute effects, this thesis showed that practicing a sport skill (i.e., passing) for more than 1000 hours using domain-specific task constraints affected how individuals oriented their attention to perceive affordances. These differences in perceptual behaviour influenced how participants transferred their skill to a new context. Learning the passing skill with shorter time to act and in a smaller space (using futsal constraints) promoted a higher magnitude of transfer to a task with longer time and larger space (soccer constraints) than vice versa. Furthermore, the results indicated that learning the passing skill with a modified equipment (futsal ball) positively transferred to the standard equipment (soccer ball). The modified equipment fast-tracked the participants' ability to perceive information that specified task-relevant affordances, which, in turn, expedited learning. Overall, this thesis extended current knowledge on the role of task constraints in promoting the development and transfer of perceptual skill. Practitioners are encouraged to manipulate task constraints to facilitate the emergence of functional behaviours that transfer to competition.

STUDENT DECLARATION

I, Luca Oppici, declare that the PhD thesis entitled ‘The role of task constraints in promoting development and transfer of perceptual skill in sport’ is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature:



Date: 15/02/2018

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CHAPTER 1

INTRODUCTION & OVERVIEW OF THE THESIS

1.1 Introduction

The ability to apply knowledge and skills learned in one context to another has been (and still is) a key issue in various fields that deal with learning, such as education (Perkins & Salomon, 1992), and sport and exercise science (Issurin, 2013). Most often, learning programs take place in environments that differ from the environment in which the learned behaviour is intended to be applied. For example, athletes apply the skills learned in training to competition; children transfer movement skills practiced during physical education classes to contexts outside school; rehabilitation exercises aim to improve an individual's physical ability outside the clinic. This phenomenon is known as transfer of learning and refers to the influence of previous learning with a set of constraints on performance or learning in another context, or with other constraints (Adams, 1987; Magill, 2011; Newell, 1996). Given the relevance of transfer to the sport and exercise science field, knowing the mechanisms and conditions that facilitate the transition between contexts is critical to the design of efficient learning programs (Issurin, 2013; Perkins & Salomon, 1992).

Transfer is considered positive if previous learning leads to performance improvement or facilitates learning in another context, while transfer is negative when it hinders learning or performance decreases, and neutral when performance and learning are unchanged or not affected (Carroll, Riek, & Carson, 2001). Ultimately, learning programs aspire to achieve positive transfer. A long-standing theory, formulated at the beginning of the 20th century in the field of education, contended that positive transfer occurs when similar elements (e.g., movement kinematics) are present between a learning task and the transfer task (Thorndike, 1906). Over the last century, different theories and approaches have been proposed to explain how transfer occurs, and the concept of 'similarity' recurs as a key aspect for promoting transfer (Barnett & Ceci, 2002; Lee, 1988; Magill, 2011). In sport and exercise science, the ecological dynamics framework (Davids, Araujo, Hristovski, Passos, & Chow, 2012) argues that transfer

occurs due to the similarity between a learned behaviour and a behaviour required in a new context to achieve the task goal. Given that learning refers to a permanent change in an individual's behaviour and this thesis discusses transfer of perceptual-motor skill learning, transfer of learning, transfer of skill, and transfer of behaviour are used interchangeably throughout the following chapters (this approach is commonly used, e.g., see Abernethy, Baker, & Côté, 2005; Rosalie & Müller, 2012; Schmidt & Lee, 2011).

The ecological dynamics framework advocates the performer-environment relationship as the basis for the analysis of human behaviour (Araújo, Davids, & Hristovski, 2006). It combines principles of ecological psychology (Gibson, 1979) and dynamical systems theory (Kelso, 1995), contending that an individual's behaviour emerges from the self-organisation of perception and action under interacting constraints (Newell, 1986; Seifert, Button, & Davids, 2013). Constraints have been defined as boundaries that limit (and enable) movement and have been classified into three categories: organismic constraints (i.e., the characteristics of the performer), environmental constraints (i.e., the characteristics of the environment in which a movement is performed), and task constraints (i.e., the properties of the task performed) (Newell, 1986).

In a given task, opportunities for action, called affordances, emerge from properties of the environment (and task) and a performer's action capabilities (Gibson, 1979). Affordances describe the behaviours that are possible at a given time under a given set of contexts and conditions (Chemero, 2003, 2009). The perception of information specifying task-relevant affordances regulates the self-organisation of movement (Gibson & Pick, 2000; Seifert, Button, et al., 2013). In this sense, perception and action are mutually dependent; a performer moves to perceive environmental information to support their action, and their movement generates more information (Gibson, 1979, 1986). Practicing with a given set of constraints, individuals develop perceptual and action behaviours that support the learning of perceptual-motor skills,

such as kicking and throwing a ball (Davids, Button, & Bennett, 2008b). In this framework, positive transfer occurs due to similarity between the practiced perception-action couplings and the coupling required in another context to achieve the task goal (Pacheco & Newell, 2015). The similarity of information available to guide action during practice and the transfer task promotes the transfer process (Snapp-Childs, Wilson, & Bingham, 2015). Therefore, the ability to perceive information that specifies task-relevant affordances is predicted to promote the transfer of perceptual-motor skills between tasks that present similar information.

A modification to one of the constraint categories during practice influences the emergence of affordances, which, in turn, is predicted to influence the development and transfer of perceptual behaviour (i.e., the perception of environmental information) supporting perceptual-motor skills (Davids et al., 2008b). In the sport and exercise field, practitioners can readily modify the properties of a task, such as equipment, playing area and rules to facilitate an athlete's skill development (Araújo, Davids, Bennett, Button, & Chapman, 2004; Farrow, Buszard, Reid, & Masters, 2016). Previous research has examined how similarity of information between contexts promoted transfer of perceptual behaviour (e.g., Causer & Ford, 2014; Moore & Müller, 2014), and how task-constraint modification influenced the development of an athlete's perceptual-motor skill (e.g., Buszard, Reid, Masters, & Farrow, 2016a; Farrow & Reid, 2010). Studies have shown transfer of perceptual behaviour to similar but not to dis-similar sport domains, indicating how correspondence of information promotes transfer (e.g., Causer & Ford, 2014; Moore & Müller, 2014). While studies have shown how modification of task constraints changes the emergence of an athlete's behaviour (e.g., Buszard, Reid, Masters, & Farrow, 2016b; Travassos, Goncalves, Marcelino, Monteiro, & Sampaio, 2014) and influences learning of sport skills (e.g., Buszard et al., 2016a; Farrow & Reid, 2010), they primarily focused on the movement outcome. Hence, it remains relatively un-explored how task constraints affect perceptual behaviour. Furthermore, a very limited

number of studies examined how task constraints influence skill transfer but (again) they focused on the movement outcome (e.g., Coldwells & Hare, 1994; Pellett, Henschel-Pellett, & Harrison, 1994). As such, it is currently unknown how task constraints influence the development and transfer of perceptual behaviour in sport tasks.

This thesis examined how task constraints promote the (development and) transfer of perceptual behaviour using futsal and soccer as vehicles. Futsal and soccer are two forms of football that share many similarities, while some task constraints differentiate them. Passing skill, which couples the perception of environmental information to make decisions and a kick towards a teammate, is performed in both sports. Passing affordances and the passing action are likely to emerge similarly in the two domains. Affordances emerge from the interaction of a passer's, teammates', and opponents' behaviour (Corrêa, Vilar, Davids, & Renshaw, 2014a; Travassos, Araújo, Davids, Vilar, et al., 2012), and the passing action involves the self-organisation of the lower limb to intercept a ball. Therefore, this relative similarity in perception and action behaviours is expected to promote skill transfer between futsal and soccer. Furthermore, between-sports differences in task constraints, such as ball properties, number of players and pitch dimensions, are expected to influence the development and transfer of perceptual behaviour underpinning passing. Specifically, futsal task constraints are expected to promote the development of skill adaptability which would facilitate transfer to soccer.

Current knowledge on the effect of task constraints on skill learning and transfer is primarily derived from lab-based studies using relatively simple movements, and is limited to the assessment of a movement outcome (e.g., Zanone & Kelso, 1992; Zanone & Kelso, 1997). The examination of the influence of task constraints on the development and transfer of perceptual behaviour supporting a whole-body movement in complex sport tasks would extend current knowledge. Furthermore, understanding how task constraints promote the learning

process has practical implications for sport coaching. A constraints-led approach to coaching, whereby practitioners primarily manipulate task constraints and act as facilitators, has been argued to promote the development of a range of functional actions (Renshaw, Chow, Davids, & Hammond, 2010). Furthermore, this approach should encourage implicit learning, which has been shown to be more robust than explicit learning under external stressors, such as anxiety (Hardy, Mullen, & Jones, 1996). While practitioners typically manipulate task constraints in practice (e.g., the type of equipment, the rules of a drill and the goal of a task), it is critical that they modify constraints in a principled manner to promote skill transfer to competition. For example, a soccer coach can choose the size of the ball, the number of players in each team, the size of the pitch and the rules of the game when preparing a training session. Which option should the coach select? What combination of task constraints would be more beneficial for improving soccer performance? Knowing how the selection of task constraints influences transfer of sport skills would help practitioners making more informed decisions.

1.2 Aims of the Dissertation

1.2.1 General Aims

This thesis aimed to extend current knowledge on the influence of task constraints on the development and transfer of perceptual behaviour supporting a perceptual-motor skill using two similar sports, i.e., futsal and soccer, as the experimental context.

1.2.2 Specific Aims

- To investigate the influence of long-term practice with different task constraints on the development of perceptual behaviour supporting the passing skill.
- To determine how task constraints influence the transfer of passing skill, and to explore how perceptual behaviour supports the transfer process.

- To determine how manipulation of equipment promotes the transfer of passing skill, and how perceptual behaviour facilitates transfer.

1.3 Chapter organisation

This chapter introduced the topic of this dissertation by providing a brief rationale for the research and set out the specific aims of the thesis.

Chapter 2 provides a critique of the research encompassing the study of skill learning and transfer, with a focus on the influence of task constraints on the emergence of an individual's behaviour.

Chapter 3 explored differences in the passing skill between futsal and soccer players during elite games. Execution time (from reception to pass), pass accuracy, and distribution of the different types of passes (i.e., direct, one-touch and held passes) of adult elite futsal and soccer players were compared. Results showed that passing is performed differently in the two sports, suggesting that domain-specific task constraints influence the emergence of passing-specific affordances which, in turn, would be expected to affect a player's development of perceptual behaviour underpinning passing.

Chapter 4 presents the development and validation of a method for measuring perceptual behaviour in a representative field task. Eye tracking technology is typically used in sport science to assess how individuals perceive environmental information to support their action. This technology records the movements of the eyes and has limitations when used in dynamic tasks that involve rapid movements, e.g., running and jumping. This chapter discusses the development of a method to approximate an athlete's orientation of **visual** attention using the

external camera of an eye tracker, during the performance of football field tasks. The developed method was used in chapters 5 and 6 to approximate participants' orientation of visual attention.

Chapter 5 examined the influence of long-term practice with different task constraints on the development of perceptual behaviour supporting passing. The orientation of visual attention during passing was assessed in futsal and soccer players which developed the passing skill with different task constraints. Results showed that practicing the passing skill for more than 1000 hours with futsal or soccer task constraints influenced players' orientation of attention during passing in a field test. Participants oriented their attention towards other players to inform decision-making at different moments during the task. Futsal players did so prior to executing a pass, while soccer players did so when they were not in possession of the ball.

Chapter 6 expanded the findings of chapter 5 by determining how learning the passing skill with futsal or soccer task constraints influenced the transfer of passing to task constraints of the other sport (i.e., futsal to soccer and soccer to futsal). While the relative similarity of information available to guide action in each sport promoted transfer in both groups of players, results showed that futsal task constraints facilitated a higher magnitude of transfer to soccer task constraints than vice versa. Futsal players adapting their perceptual behaviour to the passing-specific affordances that emerged with soccer task constraints was suggested to facilitate the superior skill transfer. This chapter highlighted that task constraints influenced transfer, and futsal-specific task constraints promoted positive transfer of perceptual behaviour that, in turn, improved passing performance.

Chapters 5 and 6 presented two cross-sectional studies that investigated the impact of futsal and soccer task constraints on participants' orientation of attention in a field test. Chapter 7 presents a randomised controlled study that isolated one task constraint in the laboratory to assess the development of perceptual behaviour in a controlled environment. This chapter evaluated the influence of ball properties on transfer of passing skill. Results showed that practicing passes with a futsal ball promoted larger improvement in the passing performance with a soccer ball than practicing with a soccer ball, indicating positive transfer of skill. The futsal ball facilitated the development of perceptual attunement to task-relevant information that supported the positive transfer from the futsal ball to the soccer ball. Overall, the findings of chapters 5, 6 and 7 highlighted how task constraints influenced the development and transfer of perceptual behaviour. Futsal task constraints and, specifically, the futsal ball facilitated the attunement to information specifying task-relevant affordances that, in turn, improved passing performance.

Chapter 8 provides a summary and a general discussion of the studies conducted. Theoretical and practical implications of the thesis are considered, along with future research directions.

Please note that the majority of chapters in this dissertation have been written with the intention to publish and, in some cases, have already been published. Consequently, the definition of key terms (e.g., transfer of learning and constraints) and the importance of this area have been repeated on several occasions.

CHAPTER 2

LITERATURE REVIEW

2.1 Transfer of learning

Transfer of learning is a relevant issue in the field of sport and exercise science as individuals often train to improve skills that are performed in different contexts (Issurin, 2013). Furthermore, the ability to transfer learned skills between different contexts and sport domains allows athletes to develop a wide range of actions, promoting the development of sport expertise (Baker & Farrow, 2015). Understanding whether and how individuals transfer their skills has theoretical and practical implications, as it provides insights into: i) the specificity of learning hypothesis ii) the training conditions that might promote transfer to competition, and iii) the preferred pathway to promote the development of sport expertise.

The specificity of learning hypothesis (Proteau, 1992) contends that learning is specific to the visual information experienced during practice and it does not transfer to other tasks that change or remove that sensory information (Proteau, Marteniuk, & Lévesque, 1992). For example, practicing a target-pointing task with full vision did not transfer to a condition where only the target was visible (Proteau, Marteniuk, Girouard, & Dugas, 1987). However, other research has shown that participants transferred a learned skill even when visual information changed from practice to the transfer task (Bennett, Button, Kingsbury, & Davids, 1999; Tremblay & Proteau, 1998), and it has been argued that other sensory information might be used to guide performance when visual information changes (Mackrout & Proteau, 2007). The type of sensory information learning is specific to and how information from different sources interact during the learning process is still debated (Tremblay, 2010). The representative learning design framework (Pinder, Davids, Renshaw, & Araújo, 2011b) contends that learning is specific to the information that emerges from the interaction of constraints during practice, and learning transfers to constraints that lead to the emergence of similar information (Chow, Davids, Button, & Renshaw, 2015); however, evidence was only derived from cross-sectional studies (Barris, Davids, & Farrow, 2013; Pinder, Davids, Renshaw, & Araújo, 2011a;

Travassos, Duarte, Vilar, Davids, & Araujo, 2012), and intervention studies are needed to better evaluate how learning evolves longitudinally. Experiments that evaluate how learning transfers and how practice conditions promote the transfer process would provide new insights into what learning is specific to, and can provide support to practitioners for the design of practice tasks.

The ultimate goal of any training program is to enhance an athlete's performance in competition. In this context, research can provide evidence on the practice conditions that promote transfer to help coaches make informed decisions when planning training (Williams, Ford, Causer, Logan, & Murray, 2012). For example, a random order of trial conditions has been shown to facilitate the transfer process (Farrow & Buszard, 2017), and researchers have developed tools that can support coaches in the design of random practice (Buszard, Reid, Krause, Kovalchik, & Farrow, 2017). Practitioners can also modify equipment or other aspects of a training (e.g., playing area and rules) and knowing how these training conditions can be manipulated to encourage transfer to competition can support a coach's decisions.

The transfer of learned skills is relevant when considering the timing of sport specialisation (i.e., practicing one sport only). Specialisation in one sport is paramount to the attainment of sport expertise (Baker & Young, 2014); however, the timing of specialisation is debated (Baker, Cobley, & Fraser-Thomas, 2009). Contrasting hypotheses argue, on the one hand, that individuals should specialise in their domain at an early age (early specialisation pathway; Ward, Hodges, Starkes, & Williams, 2007), and on the other hand, that individuals should engage in a variety of sports at an early age and delay specialisation (early diversification pathway; Côté, 1999; Côté, Lidor, & Hackfort, 2009). While an alternative hypothesis suggests that individuals should engage early in domain-related playful activities (early engagement hypothesis; Ford, Ward, Hodges, & Williams, 2009). Psychological and interpersonal skills, such as achieved identity and self-regulation, benefit from an engagement in a variety of sports and activities (Côté & Erickson, 2015). However, it is unknown how

diversification might impact the development of perceptual-motor skills, and empirical assessments of skill transfer between different sport domains in young athletes can provide new insights to the debate.

Different theoretical approaches have led to different perspectives on how transfer occurs. The two main theoretical approaches currently used in the motor control and learning field are information-processing and ecological dynamics. This thesis primarily uses the ecological dynamics framework to examine transfer of learning, and uses some concepts (e.g., skill automaticity) from the information-processing approach to examine the mechanisms underpinning transfer. The next section presents the historical contribution of different theoretical perspectives on transfer of learning.

2.2 Theoretical perspectives on transfer of learning

Different approaches to motor learning led to differences in explaining how transfer occurs. Theories of motor learning address how individuals, through practice, develop the ability to coordinate their body in response to environmental stimuli to successfully carry out actions (Fitts, 1964). Learning typically occurs as a modification of pre-existing structures and processes (Schmidt & Lee, 2011; Zanone & Kelso, 1997), and transfer of learning involves applying the learned structures to a new context. Three theories contend that different structures change with learning, and provide an explanation of transfer: identical-elements theory (Thorndike, 1906), transfer appropriate-processing (Lee, 1988), and ecological dynamics (Davids et al., 2012). While the three theories converge on the idea that ‘similarity’ is a key aspect for promoting transfer, they differ on the conceptualisation of what needs to be similar.

2.2.1 Identical-elements theory

Thorndike (1906) was one of the pioneers in the investigation of transfer of learning in the field of education and his theory of identical elements is still relevant today (Barnett & Ceci, 2002).

Thorndike's behaviourist approach to learning, where an individual's behaviour is examined at a stimulus-response level, shaped the formulation of his theory. Thorndike and Woodworth tested participants' ability to estimate the area of different sized shapes (Woodworth & Thorndike, 1901) and the ability to recognise specific letters in different words (Thorndike & Woodworth, 1901). After practicing with a set of shapes and words, participants accurately estimated the shapes and recognised the letters that were similar to the ones they practiced with, while they were not able to recognise shapes and letters that differed from the ones used during training. Based on these results, Thorndike (1906) contended that mental functions transfer to other functions so long as they share identical elements, and behaviours developed in response to a class of stimuli positively transfer only to similar task stimuli.

The identical-elements theory established the basis for future research in transfer of learning. The idea that transfer occurs between tasks that share similarities is still relevant; however, different approaches to the issue have led to the conceptualisation of theories that diverge on what needs to be similar to promote transfer. In the same historical period of Thorndike, Judd (1908) developed a principle-based theory that moved away from a task-oriented approach. He argued that transfer is promoted when knowledge, rules, and principles abstracted in learning are applied to another context, even if the task elements are not similar (Judd, 1908). For example, while identical-elements theory would not predict transfer of an athlete's ability to anticipate an opponent's action from rugby to baseball due to differences in the movement kinematics of the two sports, principle-based theory would predict positive transfer due to a rugby player applying knowledge of fundamental movement skill to the baseball context (Müller, McLaren, Appleby, & Rosalie, 2015). Judd (1908) evaluated the effect of knowing the principle of refraction on the ability to transfer darts throwing to submerged targets. Children practiced throwing darts to a target submerged 12 in. One group received information on the principle of refraction (intervention group) while another group

did not receive any explanation. After the intervention, the two groups performed equally in a post-test with the target submerged at 12 in but the intervention group outperformed the other group when the target was moved to 4 in (transfer task). Knowing the principle of refraction underpinned transfer to the novel task (Judd, 1908).

2.2.2 Transfer appropriate-processing

A cognitive approach to motor learning shaped the conceptualisation of the transfer-appropriate processing theory (Lee, 1988). In this approach, learning is viewed as a process of establishing and enriching internal representations due to practice, which lead to relatively permanent changes in the capability for skilled movement (Schmidt & Lee, 2011). Transfer depends on the compatibility of an individual's internal representations and demands of a new task (Schmidt & Young, 1987). The transfer process is promoted when the cognitive processes elicited during learning are similar to the cognitive processes required in the transfer task (Lee, 1988).

Experiments on contextual interference, in which the order of task conditions was manipulated during practice, provided the framework for the development of the transfer appropriate-processing framework (Lee, 1988). Practicing tasks in random order (random practice) consistently led to a higher degree of transfer to novel tasks than practicing the trial conditions in predefined blocks (blocked practice) (Magill & Hall, 1990; Shea & Morgan, 1979). The cognitive processes used in random practice were quickly adapted to a novel (transfer) task that required similar processes, namely the ability to elaborate and generate new action plans for the novel task, while the subjects in the blocked practice struggled to adapt to the new demands (Lee & Magill, 1983). Transfer was promoted by the similarity of cognitive processing between tasks, and only appropriate-processing transferred.

2.2.3 Ecological dynamics

Ecological dynamics combines concepts from ecological psychology and dynamical systems theory in explaining how individuals control actions and develop perceptual-motor skills (Davids et al., 2012; Seifert, Button, et al., 2013). It contends that perception of environmental information is direct and information to guide action emerges from the interaction between organism and environment (Gibson, 1979; Jacobs & Michaels, 2007; Turvey, 1990). It also views individuals as complex dynamical systems in which movement coordination emerges from the self-organisation of the different body parts (Kelso, 1995).

Ecological psychology considers the organism and environment as an interacting system where one interacts with and depends on the other (Michaels & Beek, 1995). Opportunities for action, called affordances, emerge from the dynamic interaction of a performer and their environment (Gibson, 1979). Affordances are relations between the action capabilities of a performer and features of the environment, and describe the range of behaviours that are possible in a given context or task (Chemero, 2003, 2009; Fajen, 2005). The perception of affordances that are relevant to the task at hand guides an individual's movement (Araújo et al., 2006). Affordances are perceived through the pick-up of information (mainly visual) that specifies patterns in ambient stimulation, and information, in ecological dynamics, is conceptualised as the flow of energy that can be exploited by a performer to guide their behaviour (Gibson, 1966, 1986).

Dynamical systems theory provides a framework to conceptualise how action is coordinated in response to the perceived affordances. It considers humans as complex neurobiological systems composed of many sub-systems (e.g., limbs, joints, muscles) that continuously interact with each other in different ways, which interactions and fluctuations can potentially result in infinite patterns of coordination (Bernstein, 1967). A neurobiological system is a dynamical system that has the capacity to spontaneously self-organise the

relationship among its sub-components forming stable and functional patterns of coordination, called attractors (Kelso, 1992; Schöner & Kelso, 1988). The self-organisation of coordination patterns is a dynamic process that takes place within an attractor landscape, i.e., a hypothetical construct that includes stable attractors within all the potential relationships between the system's components (Handford, Davids, Bennett, & Button, 1997). The type of attractors a complex system settles into depends on the constraints acting on the system (Kugler & Turvey, 1987).

Importantly, ecological dynamics contends that human behaviour emerges from continuous couplings of perception and action. Perception and action, information and movement, performer and environment are mutually dependent; a performer moves around the environment to pick-up information that guides their movement, and their movement generates new information (Davids, Araujo, Seifert, & Orth, 2015; Gibson, 1979). Perception and action couplings emerge within interacting boundaries provided by constraints. Constraints have been defined as features that limit (and enable) the behaviour of individuals, and have been classified into three categories: organismic, environmental, and task (Newell, 1986). Organismic constraints refer to the performer's characteristics (e.g., cognition, previous experience, intentions, physical capabilities), environmental constraints refer to the environment in which action takes place (e.g., weather and gravity), and task constraints are specific to the performance context (e.g., rules, equipment, goals) (Newell, 1986). The dynamic interaction of organismic, environmental and task constraints during goal-directed activities shapes the attractor layout of a perceptual-motor landscape, which hypothetically represents an individual's stable movement solutions (Newell, 1991, 1996).

From an ecological dynamics viewpoint, skill learning occurs as a relatively permanent change in an individual's behaviour over time as a result of goal-directed practice with a certain set of constraints (Newell, 1996). With practice, individuals become perceptually attuned to

environmental information that specifies affordances, and develop the ability to organize functional coordination patterns (Davids et al., 2012). Transfer of learning is conceptualised as a process of adapting behaviour, developed with a certain set of constraints, to a different set of constraints (Newell, 1996; Rosalie & Müller, 2012). Transfer is positive when individuals successfully adapt their behaviour and improve their performance, while it is negative when performance decreases (Carroll et al., 2001). The level of correspondence between an individual's ability to couple perception of affordances with functional movements and the requirements of a new task influences the degree of transfer (Davids et al., 2008b). If an individual's existing attractor repertoire is close to a functional attractor in the landscape of a new task, the transfer process is promoted. On the other hand, an existing attractor that is far from a functional attractor will 'pull' the entire system away from a functional coordination pattern, in turn, hindering performance (Newell, 1996).

Research in coordination dynamics has demonstrated how the correspondence between existing information-movement couplings and a new task requirement influences transfer, highlighting the role of information similarities in promoting the transfer process. In a typical experiment, participants move right and left fingers to the beat of a metronome that constrains the relative phase (position) between the two effectors (Zanone & Kelso, 1992). Generally, in-phase (i.e., 0 degree) and anti-phase (i.e., 180 degree) are inherently stable attractors within the 0-360-degree attractor landscape (Kelso, 1995). Practicing a novel relative phase (e.g., 90 degree) stabilises the attractor corresponding to the new phase, and the learned phase has been shown to transfer to the symmetrical 270-degree phase (Zanone & Kelso, 1997). Since information for the relative phase (i.e., metronome beat) guides the assembly of the coordination patterns, information that supports action has been considered the key factor in shaping learning and transfer (Bingham, 2004a, 2004b). The information at the 90- and 270-degree phases is the same and this similarity has been suggested to promote the transfer

between the relative phases (Wilson, Snapp-Childs, & Bingham, 2010). Collectively, this research indicated how the correspondence of behaviour to new task requirements encourages transfer, and how similarity of the information that guides action facilitates the transfer process (Snapp-Childs et al., 2015).

2.2.4 Evaluation of transfer

Transfer of learning is evaluated on performance achievement in a transfer task, rather than on an 'idealised' reference movement, as different behaviours can lead to successful performance (Araújo & Davids, 2015; Travassos, Araujo, & Davids, 2017). To evaluate the quality of transfer (i.e., positive, neutral or negative), the performance of individuals that learned a skill under certain practice conditions (training constraints) is evaluated against a criterion performance in a transfer task. In longitudinal studies, where an experimental group practices a skill for a period, the group's pre-test performance in a transfer task is the criterion performance against which post-test performance is compared. For example, to evaluate the transfer of anticipation skill from a random-practice intervention in the laboratory to performance in the field, an experimental group's pre- to post-test change in anticipation accuracy in a field task was assessed, and results showed positive transfer as the experimental group's performance improved from pre- to post-test (Broadbent, Causer, Ford, & Williams, 2015). Furthermore, additional experimental groups can be added to evaluate the practice conditions that lead to the highest magnitude of transfer. Going back to the previous example, another experimental group underwent a blocked-practice intervention, and its pre- to post-test change in anticipation accuracy in the field task was compared to the random-practice group. The random-practice group had a higher pre- to post-test improvement and, consequently, a higher magnitude of transfer than the blocked-practice group, and it was concluded that random practice was more beneficial than blocked practice to train anticipation skill that transfers to competition (Broadbent, Causer, Ford, et al., 2015).

In cross-sectional studies, that do not include an intervention but compare the performance of different groups, participants that have experience in the transfer task and/or novices represent the criterion performance (control group). Transfer is considered positive if the transfer group's performance is superior than novices and equivalent to the expert group's performance. For example, the performance of karate athletes in a taekwondo anticipation task was superior compared to novices and similar to taekwondo experts' performance, which indicated positive transfer of anticipation skill from karate to taekwondo (Rosalie & Müller, 2014).

In summary, from an ecological dynamics viewpoint, transfer of learning is the process of adapting the ability to functionally couple information and movement developed with a certain set of constraints to a different set of constraints. Since information directly guides action, transfer is promoted when the information used in practice is similar to the information used in a transfer task. As such, an individual's ability to perceive information that specifies affordances should transfer to tasks that present similar information, in turn, improving overall performance. The next section presents research that examined how information similarities between contexts influenced transfer of perceptual learning in sport.

2.3 Transfer of perceptual learning in sport

Perceptual learning occurs as a relatively permanent change in an individual's ability to perceive key environmental information to support action (Gibson & Pick, 2000; Williams, Davids, & Williams, 1999). The environment we live in affords a large number of behaviours (i.e., affordances), and we are surrounded by a rich array of information (in the form of energy flows) that specifies what actions the environment affords (Rietveld & Kiverstein, 2014). When performing a specific task, only a limited number of actions can lead to successful performance,

hence it is critical to perceive the information that specifies the task-relevant affordances to support the self-organisation of a movement functional to the achievement of the task goal (Bruineberg & Rietveld, 2014; Gibson, 1979). With practice, individuals attune their perception to key environmental informational and learn to exploit the information that specifies task-relevant properties of the environment in relation to their action capabilities (Gibson & Pick, 2000; Savelsbergh, van der Kamp, Oudejans, & Scott, 2004). Skilled behaviour and the development of sport expertise, thus, entails the education of attention towards information that is suited to the task at hand (Beek, Jacobs, Daffertshofer, & Huys, 2003). In this context, attention is conceptualised as attunement to the environment-performer relationship (Canal-Bruland, van der Kamp, & Gray, 2016). This perceptual attunement to task-relevant information (i.e., perceptual behaviour) supports successful performance in sport tasks.

2.3.1 Evaluation of perceptual behaviour

The ability to perceive key environmental information to successfully guide action in sport has been primarily evaluated using decision-making, anticipation and pattern recall lab-based tasks (Farrow & Abernethy, 2015; Mann, Williams, Ward, & Janelle, 2007; Travassos et al., 2013). Decision-making tasks require individuals to make a decision in response to video stimuli; in anticipation tasks, environmental information is occluded before a key event and an athlete's ability to detect affordances is assessed (temporal occlusion paradigm); pattern recall tasks present a pattern of play for a few seconds and athletes are required to recall the pattern when it disappears from the display. Typically, the performance of skilled athletes in these tests is compared to less-skilled athletes or novices to evaluate how certain perceptual behaviours support sport expertise. Experiments consistently showed experts' superior accuracy in making decisions (Starkes & Ericsson, 2003; Travassos et al., 2013), anticipating an opponent's action (Abernethy, Farrow, Gorman, & Mann, 2012; Williams, Ford, Eccles, & Ward, 2011) and

recalling patterns of play (Chase & Simon, 1973; Gorman, Abernethy, & Farrow, 2012) relative to lesser-skilled counterparts, which indicates how perceiving information that specifies affordances supports expert performance.

The specific information sources an athlete is attuned to can be directly assessed through eye tracking technology or, indirectly, using the spatial occlusion paradigm. Vision is considered the dominant sense for the perception of environmental information and eye tracking technology has been extensively used in sport to directly assess the specific information athletes focus their visual attention on during goal-directed tasks (Kredel, Vater, Klostermann, & Hossner, 2017; Panchuk, Vine, & Vickers, 2015). This technology records movements of the eyes and determines the point of gaze within the scene being viewed, showing an athlete's gaze behaviour over the performance of a task. Experts and novices quite consistently have different visual strategies during sport tasks (Mann et al., 2007). For example, expert soccer goalkeepers focused their attention on fewer areas and for a longer period than novices when saving penalties (Savelsbergh, Williams, van der Kamp, & Ward, 2002). Furthermore, the ability to focus visual attention on task-relevant information typically discriminates between successful and unsuccessful performance, e.g., successful passes were underpinned by longer attention on ball carrier than the unsuccessful ones (Vaeyens, Lenoir, Williams, & Philippaerts, 2007). Another method to assess the perception of task-specific information is the spatial occlusion paradigm that assesses what information in the environment (e.g., an opponent's arm movement) supports accurate performance. Specific areas of the video display are occluded, and expert-novice differences in performance associated with the removal of certain information indicate the sources that are most informative to support expert performance. For example, expert-novice differences were found in a badminton anticipation task when the video stimuli presented the kinematics of the racquet and an opponent's lower

body in isolation, which indicated how attunement to that information underpinned expert performance (Abernethy & Zawi, 2007).

The above-mentioned methods provide evidence on how perceptual behaviour develops and underpins sport expertise; however, they present some limitations that affect the results. Many experiments have been performed in laboratories where participants often responded to video simulations performing actions that were not specific to their domain of expertise (Travassos et al., 2013). For example, moving a joystick to save a soccer penalty projected onto a screen (Savelsbergh et al., 2002). While this approach is beneficial for controlling the stimuli presented and the potential confounding variables, the de-coupling of perception and action that athletes typically experience in their practice influences how participants perceive environmental information and, consequently, how perceptual behaviour is measured (Davids, Kingsbury, Bennett, & Handford, 2001; Farrow & Abernethy, 2003). The visual pathways are different when perception and action are coupled (perception for action) or when they are de-coupled (perception for recognition) (van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). Furthermore, the laboratory environment does not represent the interaction of constraints typical of the environment towards which the assessed skill is intended to be generalised (i.e., competition), thus limiting the generalisation of the observed behaviour (Brunswik, 1955; Pinder, Davids, et al., 2011b). To overcome these issues there has been a shift in the skill acquisition field from lab-based to in situ assessments, i.e., field-based tasks that maintain perception-action coupling and represent the constraints of the competition (Baker & Farrow, 2015).

Recent advancements in technology facilitates the assessment of perceptual behaviour in situ (Renshaw & Gorman, 2015; van Maarseveen, Oudejans, Mann, & Savelsbergh, 2016). For example, mobile eye trackers allow the assessment of attention control while leaving individuals free to perform sport-specific actions, and occlusion goggles permit the occlusion

paradigm in the field. Furthermore, perceptual behaviour supporting expert decision making can be inferred from the assessment of performer-environment dynamics during field tasks (Araújo et al., 2006). For example, position and inter-personal distance of team-sport athletes associated with successful or unsuccessful performance during games (e.g., Duarte et al., 2012; Vilar, Araujo, Davids, et al., 2014) reveal how task-relevant affordances emerge and, consequently, what information needs to be perceived to guide performance (Vilar, Araujo, Davids, & Button, 2012). While these approaches allow skill assessment in situ and improve the representativeness of experiments, they present some challenges, such as difficulties in recording eye movements in dynamic tasks, issues in selecting key variables when assessing performance dynamics, and, in turn, the complexity of an assessment task may need to be sacrificed (Mann & Savelsbergh, 2015; Renshaw & Gorman, 2015).

In summary, the evaluation of perceptual behaviour in sport is challenging and researchers are required to balance the pros and cons of lab-based and in situ assessments to properly design data collection and interpret the collected data.

2.3.2 Transfer of perceptual behaviour in sport

Previous research in sport and exercise science has examined whether perceptual behaviour developed with domain-specific constraints transferred to similar sport domains. Most studies were based on the prediction that similarity between information an athlete was attuned to and information in a similar domain promoted positive transfer (e.g., Causer & Ford, 2014; Roca & Williams, 2017). Typically, athletes' performance in a transfer task was compared to athletes that were expert in the transfer task and/or novices, and expert-in-the-domain athletes' and novices' performance was considered the criterion performance against which the quality of transfer was evaluated (e.g., Moore & Müller, 2014; Rosalie & Müller, 2014).

Athletes transferred their decision accuracy to similar sports, soccer to basketball (Roca & Williams, 2017) and invasion sports, including basketball, hockey and rugby union to soccer

(Causser & Ford, 2014), but not to dis-similar sports in video-based decision-making tasks. Anticipation accuracy transferred between similar sports, from karate to taekwondo (Rosalie & Müller, 2014) and partially from baseball to cricket (Moore & Müller, 2014), and between dis-similar sports, from karate to Australian rules football (Rosalie & Müller, 2014). In contrast, rugby experts did not transfer their anticipation accuracy to cricket (Müller et al., 2015). These contrasting results in skill transfer between dis-similar sports could potentially be explained by the small sample size of 5 participants per group in Rosalie and Müller (2014). Lastly, pattern recall accuracy transferred between netball, basketball and hockey (Abernethy et al., 2005), and pattern recall time transferred between soccer and hockey but not to volleyball (Smeeton, Ward, & Williams, 2004). While the number of studies is limited, this research suggested a positive trend of perceptual behaviour transfer only to similar sport domains.

The results of these studies collectively show how the ability to perceive task-relevant affordances in decision-making, anticipation or pattern-recall tasks transfer to tasks that present similar information – as the ecological dynamics framework would predict (Davids et al., 2012; Davids et al., 2008b). While most of the studies presented were conducted in the laboratory and de-coupled perception and action, a limited number of studies have been conducted in situ and provided insights into how the transfer of affordance perception was functional to the performance of a skill. Karate athletes transferred their perceptual behaviour to taekwondo and successfully anticipated a taekwondo opponent's action blocking different types of kicks (Rosalie & Müller, 2014). Similarly, despite perceptual behaviour being indirectly measured, transfer of affordance perception from rock climbing to ice climbing underpinned successful climb performance on an ice wall (Seifert, Wattedled, et al., 2013). Additional in situ research designs are needed to provide new insights into how transfer of affordance perception might underpin successful performance in a transfer task.

Different approaches to motor learning shape the design of practice conditions that exploit context similarity to improve skill transfer. From an information-processing perspective, the sequence of skill variations has been manipulated in training to elicit cognitive processing similar to competition, which, in turn, encouraged positive transfer from training to sport competition (Broadbent, Causer, Ford, et al., 2015). While from an ecological dynamics perspective, the constraints-led approach advocates the manipulation of constraints to modify how task-relevant affordances emerge and, consequently, how the development of functional information-movement couplings transfer to contexts that present similar information (Davids et al., 2008b; Newell, 1996). The next section presents research that has addressed how manipulating task constraints influenced an individual's behaviour and transfer of learning.

2.4 Task-constraints manipulation and transfer of learning

Task constraints have been investigated the most in sport and exercise science, particularly equipment, playing area and rules, as they can be readily manipulated by researchers and practitioners (Araújo et al., 2004). These constraints can be modified to simplify the execution of sport skills in children and novices, and to encourage learners to explore different movement solutions. Typically, children progress through various sport modifications to the adult version of the sport (Buszard et al., 2016b) and athletes train to improve performance in competition (Farrow & Robertson, 2017). As such, it is critical to verify that behaviour developed with task-constraint modifications is functional and transfers to competition or to the standard equipment.

The manipulation of task constraints influences how affordances emerge and, in turn, affects how individuals couple perception and action. Practicing with certain task constraints, individuals attune their perception to key information specifying affordances, and a perceptual behaviour develops over time (Ericsson & Lehmann, 1996; Newell, 1991; Phillips, Davids, Renshaw, & Portus, 2010; Williams, Janelle, & Davids, 2004). The perceptual behaviour

developed should transfer to a new set of constraints that presents similar information to guide action. As such, it is reasonable to expect task-constraint manipulations to influence an individual's behaviour, the development of perceptual skill over time and transfer of a learned skill.

2.4.1 Task constraints in training vs competition

Training drills aim to improve an athlete's skill repertoire and, ultimately, enhance competitive performance. Recent research has demonstrated how task constraints typically present during training are different to task constraints during competition, which influence how athletes perform in the two contexts (Barris et al., 2013; Pinder, Davids, et al., 2011a). Elite divers typically practice springboard diving in dry-land facilities where they land with their feet first on crash mats, as opposed to landing with their head first in the water in competition; and athletes' kinematics of the take-off differed when they were asked to land on mats instead of in the water (Barris et al., 2013). Similarly, cricketers practice a high volume of batting with a bowling machine, while in competition they respond to bowlers (Pinder, Renshaw, Davids, & Kerherve, 2011). The athletes' initiation of movement and batting performance differed when they responded to bowling machines, to video stimuli, and to bowlers; the video-stimuli condition held the highest similarity to the bowler condition (Pinder, Davids, et al., 2011a). Given the relative similarity of athlete's behaviour when responding to video-stimuli and bowler condition, Pinder, Davids, et al. (2011a) argued that the use of video stimuli would be more beneficial than a bowling machine in transferring batting skill to competition, based on the concept of action fidelity.

Action fidelity refers to the degree to which an athlete's movements (i.e. the spatiotemporal kinematics) during training compare to competition (Stoffregen, Bardy, Smart, & Pagulayan, 2003). High action fidelity exists when an athlete's movements are the same in training as in competition, and the higher the action fidelity between a training drill and

competition, the higher the magnitude of skill transfer (Araújo, Davids, & Passos, 2007; Pinder, Davids, et al., 2011b). Providing more opportunities for passes (i.e., passing to 1, 2, 3 or 4 teammates) in a futsal training drill resulted in increased action fidelity to competition; the correspondence of passing accuracy, ball speed and regularity of passes increased as the number of teammates that could receive a participant's pass increased (Travassos, Duarte, et al., 2012). This study showed how the manipulation of task constraints in training can encourage the emergence of behaviour required during competition.

Together, these studies highlighted how athletes' behaviour in training often differs to the behaviour required in competition, which presumably decreases the potential for transfer. Furthermore, they highlight how task constraints can be modified to elicit different behaviours, in turn, promoting transfer of skill to competition. This suggests that practitioners have a powerful tool in task constraint manipulation to encourage functional adaptations in their athletes. The next section presents research that has evaluated how behaviour emerges when task constraints are manipulated in sport tasks.

2.4.2 Task-constraints manipulation and behaviour

The properties of sport equipment, for example ball mass and racquet length can be modified, and modifications have been suggested to facilitate the emergence of functional movements (Araújo et al., 2004; Farrow et al., 2016). Table 2.1 presents the results of studies that evaluated the acute impact of modified equipment on individuals' behaviour. These experiments mainly assessed skill performance in relatively novice children and, in general, showed that modified equipment promoted higher skill accuracy and more opportunities for action when it was scaled to the children's characteristics, namely when it was lighter and/or smaller than adult size (Buszard et al., 2016b). Results were consistent when different sports and skills were examined; for example, basketball shooting (Arias, 2012; Arias, Argudo, & Alonso, 2012b; Chase, Ewing, Lirgg, & George, 1994; Satern, Messier, & Keller-McNulty, 1989; Szyman, Ito,

Garner, Munoz, & Reed, 2014) and tennis striking (Buszard, Farrow, Reid, & Masters, 2014a; Kachel, Buszard, & Reid, 2015; Larson & Guggenheimer, 2013; Timmerman et al., 2015). Similarly, ball speed was higher when adult woman footballers performed shots using a smaller and lighter ball relative to the standard one (Andersen et al., 2016). Together, this research highlighted that modified equipment influenced individuals' behaviour and, when scaled to an athlete's characteristics, facilitated the performance of a sport skill, which is likely to promote skill learning.

Table 2.1 *Results of studies that examined the acute effects of equipment modification on athletes' behaviour.*

<i>(Reference)</i>	<i>Equipment modification</i>	<i>Participants</i>	<i>Effect on behaviour compared to standard equipment</i>
(Szyman et al., 2014)	Basketball size and mass	Children	Higher shooting accuracy in a free-throw test when basketballs were smaller and lighter.
(Arias, 2012)	Basketball mass	Children	Higher shooting accuracy during games when basketball was lighter.
(Arias, Argudo, & Alonso, 2012a)	Basketball mass	Children	Higher number of passes, pass receptions and dribbles during games with lighter basketball
(Arias et al., 2012b)	Basketball mass	Children	Higher shooting accuracy and higher number of shots during games with lighter ball
(Arias, Argudo, & Alonso, 2012c)	Basketball mass	Children	Higher number of one-to-one situations during games with lighter ball
(Chase et al., 1994)	Basketball size and basket height	Children	Higher shooting accuracy in a free-throw test with lower basket height; no effect of basketball size on shooting
(Satern et al., 1989)	Basketball size and basket height	Children	Shooting trajectory was affected by basket height but movement kinematics was not affected
(Timmerman et al., 2015)	Tennis court dimension and net height	Children	Lowering the net resulted in higher number of skills and shot accuracy during rallies

(Kachel et al., 2015)	Tennis ball compression	Children	Increase in technique fluency and shot speed with lower compression ball during matches
(Larson & Guggenheimer, 2013)	Tennis ball compression and court dimension	Children	Performance of a skill test was higher with lower ball compression and shorter court
(Buszard et al., 2014a)	Tennis ball compression and racquet length	Children	Lower compression ball and smaller tennis racquet led to higher shot accuracy and technique fluency in a lab-based test
(Andersen et al., 2016)	Soccer ball size	Female adults	Ball peak velocity was higher with a smaller and lighter ball in a lab-based test; no difference between balls in game

Modified games, in particular small-sided games (SSG), are widely used in sport as training stimuli to foster the development of a player's skills (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). The dimensions of the court, number of players involved in the game, and rules can be modified to manipulate how task-relevant affordances emerge and, in turn, encourage the development of skills that transfer to competition (Davids, Araújo, Correia, & Vilar, 2013). Table 2.2 presents results of previous research that has evaluated how acute changes of task constraints in SSGs have influenced an athlete's skill accuracy and opportunities for action. A reduction in court dimension and number of players promoted more opportunities for action in soccer (Almeida, Ferreira, & Volossovitch, 2013; Kelly & Drust, 2009; Owen, Wong, McKenna, & Dellal, 2011) and basketball (Conte, Favero, Niederhausen, Capranica, & Tessitore, 2016) SSGs. Furthermore, soccer passing accuracy decreased as rules became restrictive, from free touches to a 1-touch rule (Dellal, Lago-Penas, Wong, & Chamari, 2011) and when the surface was unfamiliar, sand vs turf (Rago, Rebelo, Pizzuto, & Barreira, 2016).

Table 2.2 *Results of studies that examined the acute effects of task-constraints modification on skill performance and opportunities for action during small-sided games.*

(Reference)	<i>Constraint modification</i>	<i>Effect on behaviour</i>
(Kelly & Drust, 2009)	Pitch dimension: Soccer 4v4 on small (30x20m), medium (40x30m) and large (50x40m) pitches	Number of skill executions (e.g., shots and tackles) increased as dimension of the pitches decreased
(Elliott, Plunkett, & Alderson, 2005)	Pitch length: Cricket bowling on standard (20.12m), medium (18m) and short (16m) pitches	Bowling accuracy increased as length of the pitches decreased
(Owen et al., 2011)	Number of players: Soccer 3v3 and 9v9	Higher individual involvements with the ball (e.g., pass and dribbles) in 3v3 relative to 9v9
(Conte et al., 2016)	Number of players: Basketball 2v2 and 4v4	Players executed a higher number of skills in 2v2 than 4v4
(Almeida et al., 2013)	Number of players: Soccer 3v3 and 6v6	Higher number of skill executions in 3v3 compared to 6v6
(Harrison, Gill, Kinugasa, & Kilding, 2013)	Number of players: Soccer 3v3, 4v4 and 6v6	Players' involvement with the ball increased as number of players decreased
(Dellal et al., 2011)	Rules: Soccer 4v4 with 1 touch, 2 touches and free-touches rules	Pass accuracy decreased from free-touches to 1 touch rule.
(Rago et al., 2016)	Surface: Soccer 5v5 in sand and turf surface	Passing accuracy was higher when games were played on a turf pitch than a sand pitch.

The ecological dynamics framework advocates the analysis of an individual's behaviour on a performer-environment scale (Davids et al., 2012). In this context, the behaviour of players during SSGs is conceptualised as a dynamical system where a team's

behaviour emerges from the self-organisation of players' interactions under task and environmental constraints (Araújo et al., 2006; Vilar et al., 2012). Following this approach, the spatiotemporal relationship between players is analysed considering variables such as i) the area occupied by a team (effective playing space, EPS), ii) the shape of the area occupied by a team (playing length per width ratio, PLpW) (Silva, Duarte, et al., 2014), iii) the distance between a team and another team or a goal (Silva, Garganta, Vilar, Araújo, & Davids, 2016), iv) the regularity of players' behaviour (i.e., the degree of regularity in a team's behaviour variable over different phases of a game, such as attacking or defending phases) (Torrents et al., 2016), and v) the exploration of different movement solutions (exploratory behaviour) (Ric et al., 2016).

Results of studies that have adopted this approach in evaluating the acute effect of manipulating task constraints in SSGs are presented in Table 2.3. In summary, a reduction in pitch dimensions and number of players resulted in a decrease of playing area, regularity of players' behaviour and opportunities to maintain ball possession (Aguilar, Gonçalves, Botelho, Lemmink, & Sampaio, 2015; Silva, Garganta, Santos, & Teoldo, 2014; Silva, Duarte, et al., 2014; Vilar, Duarte, Silva, Chow, & Davids, 2014). Increasing the number of opponents, from 4v3 to 4v7 and from 5v3 to 5v5, resulted in teams decreasing inter-player distance and shifting towards their own goal (Silva, Travassos, et al., 2014), with the defending players performing more visual exploratory behaviours to perceive the higher number of opponents (Ric et al., 2016; Torrents et al., 2016). Similarly, an increase in the number of targets, from 2 goals to 6 small goals, encouraged a more efficient use of the space with a higher exploration of the pitch areas to score goals in the additional targets (Travassos et al., 2014).

Table 2.3 *Results of studies that examined the acute influence of task-constraints modification on inter-personal coordination during small-sided games.*

(Reference)	<i>Constraint modification</i>	<i>Effect on inter-personal coordination</i>
(Silva, Duarte, et al., 2014)	Pitch dimension: Soccer 5v5 on small (36.8x23.8m), medium (47.3x30.6m) and large (57.8x37.4m) pitches	Effective playing space and team separateness increased when field dimension increased. The playing shape was more elongated in medium and large pitches than the small pitch. Regularity of players' behaviour increased with increase of pitch dimension
(Vilar, Duarte, et al., 2014)	Pitch dimension: Soccer 5v5 on small (28x14m), medium (40x20m) and large (52x26m) pitches	More opportunities to maintain ball possession as pitch dimension increased
(Silva et al., 2016)	Individual playing area: Soccer SSG with 168 m ² (3v3), 126m ² (4v4) and 101 m ² (5v5)	EPS of both teams increased as individual playing area decreased but other behaviour parameters remained similar, indicating that players' dispersion increased to keep similar tactical behaviours
(Aguiar et al., 2015)	Number of players: Soccer 2v2, 3v3, 4v4 and 5v5	Inter-player distance and regularity of behaviour increased as number of players increased
(Silva, Garganta, et al., 2014)	Number of players: Soccer 3v3 and 6v6	3v3 promoted actions that tended to rupture the defensive line leading to 1v1 duels, while 6v6 encouraged collective team actions to beat opponents. 3v3 encouraged more aggressive behaviour, while 6v6 encouraged safer behaviour.
(Silva, Travassos, et al., 2014)	Numerical relation: Soccer 5v5, 5v4 and 5v3	Exploratory behaviours and playing space increased as one of the teams 'lost' players (5v5 to 5v3).
(Torrents et al., 2016)	Numerical relation: Soccer 4v3, 4v5 and 4v7	An increase in the number of teammates (from 3 to 7) promoted more offensive patterns and regularity of behaviour, while an increase in the number of opponents led to a decrease in offensive actions and exploration of defensive and offensive behaviour.
(Ric et al., 2016)	Numerical relation: Soccer 4v3, 4v5 and 4v7	An increase in number of opponents increased players' breadth of attention to perceive the opponents' behaviour.

(Travassos et al., 2014)	Number of targets: Soccer 5v5 with 2 goals and 6 targets	An increase from 2 to 6 targets promoted higher between-team distance, higher playing space, higher exploration of pitch zones, and higher breadth of attention to perceived additional targets.
(Bredt et al., 2018)	Rules: Basketball 3v3 in full pitch and half pitch, and reduced-clock rule	The reduced-clock rule resulted in players seeking and creating more opportunities for ball dribbling than the other two conditions.

This large number of studies have provided evidence on how different information-movement couplings emerge when equipment, rules, player number and pitch dimensions are modified. Furthermore, inter-player coordination and individuals' exploratory behaviour emerged as a function of the manipulated constraints, indicating that individuals modified their behaviour in response to the different situations. While these studies provided relevant information on how the modification to certain task constraints influences an individual's behaviour, they did not examine how these behavioural changes would promote the learning or transfer process. Furthermore, these studies primarily assessed the outcome of a movement or inter-player dynamics, and did not directly assess how the perceptual behaviour supported changes in movement outcome.

While none of the studies discussed in this section evaluated transfer, some studies showed how manipulating the number of players and pitch dimensions encouraged exploration of different movement solutions (Ric et al., 2016; Torrents et al., 2016; Travassos et al., 2014), which has been suggested to promote skill transfer (Pacheco & Newell, 2015). The next section discusses how perceptual-motor exploration could promote transfer of skills.

2.4.3 Task-constraints manipulation and perceptual-motor exploration

Practice has been conceptualised as a continuous search for movement solutions through the perceptual-motor workspace (Newell, 1991). It has been recently shown how task constraints

that encourage exploration of the perceptual-motor workspace in a virtual object-projection task facilitated transfer to a novel task (Pacheco & Newell, 2015). Pacheco and Newell (2015) defined exploration as the number of different types of movement performed during the task. Similarly, in sport, studies have provided preliminary evidence on the relation between task constraints and perceptual-motor exploration, and the role of exploration in facilitating skill transfer (Bennett et al., 1999; Seifert, Boulanger, Orth, & Davids, 2015).

Practicing one-handed catching with restricted vision facilitated positive transfer to full-vision catching; authors speculated that the restriction of vision encouraged participants to visually explore and attune their attention to the key information that specified task-relevant affordances to accurately catch a ball, which then promoted transfer to full vision (Bennett et al., 1999). Seifert et al. (2015) directly measured perceptual-motor exploration during an indoor climbing task, and showed that modification of hold orientations promoted exploration of movement solutions. However, when the first session and transfer task were compared, time of ascent did not improve, which suggested that transfer of performance did not occur. While more research on this topic is needed, these two studies suggest that the manipulation of task constraints can encourage perceptual-motor exploration, which, in turn, could promote skill transfer in sport.

The results of the studies presented in this section provided insights into the mechanisms that might facilitate transfer when task constraints are modified. In this context, modified equipment that facilitates the execution of a skill has been shown to promote the development of skill automaticity (Buszard, Farrow, Reid, & Masters, 2014b), which has been suggested to promote transfer (Bebko, Demark, Im-Bolter, & MacKewn, 2005; Stefanidis, Scerbo, Montero, Acker, & Smith, 2012). While further research in sport is required, this research suggests that task-constraints modification might promote skill transfer through perceptual-motor exploration and skill automaticity.

The next section presents research that has assessed how task constraints directly influence perceptual skill.

2.4.4 Task-constraints manipulation and perceptual behaviour

While the majority of research has focused on measuring the outcome of a skill, a limited number of studies has directly assessed how perceptual behaviour supporting a sport skill is influenced when task constraints are modified. Changes in eye movements associated with modifications to the number of players and the participants' distance to the ball have been assessed in lab-based soccer tasks (Roca, Ford, McRobert, & Williams, 2013; Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007). An increase in the number of players and in the number of opponents (e.g., a 3v2 condition) contained within the video stimuli presented resulted in an increase in number of visual fixations and number of fixation alternations respectively (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). Furthermore, soccer players had a higher number of fixations when anticipating a ball that was placed in the far half of the pitch (in a video) relative to the close half of the pitch (Roca et al., 2013). If the far- and close-ball conditions are considered as large and small pitch dimensions respectively, these results suggest that an increase in pitch dimensions could encourage an increase in number of visual fixations.

The pattern of eye movements employed by soccer goalkeepers was shown to differ when they responded to video simulations or to an actual opponent (in situ), with a higher number of fixation locations in the in situ condition (Dicks, Button, & Davids, 2010). This study showed how de-coupling perception and action and the representativeness of task-constraints interaction influence an individual's eye movements. Panchuk, Farrow, and Meyer (2014) assessed changes in eye movements associated with equipment modification using a golf representative task, showing a slight increase in quiet eye (i.e., last fixation before movement initiation) when vision was restricted during golf putting.

Despite providing evidence that task constraints influence perceptual skill, these studies were limited to acute changes and they did not examine the learning and transfer process. The next section presents experiments that evaluated the influence of task constraints on skill learning and transfer.

2.4.5 Task-constraints manipulation and transfer of learning

Longitudinal studies have investigated the influence of equipment modification on learning handball (Skoufas, Stefanidis, Michailidis, & Bassa, 2003) and tennis (Buszard et al., 2016a; Elliott, 1981; Farrow & Reid, 2010; Hammond & Smith, 2006) skills. Equipment was modified in different ways, including a reduction in ball mass and compression, and reduction in racquet size and mass relative to the standard equipment. Overall, research has showed that equipment scaled to the participants' physical characteristics (i.e., being lighter and/or smaller for children and novices) facilitated the development of handball shooting speed (Skoufas et al., 2003), and technical fluency in tennis (Buszard et al., 2016a; Elliott, 1981; Hammond & Smith, 2006). Similarly, a reduction in court dimensions promoted the development of children's technical proficiency and increased hitting opportunities in tennis (Farrow & Reid, 2010). This research showed how practicing a skill with different equipment and playing area influenced the learning process, and the results are in line with results of acute studies (discussed in the previous section), namely when the modified task constraints facilitated skill execution learning was facilitated. These studies were limited to the learning process and they did not include a transfer task.

The practice tasks of these studies coupled perception and action (e.g., a tennis rally between 2 players) but the assessment tasks of most studies, with the exception of Farrow and Reid (2010), de-coupled perception and action. For example, participants hit a tennis ball, manually delivered to them by an experimenter, towards a static target on the ground (Buszard et al., 2016a). Conversely, Farrow and Reid (2010) used a tennis rally as vehicle to assess

participants' skill learning and showed an increased volume of strikes in the post-test, which suggests that scaled task constraints improved participants' ability to couple perception of affordances and execution of action.

While the above research focused on learning, a limited number of studies directly evaluated the impact of task constraints on transfer of football (Button, Bennett, Davids, & Stephenson, 1999; Chapman, Bennett, & Davids, 2001; Raastad, Aune, & Tillaar, 2016), tennis (Coldwells & Hare, 1994) and volleyball (Pellett et al., 1994) skills. In soccer, two groups of novices that trained their juggling skills for 24 sessions with either a small- or large-size ball performed similarly in a transfer task using a medium-size ball, indicating similar benefits of using one or the other ball (Raastad et al., 2016). The lack of a control group (i.e., practicing with the medium-sized ball) in this study limited possible conclusions on skill transfer from modified to standard equipment. Similarly, two other studies examined the transfer of juggling and dribbling skill from a modified football (i.e., smaller with a lower coefficient of restitution) to the standard football showing contrasting results. While Button et al. (1999) showed positive transfer of juggling skill in youth beginners, Chapman et al. (2001) found similar performance between the experimental and control group. As such, it is unclear whether learning juggling skill with a modified ball transfers to the standard football.

Practicing a modified version of tennis, with smaller racquet, foam ball and on a shorter court, for 20 hours promoted children's transfer of technical proficiency to the standard tennis as they outperformed the control group, who practiced the standard version of tennis (Coldwells & Hare, 1994). However, the authors did not control for the amount of skills performed in the two groups during training, which might have potentially influenced the results. The influence of ball mass on transfer of volleyball skills was evaluated in young students, and results showed that participants who practiced with a lighter ball outperformed a

control group in volleyball games using the standard ball, hence they positively transferred the learned skills (Pellett et al., 1994).

These studies showed contrasting results on the benefits of task-constraints manipulation in facilitating transfer of skills (in general), and none of them directly assessed transfer of perceptual skill. Furthermore, most studies de-coupled the typical perception and action of the examined sports, e.g., dribbling cones in football (Button et al., 1999) and hitting a tennis ball towards the wall (Coldwells & Hare, 1994). Only Pellett et al. (1994) coupled perception and action in volleyball games, and provided insights into the effect of task constraints on transfer of functional information-movement coupling. After training with a lighter ball, participants transferred their ability to perform sets which coupled perception of teammates' behaviour and skill execution. This might suggest that modified equipment that facilitates the execution of a skill could promote the transfer of perceptual skill to the standard equipment. Furthermore, it shows how task-constraints modification might improve transfer of skill between tasks that present similar information, given that the only difference between practice and transfer was the ball. Despite preliminary evidence on the relation between task constraints and transfer of information-movement couplings, it is currently unknown how task constraints affect the transfer of perceptual skills.

In summary, the constraints-led approach contends that constraints impinging on individuals influence the emergence of behaviour and, over time, the development of perceptual skill. Current evidence on this issue is mainly limited to the acute effects of task-constraint manipulation on physical aspects of performance, while a limited number of studies directly showed acute changes in attentional processes and changes in teams' behaviour, which indirectly provides information on affordance perception. As such, it is currently unknown how task constraints impact the development of perceptual skill in sport. The constraints-led

approach also argues that skills, developed with a set of constraints, would transfer to other sets of constraints that require similar behaviour, and similarity of information between practice and the transfer task is expected to promote the transfer process. A very limited number of studies have investigated this issue, focussing on the physical aspect of performance. As such, in addition to a lack of studies on learning, it is currently unknown how practicing with different task constraints influences transfer of perceptual skill.

This thesis examines how task constraints influence the development and transfer of perceptual skills using futsal and soccer as vehicle. Futsal and soccer are two forms of football that share many similarities, but their respective task constraints differentiate them. Hence, the different task constraints are expected to promote individuals' attunement to different perceptual information. While the similarities are expected to facilitate skill transfer between the two sports, the differences are expected to impact the magnitude of transfer. The next section presents the differences and similarities of futsal and soccer in detail.

2.5 Futsal and soccer

Futsal and soccer are two forms of football officially regulated by the Fédération Internationale de Football Association (FIFA). On a macro level, the two sports are very similar as they are invasion sports where the ball is only handled with the feet (except the goalkeeper) on a rectangular pitch and the aim is to score more goals than the opponents (Figure 2.1). Outside of the similarity in these rules, the two disciplines are characterised by different task constraints, including: ball properties, pitch surface and dimensions, number of players and specific rules (Table 2.4). These different task constraints are predicted to influence the emergence of opportunities for action and, in turn, the development and transfer of perceptual skill.

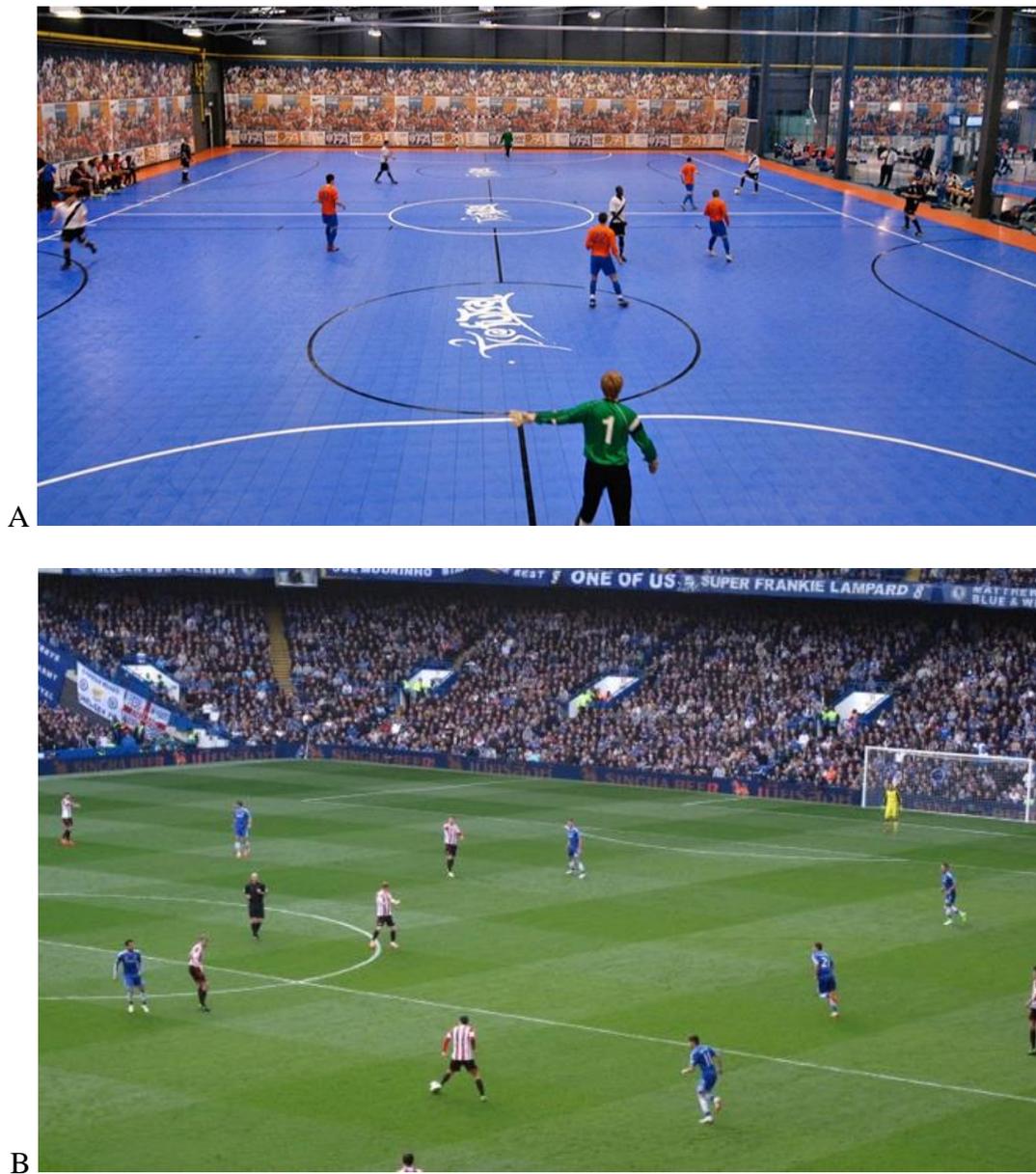


Figure 2.1 Futsal (A) and soccer (B).

This thesis focuses on the perceptual behaviour underpinning passing, given that it is the main skill performed in both sports (Liu, Gomez, Goncalves, & Sampaio, 2016; Mohammed, Shafizadeh, & Platt, 2014; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009), and couples perception and action. Passing is a complex perceptual-motor skill which involves the reception of the ball and a pass towards a teammate. The passing skill emerges from the interaction of a passer with their environment and the characteristics of the task, whereby perception, decision-making, and the passing action are intertwined and support the

passing skill. A successful pass entails perceiving key information that specifies passing-relevant affordances and organising a functional kicking action to successfully kick the ball to the intended player. Passing affordances emerge from the interaction of the various players on the pitch, the location of the ball, and a player's position on the pitch (Corrêa et al., 2014a; Travassos, Araújo, Davids, Esteves, & Fernandes, 2012; Travassos, Araújo, Davids, Vilar, et al., 2012). Given the coupling of perception and action, the passing skill is suitable for the evaluation of how the perceptual behaviour underpinning a perceptual-motor skill develops and transfers to different task constraints.

Table 2.4 Similarities and differences in task constraints between futsal and soccer.

<i>Similarities</i>	<i>Task constraint</i>	<i>Differences</i>		
		<i>Futsal</i>	<i>Soccer</i>	
	<i>Number of players</i>	5 vs 5	11 vs 11	
Rectangular	<i>Pitch</i>	Dimension (m)	40 x 22.5	100 x 65
		Surface	Flat, hardwood or synthetic material	Natural or synthetic grass
	<i>Individual playing area</i>	90 m ² /player	295 m ² /player	
Sphericity	<i>Ball</i>	Circumference (cm)	62.5 – 63.5	68.5 – 69.5
		Weight (gr)	410 – 430	420 – 445
		Coefficient of restitution (AU)	0.5 – 0.57	0.82 – 0.88
		Height of first bounce from a 2-m drop (cm)	55 – 65	135 – 155
Invasion sport Ball handled only with feet	<i>Rules</i>	Offside	No	Yes
		Substitution	Unlimited and rolling	Max 3 substitution
		Body contact	Limited	Allowed
		Accumulated fouls	No slide tackles Penalty after the 6 th foul	Unlimited

2.5.1 Task constraints and perceptual behaviour underpinning passing

The interaction of the sport-specific task constraints is expected to affect the perceptual behaviour underpinning passing and the context in which passes are performed in the two sports (Travassos et al., 2017; Yiannaki, Carling, & Collins, 2018). Relative to soccer, futsal's accumulated fouls and limited body-contact rules should encourage lower 'physicality' when attempting to gain possession of the ball and promote, instead, more team coordinated movements to quickly cover potential passing options. Furthermore, the futsal's rolling-substitution rule allows infinite substitutions (as opposed to the 3-substitution limit in soccer), and is likely to reduce accumulated fatigue in futsal, leading to a higher game intensity in futsal than soccer. The constant high-intensity running during both attacking and defending is one of futsal's defining characteristics (Castagna, D'Ottavio, Granda Vera, & Barbero Alvarez, 2009), while periods of high-intensity running are interspersed with periods of low intensity in soccer (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009). It has been shown that attackers need to move quicker than their direct opponent to create goal scoring opportunities in futsal, which highlights the high movement demands of futsal (Vilar, Araujo, Davids, et al., 2014).

These continuous and rapid movements of players in futsal lead to a constant emergence of passing opportunities that last just for the 'blink of an eye' (Corrêa et al., 2014a). The timing of passing affordances and the low individual playing area in futsal, which creates high pressure from the direct opponent, suggests that players need to attune their attention to the affordances that emerge when, or potentially before, they control the ball. The futsal ball's low coefficient of restitution, which reduces its bounce, coupled with the flat playing surface is likely to result in a regular, predictable trajectory of the incoming ball. This also means the futsal ball 'sticks' to the foot when controlled which facilitates ball control (Araújo et al., 2004). The regularity in ball behaviour and relative easiness of ball control could facilitate the orientation of a

player's attention towards other players' behaviour, to perceive passing affordances, during and/or before ball control.

In soccer, passes are likely to be performed with lower pressure from a direct opponent (due to the higher individual playing area) and the incoming ball is likely to have a more irregular trajectory (due to the higher coefficient of restitution and potential irregularity of the playing surface), relative to futsal. Furthermore, the coefficient of restitution of the soccer ball might make ball control more difficult than futsal. Together, this might suggest that soccer players direct their attention primarily to the coming ball, given the potentially irregular trajectory, and visually scan other players' behaviour after the ball is controlled, as the low opponent pressure would allow to do so. Furthermore, soccer players are required to attune their attention towards a larger number of players than futsal.

In summary, the same skill, passing, is performed in both futsal and soccer. However, the sport-specific task constraints are predicted to influence how the passing skill and the perceptual behaviour supporting it emerge in the two sports. The futsal task constraints are expected to encourage players to attune their attention towards other players' behaviour before or during ball control to perceive passing affordances, while soccer task constraints might promote players' attunement to the ball before ball control and towards other players' behaviour after ball control. To-date, no study has examined this issue and it is unknown how futsal and soccer task constraints influence the perceptual behaviour underpinning passing.

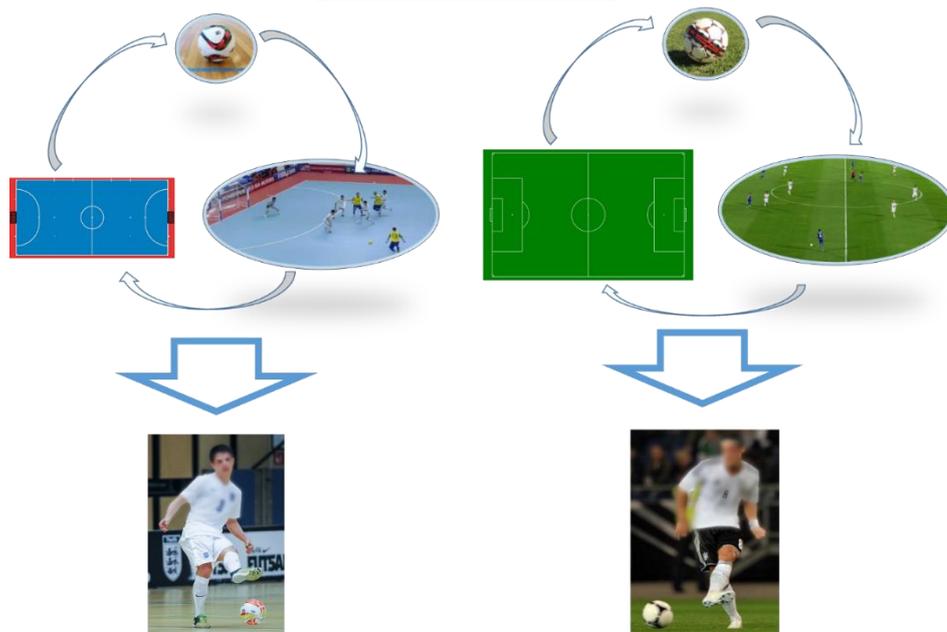


Figure 2.2 Schematic representing the interaction of constraints, e.g., ball, surface and individual playing area, when passing in futsal (left side) and soccer (right side) that are expected to influence perceptual behaviour underpinning passing.

2.5.2 Task constraints and transfer

Passing affordances and the passing action emerge similarly in futsal and soccer. In both sports, opportunities for passes emerge from the interaction of a passer's position in the pitch (proximity to the ball, to its own goal, and to the opponent's goal), other players' position, between-players' distance, and players' movements (Corrêa et al., 2014a; Corrêa, Vilar, Davids, & Renshaw, 2014b; Correia et al., 2012; Travassos, Araújo, Davids, Esteves, et al., 2012). Information about these relationships, such as distance, angles, and speed of movement (Travassos, Araújo, Davids, Vilar, et al., 2012; Vilar, Araujo, Travassos, & Davids, 2014) specify what types of passes a game context affords. For example, I can pass the ball to my teammate 'A' if his direct opponent is not close enough to him to intercept the ball, and other players are not positioned in the pass trajectory. Furthermore, the passing action emerges from the self-organisation of the lower-limb segments in both sports. Typically, a player's knee

flexion and hips extension are followed by a knee extension and hips flexion throughout a pass. These similarities in the coupling of passing affordance perception and kicking action should promote transfer of the passing skill and perceptual behaviour between soccer and futsal.

The sport-specific task constraints are expected to influence the magnitude of skill transfer between the two sports and how the perceptual behaviour supports the transfer process. As previously discussed, passing in futsal is performed in a smaller area, with shorter time to act, and with a ball that is relatively easier to control. The landscape of passing affordances in futsal is highly unpredictable (Corrêa, Alegre, Freudenheim, Dos Santos, & Tani, 2012) and changes continuously due to the high-intensity movements of players (Corrêa et al., 2014a). In theory, these futsal task constraints should encourage players to quickly adapt to sudden changes of constraints during a game. Given that the ability to adapt a behaviour to a different set of constraints underpins transfer, futsal task constraints should promote transfer to soccer. In addition, equipment that facilitates the execution of a skill, such as the futsal ball encourages skill automaticity (Buszard et al., 2014b), which has been suggested to promote transfer (Bebko et al., 2005; Stefanidis et al., 2012). Together, this might suggest that futsal task constraints could facilitate a higher magnitude of skill transfer to soccer, than vice-versa.

Anecdotal evidence suggests that futsal task constraints fast-track the development of perceptual skill that positively transfers to soccer. Many elite soccer players and coaches stated that futsal is extremely beneficial in developing ‘intelligence’ and decision-making skills that can enhance soccer performance (FIFA, 2012). For example, Neymar (currently one of the most valued and talented soccer players) said ‘futsal helps a lot (soccer performance) because you need to think quickly. It’s a more dynamic game... and today, in Europe, there’s not much space so you need to think quicker and futsal has helped me a lot with that (UEFA, 2014)’. Similarly, Dani Alves (a Paris Saint Germain soccer player) stated ‘...what futsal can give you is intelligence and a way of thinking. Why? Because you have a small limited space, man

marking is very used there. So you have to be intelligent, you have to be very quick in thinking and in moving... if somebody is successful in futsal, he can be successful in football as well (UEFA, 2014)'. While this anecdotal evidence and previous research (Travassos et al., 2017; Yiannaki et al., 2018) suggests there is potential for higher magnitude of transfer from futsal to soccer than vice-versa, research has not yet tackled the soccer-futsal relationship. As such, it is unknown how futsal and soccer task constraints influence the transfer of perceptual behaviour between the two sports.

The next five chapters present experiments that examine how the task constraints of futsal and soccer influence the emergence of passing affordances, the development of perceptual behaviour, the transfer of passing skill, and how perceptual behaviour supports transfer.

CHAPTER 3

PILOT STUDY. FUTSAL – SOCCER DIFFERENCES IN PASSING DURING ELITE MATCHES

3.1 Introduction

Passing is a key skill for successful performance in team sports (Rein, Raabe, & Memmert, 2017). Passing is the means of interaction between teammates to build offensive sequences with the aim of creating scoring opportunities (Grund, 2012), and a team's ability to create an efficient passing network is linked to successful performance (Cotta, Mora, Merelo, & Merelo-Molina, 2013; Sarmiento et al., 2017). Passing is a complex perceptual-motor skill that involves making a decision on where to pass the ball to and executing a pass towards a teammate. Here, the passing skill is considered as combination of reception and delivery of the ball and athletes need to perceive information about other players' movement to guide the decision-making process, and about the ball to organise ball control and pass.

Passing is a key skill in two forms of football, namely futsal and soccer. Futsal is the 5-a-side indoor form of football (played on a 40 x 22.5 m hardwood pitch), whereas soccer is the 11-a-side outdoor form of football (played on a 100 x 65 m grass pitch). Passing is the most performed skill during games (Liu et al., 2016; Mohammed et al., 2014; Rampinini et al., 2009) and it has been shown to differentiate skilled from less-skilled players in both sports (Naser & Ali, 2016; Wen, Robertson, Hu, Song, & Chen, 2017). Despite being performed with the feet in both domains, the different task constraints of futsal and soccer likely influence how passes are performed during games.

Passing in futsal is performed in a dynamic environment where the high-intensity movements of players continuously create opportunities for passes (affordances) that quickly vanish (Corrêa et al., 2014a), with high pressure from the direct opponent due to a low individual playing area, and with a ball that is easier to handle, due to a low coefficient of restitution (Araújo et al., 2004). Relative to futsal, passing in soccer is performed with lower pressure from the direct opponents and alternations of high-intensity and low-intensity game periods, with a ball that is more difficult to handle, and with a higher number of possibilities

for passes (i.e., 10 teammates). As such, futsal task constraints might encourage players to execute quick passing, which would imply making quick decisions, while soccer task constraints might promote slower execution of passing to scan all the different passing opportunities. To-date, no study has compared the passing skill between soccer and futsal, and the differences that might emerge from sport-specific task constraints are unknown.

The aim of this pilot study was to explore how futsal and soccer players performed passes during games. Execution time, from reception to pass, and pass accuracy of elite futsal and soccer players was compared. It was hypothesized that futsal players would be quicker in the action of controlling and passing the ball than soccer players.

3.2 Method

3.2.1 Apparatus and procedure

A total of 4 elite games of adult futsal (n=4) and soccer (n=4) clubs were sampled for the study. The games were: the 2 semi-finals of the 2015 Union of European Football Associations (UEFA) Champions league in soccer, and the 2 semi-finals of the 2015 UEFA futsal cup, which represent the top international competitions for clubs in Europe in soccer and futsal, respectively. TV-broadcasting videos of the 4 games were directly obtained from UEFA, which held the broadcasting copyright. The videos had a recording frequency of 30Hz.

3.2.2 Data analysis

The full duration of the games (i.e., 90 minutes in soccer and 40 minutes in futsal) was considered for the analysis. Passing execution time, pass accuracy and the frequency of passes were evaluated.

Passing execution time. The passing execution time was coded using a commercially-available video analysis software (Sports Code, SportsTec by Hudl, Australia). Pass onset was set at a player's first contact with the ball, i.e., ball reception, and pass offset was set at the

moment the ball left the foot. Furthermore, passes that were performed without control of the ball were coded as direct passes (as there was no time between reception and pass).

Pass accuracy. A pass was considered accurate when the ball reached a teammate (i.e., the teammate made contact with the ball before any opponent) and ball possession was retained.

Distribution of passes. Each pass was categorised into one of three categories, direct, one touch and held. *Direct pass* refers to a pass that did not include the reception of the ball, *one-touch pass* includes reception and pass only, without any touch in between, and *held pass* includes different ball touches between ball control and delivery. Each category was analysed as percentage of the total number of passes.

Player's actions that resulted in a shot or a dribble were not coded. A total of 1598 and 1579 passes were coded and analysed in soccer and futsal, respectively.

3.2.3 Statistical analysis

Execution time of one-touch and held passes, pass accuracy and the distribution of passes were analysed separately using an independent t-test for the two groups, futsal and soccer. Significance was set at $p < 0.05$ and the magnitude of changes was assessed using effect sizes (Cohen's d) and defined as follows: <0.2 trivial, $0.2-0.6$ small, $0.6-1.2$ moderate, $1.2-2.0$ large, >2.0 very large (Hopkins, 2010a).

3.3 Results

There was a significant between-groups difference in passing execution time in one-touch passes ($p < 0.01$, $d = 0.35$) and held passes ($p < 0.01$, $d = 0.30$). Futsal players performed quicker passing than soccer players (Figure 3.1A). There was a near-significant group difference in pass accuracy in one-touch passes ($p = 0.1$, $d = 1.9$) and a significant group difference in pass accuracy in held passes ($p < 0.05$, $d = 2.5$), while there was no difference in direct passes. Futsal players performed more accurate one-touch and held passes than soccer

players (Figure 3.1B). Furthermore, there was a significant group difference in the frequency of direct passes ($p < 0.01$, $d = 7.8$) and one-touch passes ($p < 0.01$, $d = 8.3$). There was no group difference in held passes. Futsal players performed a lower number of direct passes but more one-touch passes than soccer players (Figure 3.2).

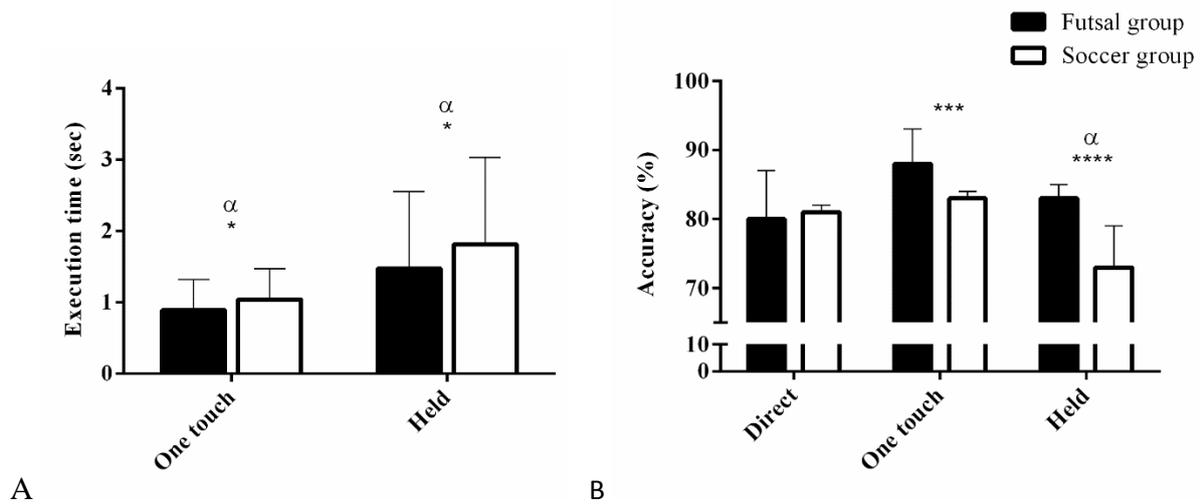


Figure 3.1 Mean passing execution time (A) and mean pass accuracy (B). α : statistically significant, effect sizes: *small, **moderate, ***large, ****very large. Error bars represent ± 1 SD from the mean.

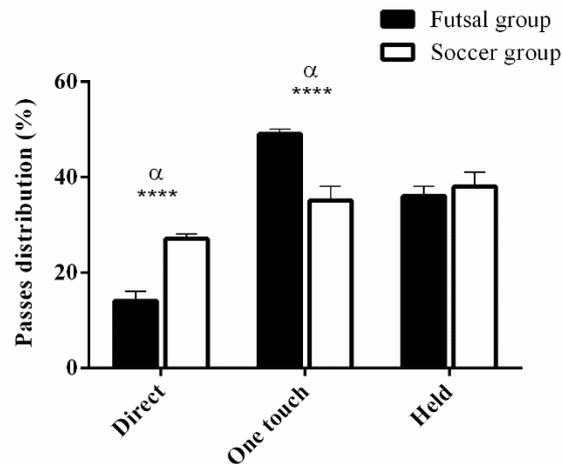


Figure 3.2. Mean frequency of direct, one-touch and held passes. α : statistically significant, effect sizes: *small, **moderate, ***large, ****very large. Error bars represent ± 1 SD from the mean.

3.4 Discussion

This pilot study aimed to explore differences in passing performance between futsal and soccer players during games. It was hypothesised that futsal players would be quicker in the execution of ball reception and delivery as a result of the different sport-specific task constraints, as passes in futsal are performed in a more dynamic and demanding environment relative to soccer. The results confirmed this hypothesis as the futsal group was quicker than soccer group in both one-touch and held passes (Figure 3.1). Furthermore, the results showed a trend of higher passing accuracy in the futsal group compared to the soccer group, and differences in the frequencies of the three types of passes, with futsal players performing fewer direct passes and more one-touch passes. The fact that futsal players performed quicker and more accurate passes does not necessarily mean that they were more proficient in the passing skill. It simply indicates that the two groups performed the passing skill differently.

Considering that the players sampled in this study were elite adults who have practiced passing for several years with different constraints, it can be speculated that futsal and soccer task constraints affected the performance (and likely the development) of passing skill. Futsal task constraints, including high pressure from opponent, high game dynamics and an easy to control ball, encouraged players to quickly execute ball control and delivery; while soccer task constraints, including low pressure from opponent, a high number of passing options and a relatively difficult to control ball, promoted a slower execution of passing. Futsal players mainly performed one-touch passes (Figure 3.2) with a higher pass accuracy than the other pass types (Figure 3.1) which might suggest that task-relevant passing affordances in futsal emerge during or right after the ball is controlled (Corrêa et al., 2014a). Soccer players performed more direct passes than futsal players, suggesting that relevant passing affordances in soccer might also emerge before the ball is controlled, and soccer players may need to visually explore the various passing options before making contact with the ball. Furthermore, results showed a decline of pass accuracy in held passes in soccer players (Figure 3.1), suggesting an increase in opponent pressure which reduces the time to perceive task-relevant passing affordances when players took too many touches before passing. Together, these results indicated how passing is performed differently in futsal and soccer games, and suggest that task-relevant passing affordances emerge in futsal and soccer games at different periods of time, which would influence the development of sport-specific information-movement coupling to achieve successful passing.

While the small sample size of this study limits the conclusions on differences in passing performance between futsal and soccer players, this pilot study provided insights into the potential effect of different task constraints on the performance (and development) of a perceptual-motor skill in sport.

The next chapter presents the development and validation of a method to approximate participants' orientation of attention during representative football tasks. This method allows the examination of the effect of futsal and soccer task constraints on perceptual skill underpinning passing to extend the findings of this pilot study.

CHAPTER 4

DEVELOPMENT AND VALIDATION OF A PROXY FOR ATTENTION ORIENTATION MEASUREMENT IN FOOTBALL REPRESENTATIVE TASKS

4.1 Introduction

Eye tracking technology is widely used in psychological research to assess eye movements and provide insights into the processes underpinning human attention and perception (Van Gompel, Fischer, Murray, & Hill, 2007). Human vision can only focus on a small area, approximately two to three degrees of visual angle, and individuals purposefully move the eyes to select the most relevant information sources in the visual array (Vickers, 2007). While attention can move independent of the eyes, gaze shifts are strictly correlated with shifts in attention and the analysis of eye movements is used as proxy for examining attentional processes (Henderson, 2003). As such, eye tracking is often used in sport research to evaluate the distribution of visual attention that underlies sport expertise. For example, expert performers typically adopt different gaze patterns during decision-making tasks relative to non-experts (Williams et al., 1999). Furthermore, changes in perceptual skill underpinning the development of sport skills can be evaluated through the assessment of an individual's gaze behaviour (Panchuk et al., 2015).

Current literature on visual attention underpinning football expertise is potentially constrained by limitations in eye tracking technology that influence the design of experiments. Eye movements of football players have been typically assessed in controlled environments, i.e., laboratory-based experiments, which are removed from the demands of effective context of performance (Vaeyens, Lenoir, Williams, & Philippaerts, 2007; Williams & Davids, 1998). This reductionist approach allows researchers to control for potential confounding variables and to carefully manipulate the stimuli presented to players; however, a trade-off of this approach is that generalization of the results is questionable because the stimuli do not represent the performers' typical environment (Araújo & Davids, 2015; Araújo et al., 2007). In a typical experiment, participants are instructed to make decisions while viewing life size videos that show different patterns of football-specific play, (e.g., attacking or defending

situations; Roca et al., 2013; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). Furthermore, the types of response required are not typical of a football game, and can include: verbalization (Roca, Ford, McRobert, & Williams, 2011), mimicking actions (Williams & Davids, 1998), and performing a football action using a stationary ball (Vaeyens, Lenoir, Williams, & Philippaerts, 2007). These experimental constraints do not reflect the sport-specific actions and visual perspective typical of a football game. These issues are known to affect the results of psychological studies and are the result of poor stimuli representativeness and information-movement decoupling (Pinder, Davids, et al., 2011b).

An athlete's behaviour during goal-directed tasks is directly guided by information that emerges from the interaction between the performer and environment (Gibson, 1979). This interaction has to be represented in experiments to properly capture an athlete's behaviour (Farrow & Abernethy, 2003; Pinder, Davids, et al., 2011b). Brunswik (1955) contended that experimental perceptual information should be sampled from the environment the organism usually interacts with and to which the behaviour is intended to be generalized. Generalizing results from experiments that lack in representing environmental information is questionable (Dhimi, Hertwig, & Hoffrage, 2004). Furthermore, the perception of the environment-specific information should be coupled with sport-specific movements (Davids et al., 2001). The visual processing pathways (i.e., ventral or dorsal; van der Kamp et al., 2008) and the patterns of eye movements (Afonso, Garganta, McRobert, Williams, & Mesquita, 2014; Dicks et al., 2010) are different when physically responding to (i.e. perception for action) or just perceiving information (i.e. perception for recognition). As such, it is critical to design experimental tasks that adequately represent the perception-action coupling that athletes typically experience in competition. Despite football researchers acknowledging the importance of overcoming these issues to strengthen findings (Vaeyens, Lenoir, Williams, & Philippaerts, 2007), improvements in the design are challenging due to limitations of eye-tracking technology.

Head-mounted eye trackers allow the assessment of eye movements outside the laboratory; however, gaze assessment during representative tasks that couple perception and action is problematic in football. Considerable improvements have been achieved in penalty kick research (Dicks et al., 2010; Timmis, Turner, & van Paridon, 2014); however, highly-dynamic tasks in an outdoor environment, such as a football game, pose serious challenges to current eye tracking technology. The changes in light reflections and brightness in an outdoor environment limit the eye tracker's ability to capture the reflection of cornea and pupil, which are used to derive the movements of the eyes. In addition, the quick movements of head and body cause vibrations that further impair the detection of eye features, making the computation of the point of gaze and, consequently, the examination of participants' attentional focus unreliable. Here, the development and validation of a new approach of approximating attention orientation to overcome these issues, which uses head orientation to derive the location of the gaze is discussed.

The underlying assumptions of the approach proposed here are that i) individuals tend to direct their gaze to the centre of the environment being viewed (i.e., centre bias) in both laboratory and natural experiments (Foulsham, Walker, & Kingstone, 2011), and ii) head movements assist eye movements in shifting gaze between locations during unconstrained daily tasks (Freedman, 2008). Given this tendency it is reasonable to assume that head orientation can predict where the gaze is directed (Nakashima et al., 2015) and could then act as a proxy for examining attentional processes due to the partial-interdependence of attention and eye movements. In this context, Pluijms et al. (2016) validated a method to quantify the external focus of attention using head orientation by means of an eye-tracker scene camera. Despite being a very useful approach for coaches and practitioners as inexpensive action cameras can be used and the coding procedure is less time-consuming, the method presents some limitations. The gaze location was derived by coding the centre of the scene image,

presumably drawn from the centre bias issue; however, the dimension of the ‘centre’ was not specified and the procedure was not specifically designed for the examined task, which makes difficult to replicate the method in a football context.

The present paper outlines the development and validation of a rigorous approach to obtain a player’s orientation of attention underpinning the passing skill during representative tasks in two football disciplines, soccer (association football) and futsal. The method uses the scene view of a mobile eye-tracking device without point of gaze data. Gaze data of young male soccer and futsal players performing 6-vs-6 modified games was examined. First, a ‘gaze window’ that included most of the participants’ gazes was designed by examining the gaze scattering within the scene view. This window was then used as reference to approximate the gaze location, and its ability to classify the location of the gaze in two football-specific categories by comparing it with the standard point-of-gaze coding method was assessed.

4.2 Method

4.2.1 Participants

A total of 48 skilled players were recruited and assigned to two different groups according to their domain of expertise: soccer players (n=24, 13.6 ± 1.2 years old) and futsal players (n=24, 13.6 ± 1.2 years old). Participants were fully informed of the risks involved in participating in the experiment and their parents or guardian gave written consent for them to participate. The study was approved by the research team’s university Ethics Committee.

4.2.2 Experimental task and procedure

Participants performed a 6-vs-6 (including goalkeeper) modified game. The futsal group performed a task on a 15 x 24 m indoor futsal court with a futsal ball, whereas soccer players performed the task on a 24 x 36 m outdoor pitch with a soccer ball, to reflect the most recurrent player density encountered in games in the respective disciplines (Fradua et al., 2013). The

designed tasks were representative of the passing skill in the two sports. The typical perceptual information that guide the passing action of players (i. e., ball, orientation in the field, players' positions and movements) were represented. No special rules were applied; players were instructed to perform the modified game as they normally would in training, aiming to win the game.

A Mobile Eye system (Applied Sciences Laboratories, Bedford, MA, USA) was used to collect participants' gaze behaviour. The Mobile Eye is a monocular system that records the movements of the left eye, and uses an eye-tracking technique known as 'Pupil to CR' which correlates pupil and corneal reflection features to compute gaze within the scene being viewed. Despite sampling at low frequency (i.e. 30 Hz), the ASL Mobile Eye is commonly used in applied sport research due to its comfortable fit and non-intrusive goggle (Kredel et al., 2017; Panchuk et al., 2015). An external camera (GoPro Hero 3+) was placed in one corner of the pitch to capture the participants' execution of passes.

Each group was divided into two sub-groups (n=12) in order to perform the 6-vs-6 game. Each sub-group performed one session that comprised of six games that were 5 minutes in duration with 5-minute breaks between games to allow players time to recover. After a standardised 10-minute warm-up, participants were fitted with the eye tracker and the system was calibrated using a 7-point reference grid. Two participants wore the Mobile Eye during each game and the participants rotated between tasks (e.g., participants A and B wore the camera in game 1, then participants C and D wore the camera in game 2, and so on) to assess all 12 players throughout the session.

The videos recorded from the eye tracker and the external camera, both sampling at 30 Hz, were synchronized to detect the periods in which participants performed the passing skill. The action of receiving and passing the ball was examined, being a key skill and the most commonly performed action in both futsal and soccer (Naser & Ali, 2016; Rampinini et al.,

2009; Wen et al., 2017). A commercially available observational coding software (Quite Eye Solutions; QES) was used to accurately define onset and offset of the passing skill. The trial onset was set at 2 s prior to ball reception and the offset was set at the moment of the pass execution (Figure 4.3), consistent with previously published procedures (Panchuk & Vickers, 2006).

4.2.3 Stage 1: development of a gaze coding window

Raw data that met specific criteria (i.e., retina reflection and pupil were properly detected in at least 90% of the data points) was extracted from the eye tracking of six participants (3 participants per group). Following these criteria, only raw gaze coordinates of 18 trials (3 trials per participant) were further analysed. The Mobile Eye software provides x and y coordinates of the gaze location for each data point. The extracted x and y coordinates were plotted separately to analyse the scatter of the dispersion throughout the trial, using Microsoft Excel (Figure 4.1). The origin (0, 0) of the Cartesian coordinate system was the top left corner of the window showing the video on the screen. A total of 2092 data points (1046 for each axis) were examined.

The gaze coordinates corresponding to 1, 1.5 and 2 SD from the mean were initially selected as references to draw potential coding windows with the purpose of deriving the location of the gaze in the absence of point-of-gaze references. Pilot analysis showed that the 2 SD window was the most accurate for approximating the location of gaze when compared to the standard point-of-gaze method, with 94% agreement between the two methods. The accuracy decreased as the window size decreased to 1.5 and 1 SD, 89% and 88% of agreement respectively. This approach led to the development of a gaze coding window defined by the specific coordinates of 150, 47 (x, y), top-left, and 388, 379, bottom-right, corresponding to $\pm 2SD$ from the group's mean, to derive the location of the gaze (Figure 4.1).

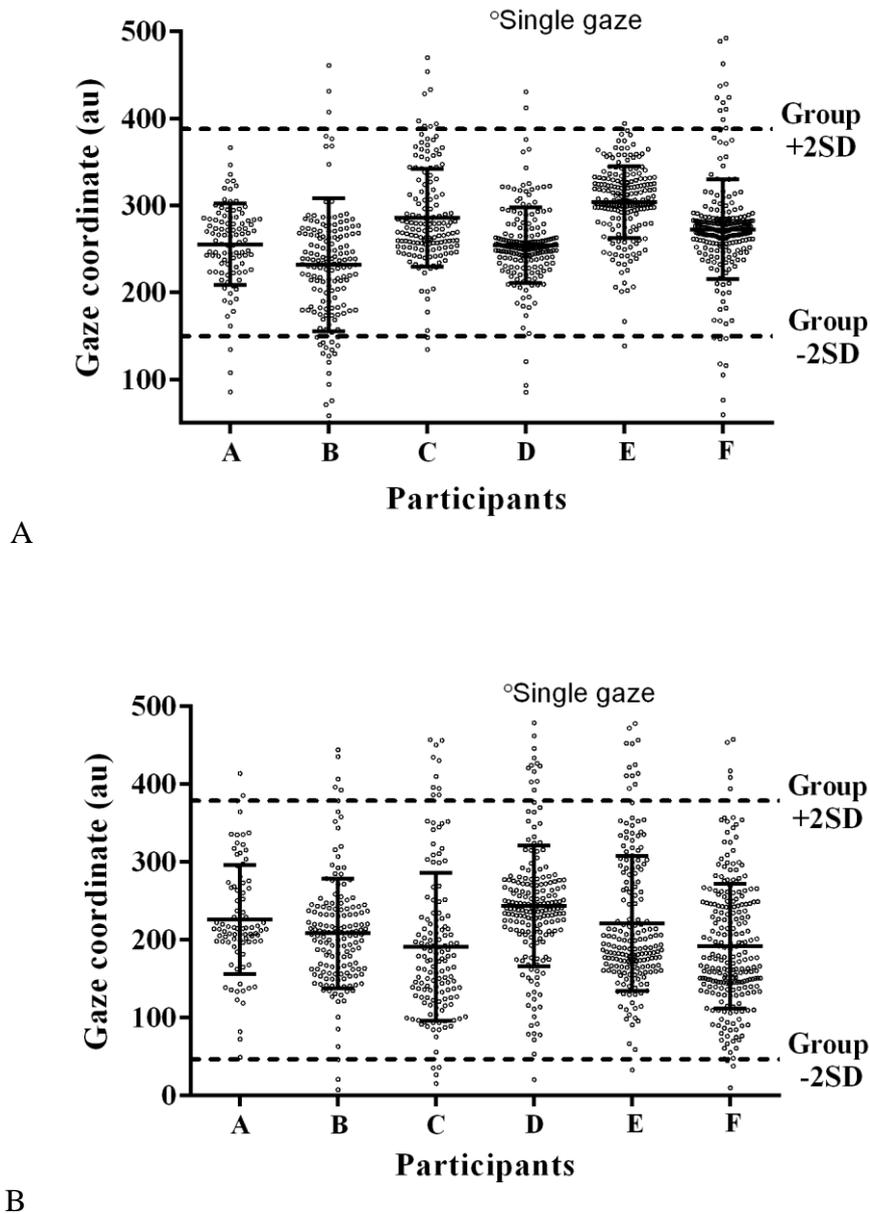


Figure 4.1 Participants' x-axis (A) and y-axis (B) gazes dispersion. The mean and standard deviations of the coordinate distribution for each participant are represented by the horizontal long solid line and short solid lines respectively. The dotted lines represent two standard deviations (SD) from the group's mean. Despite the inter-participant variability, the group 2 SDs include mean and SDs of all the participants.

Studies on gaze behaviour underpinning decision making in soccer have typically classified the gaze location in various areas including unmarked attacker, attacker closely

marked by an opponent, marking opponent, free space, ball, etc. (Vaeyens, Lenoir, Williams, & Philippaerts, 2007; van Maarseveen et al., 2016). However, the coding window did not allow to discriminate all these locations, and the areas of interest were merged into two groups, ball/ground-directed and player-directed. These two areas are relevant during the passing action as players are required to direct their attention towards other players' behaviour, to inform decision making, and towards the ball, to guide skill execution. Previous studies created a specific variable, fixation order, to evaluate the players' ability to alternate the attention between ball-related and player-related areas (Williams & Davids, 1998; Williams, Davids, Burwitz, & Williams, 1994). Research has shown that the ability to frequently alternate attention between these two areas underlies successful decision making (Vaeyens, Lenoir, Williams, & Philippaerts, 2007) and discriminates elite to sub-elite young soccer players (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). Furthermore, the evaluation of 'exploratory' visual behaviour of English Premier League players, assessed through video analysis, showed a positive relationship between ball-player gaze alternations and passing performance (Jordet, Bloomfield, & Heijmerikx, 2013). Coding rules, therefore, were designed to categorize attention orientation into ball-directed and player-directed areas.



Figure 4.2 Gaze window superimposed to the footage from the eye tracker with the point of gaze and eye references. The light area within the grey area is the gaze window. The green circle represents the point of gaze, the pink circle represents the location of the pupil and the small pink cross represents the corneal reflection.

The gaze window was superimposed onto the scene video using a commercially-available video analysis software (Sports Code, SportsTec by Hudl, Australia) and objects within the window were used as a reference to classify the location of participants' gaze (Figure 4.2). During the analysed event, which included ball reception and control, and a phase where the participant's team was in possession of the ball (Figure 4.3), players typically move their head vertically and horizontally to switch attention between ball and other players. As such, the displacement of the head was considered and attention orientation was classified as i) ball/ground-directed, whenever the ball was visible or, alternatively, when only below a player's knee was visible (i.e., head down); ii) player-directed, when above a player's knee was visible (i.e., head up) and the ball was not visible.

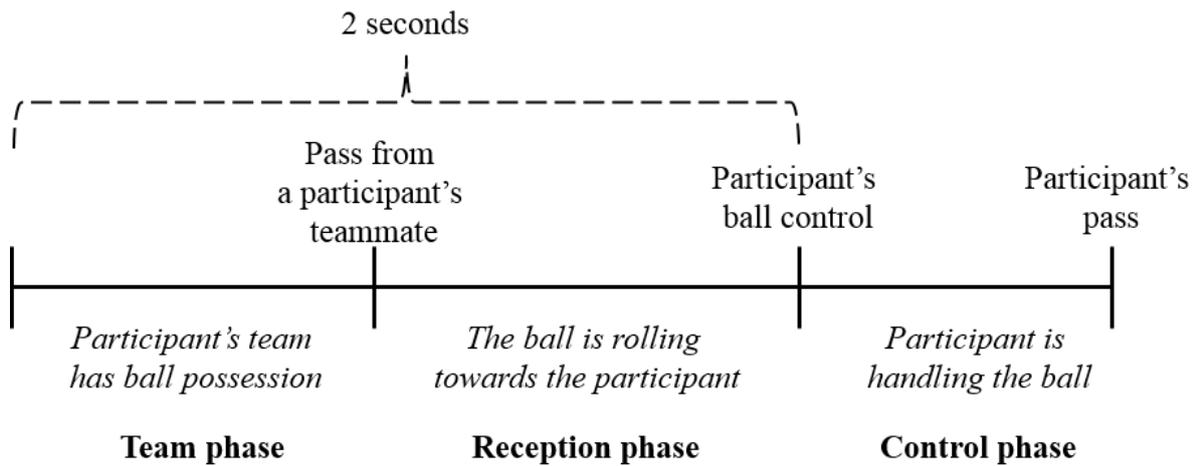


Figure 4.3 The passing event comprised the time from 2 s prior ball reception to participant's pass. This time window included three different phases i) team phase when a participant's team had the ball, ii) reception phase when the ball was rolling towards a participant, and iii) control phase when a participant was handling the ball

4.2.4 Stage 2: validation of the new coding method

To validate the window coding method, a representative sample of 12 participants (6 per group) from the 48 participants who took part in the modified games, including the 6 participants from the initial development of the coding procedure, was analysed. Four trials per participant in which eye features were detected in at least 90% of the data points were randomly sampled. As such, a total of 48 trials were examined to validate the new method.

Procedure. Video captured by the eye tracker was re-recorded twice for each trial, once with and once without superimposing the point-of-gaze onto the scene view (48 gaze and 48 scene videos, respectively), using the Mobile Eye Software. A single coder manually coded the two types of videos, gaze and scene, using Sports Code software. The gaze location was classified in the two categories, player-directed and ball/ground-directed, for each frame of the trial.

The gaze location in the gaze videos was classified as i) player-directed when the point of gaze was located on teammates or opponents without the ball, or free space (i.e., above the

closest player's feet) and; ii) ball/ground-directed when gaze was located on the ball carrier, ball or ground (i.e., below the closest player's feet). In the scene videos, gaze location was derived by coding the visible objects inside the gaze window. The gaze was classified as i) player-directed when above a player's knee was visible and the ball was not present (Figure 4.4A) and; ii) ball/ground-directed whenever the ball was visible (Figure 4.4B) or, when the ball was not present, below a player's knee was visible.

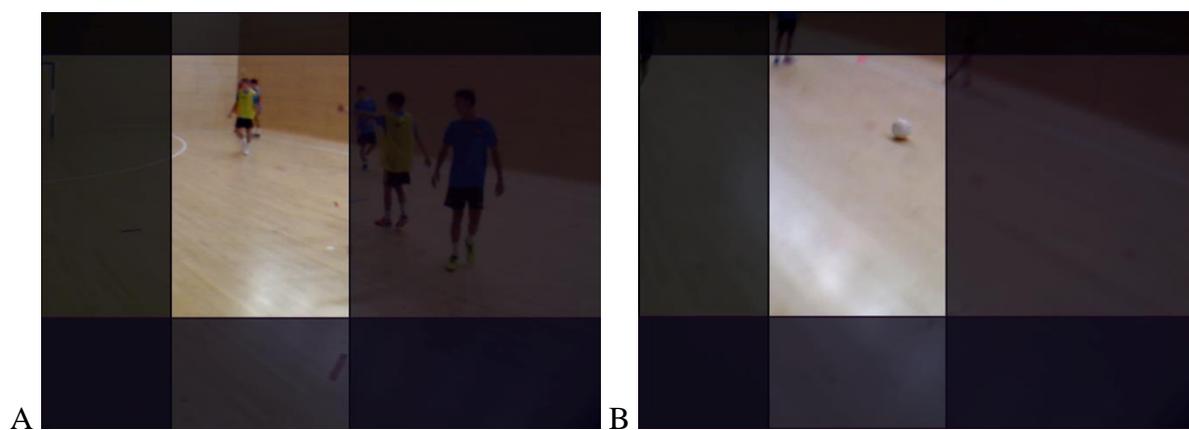


Figure 4.4 Example of gaze classification using the gaze coding window. Picture A was coded as player-directed, whereas picture B was coded as ball/ground-directed (i.e., ball and only below another player's knee was visible).

Data analysis

Validity. Each video frame was rated as ball/ground-directed or player-directed, with the resulting nominal data organized in a two-category scale. As such, the validity of the new method was evaluated by measuring the agreement between the data sets of the two coding methods – gaze window and point-of-gaze. Overall percentage of agreement and Cohen's Kappa coefficient of agreement (k), which takes into account the agreement expected by chance (Cohen, 1960), were calculated using SPSS Statistics 22 (IBM SPSS Inc., Chicago, USA). Cohen's k computes the observed agreement and the expected agreement among the ratings. The expected agreement can be influenced by a skewed marginal distribution of the

data, as a result of a much higher rate of a nominal value over the other (prevalence issue), and different patterns of disagreement between the rating systems (bias issue), which in turn affects the magnitude of k (Feinstein & Cicchetti, 1990; Zwick, 1988). Prevalence and bias indexes were computed, and a kappa adjusted for both issues was also calculated. The prevalence-adjusted, bias-adjusted kappa (PABAK) was obtained replacing the values of agreement and disagreement with their average to normalize the marginal distribution of the ratings (Byrt, Bishop, & Carlin, 1993).

Reliability. Five random trials, constituting 10% of the total sample, were selected for inter- and intra-coder reliability. The trials were recorded and coded by the primary coder a week after the original coding was completed, and by a second coder. Cohen's kappa was 0.98 and 0.94 for intra-coder reliability in point-of-gaze and gaze window coding respectively, whereas kappa was 0.90 and 0.93 for inter-coder reliability in point-of-gaze and gaze window coding respectively, all representing perfect agreement (Landis & Koch, 1977).

4.3 Results

The overall percentage of agreement, also called observed agreement, was 90%. Table 4.1 shows the cross tabulation of the ratings computed with SPSS. It shows how the number of false positive and negative in player-directed area was higher than in ball-directed area. This can be explained by the players moving their eyes first and then their head when quickly switching their gaze from the ball to a player; therefore, the point-of-gaze coding would classify the gaze as player-directed while the gaze coding window as ball-directed, hence the low agreement. Cohen's k was 0.64 ($p < 0.001$); however, the prevalence index was 0.67, which indicates a clearly skewed distribution of the data that negatively impacts the expected agreement and the magnitude of k . The bias index was very low, 0.02, indicating very limited influence of disagreement pattern on k magnitude. The adjusted kappa, PABAK, was 0.80.

Kappa values can range from -1, indicating absolute disagreement, to 1, indicating perfect agreement. The values of kappa are widely interpreted using the scale provided by Landis and Koch (1977), which interprets the level of agreement, slight, fair, moderate, substantial and perfect, for the different kappa range, respectively, 0 – 0.20, 0.21 – 0.40, 0.41 – 0.60, 0.61 – 0.80 and 0.81 – 1. The calculated kappa values of 0.64 and PABAK of 0.80 represent substantial agreement. As such, the gaze-window coding and the point-of-gaze coding were in substantial agreement, indicating a good validity of the method developed.

Table 4.1 *Cross tabulation of the ratings obtained with the point-of-gaze coding and the gaze window coding.*

		Point-of-gaze coding		
		<i>Ball-directed</i>	<i>Player-directed</i>	<i>Total</i>
Gaze Window Coding	<i>Ball-directed</i>	2686	200	2886
	<i>Player-directed</i>	144	397	541
	<i>Total</i>	2830	597	3427

4.4 Discussion

The quality of the data collected through eye tracking technology has a significant impact in psychology research as low-quality data resulting from experimental constraints can compromise the success of an investigation. The unreliable detection of eye features that often occurs during outdoor dynamic tasks has always been a concern for applied scientists (Holmqvist et al., 2011). Impacts associated with running cause vibrations that combined with environmental brightness limit the eye tracker's ability to recognize the pupil. This makes the computation of the point of gaze and, consequently, the examination of attentional orientation difficult in a representative setting. These issues have constrained experiments on perceptual skills in football, limiting the generalization of results.

This study validated a new approach to overcome this issue by obtaining a player's attention orientation using head orientation only, via the scene view of a mobile eye-tracking device. A gaze coding window was drawn, from the analysis of participants' gaze to include 95.4 % of the total gazes, and superimposed onto the eye-tracker scene camera. The visible objects within the gaze window were used to classify gaze behaviour in two football-specific areas of interest, namely ball/ground-directed and player-directed. This new coding method was in substantial agreement with the standard point-of-gaze coding method in the ability to categorize gaze behaviour in the two categories. This method provided a valid alternative to the standard coding method in approximating participants' attention orientation, when dealing with unreliable eye tracking data. Applied researchers should try to assess eye movements even in challenging contexts (e.g., outdoor, dynamic tasks, etc.); however, when the collected data is unstable and the detection of eye features unreliable, the proposed method could be used for the analysis.

The new method allows the categorization of attention orientation in two areas, ball/ground-directed and player-directed, during different phases of the passing skill (i.e., reception, control and team phase) in futsal and soccer games. While it does not allow to discriminate what specific information supports action, the method provides a way to effectively use eye-tracking data collected in a dynamic and outdoor task that would otherwise be useless with the standard gaze coding methods. The ability to alternate visual attention between two areas only, i.e., ball-related and player-related, has been previously evaluated providing insights into the pathway to soccer expertise (Vaeyens, Lenoir, Williams, & Philippaerts, 2007). Being able to evaluate attentional processes in the performer's typical environment is important in applied soccer and futsal research, where one of the aims is to generalize the findings to the game. Furthermore, the attentional processes underlying passing can be evaluated whilst maintaining the coupling of perception and action during passing. To-

date, no studies have examined this complex action, coupling the full movement and decision making as typically happens in games.

While no studies have been conducted in futsal, the attentional processes underlying successful passing skill in soccer have been examined in lab-based experiments and anecdotally explored. While previous research highlighted that the ability to efficiently alternate attention between ball-related and player-related areas may underpin expertise (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Vaeyens, Lenoir, Williams, & Philippaerts, 2007), other research has found no differences between experts and non-experts (Williams & Davids, 1998). A positive relationship between gaze alternations, to scan players' and ball's behaviour, and performance with the ball has been shown in English Premier League (Jordet et al., 2013). Furthermore, anecdotal videos on YouTube display the numerous visual scans that the top players (e.g., Messi and Ronaldo) adopt during games. Experimentally and anecdotally it appears that efficiently alternating attention between ball-related and player-related locations is an important attribute underpinning expertise. The method developed in this study allows the examination of players' attention orientation during soccer and futsal games, potentially providing new insights into this topic.

The practical application of the new method is relatively simple as only basic knowledge on Microsoft Excel is required and it's low-cost. Eye tracking technology is necessary only for the development of the coding window as raw gaze coordinates are required. The specific window can then be used in experiments with similar cohorts performing a similar task and head orientation can be derived from action camera footage. This would allow coaches and practitioners to examine an athlete's gaze behaviour without recourse to expensive eye tracking technology. Pluijms et al. (2016) showed that a similar approach was valid in examining athletes' external focus of attention in sailing. The approach outlined in this paper

could be extended to the general field of applied research in team sport, and could guide the development of domain-specific gaze window.

This method was used to approximate participants' orientation of attention during modified soccer and futsal games in chapters 5 and 6.

CHAPTER 5

**LONG-TERM PRACTICE WITH DOMAIN-SPECIFIC TASK
CONSTRAINTS INFLUENCES PERCEPTUAL SKILLS.**

5.1 Introduction

The constraints-led perspective (Newell, 1986) contends that human behaviour in goal-directed activities emerges as a result of the self-organization of interacting constraints (Davids et al., 2008b; Newell, 1986). Constraints have been defined as boundaries or features that limit (and enable) the behaviour of individuals and have been classified into three categories including: organismic, environmental and task (Newell, 1986). With practice, skilled performers develop the ability to functionally organize an optimal coordination pattern that best suits the contextual demands. Task constraints (e.g., rules, equipment and field dimensions) have been the main constraint examined in sport and exercise research (Araújo et al., 2004; Davids et al., 2008b) as they can be readily manipulated by practitioners to promote appropriate movement adaptations. For example, research has investigated the influence of task constraints on skill execution, showing variations in tennis performance (e.g., successful hits) and types of movement when equipment size was modified (Buszard et al., 2014a; Fitzpatrick, Davids, & Stone, 2017; Timmerman et al., 2015), and the manipulation of task constraints to promote skill acquisition (Farrow et al., 2016), highlighting a higher number of hitting opportunities and individuals' engagement during training with children-scaled tennis equipment (Farrow & Reid, 2010). While this research has largely focused on the physical aspects of performance, the influence of task constraints on the development of perceptual processes underpinning performance has remained relatively un-explored.

Sport expertise is characterized by superior perceptual skills that allow experts to identify and use relevant environmental information to successfully guide their actions (Williams et al., 1999; Williams & Ford, 2008). Athletes explore the vast amount of information contained in the sporting environment and learn, with practice, to exploit the information that specifies task-relevant attributes from the environment (Gibson & Pick, 2000; Savelsbergh et al., 2004). The development of expertise, thus, entails the education of attention

towards information that is suited to the task at hand (Beek et al., 2003). In this context, domain-specific task constraints that specify different information and afford different types of action are expected to influence an athlete's search for environmental information, thus, shaping the development of perceptual skills (Ericsson & Lehmann, 1996; Newell, 1991; Phillips et al., 2010; Williams et al., 2004).

Task constraints, including the type of information athletes are required to respond to, instructions, and equipment, have been shown to affect the attentional processes underlying performance. For example, the pattern of eye movements, which assesses attention control (Panchuk et al., 2015), was different when goalkeepers responded to video simulations or to an actual opponent, with higher mean fixation locations in the in situ condition (Dicks et al., 2010). Visual search behaviours of youth soccer players were also influenced by the number of players; an increase in the number of players and in the number of opponents (e.g., a 3v2 condition) contained within the video stimuli presented resulted in an increase in the number of visual fixations and number of fixation alternations respectively (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). The interaction between thought processes and visual search was altered when the task required athletes to respond to a far or near stimulus in a decision-making task, higher number of fixations in the far condition and more predictive and planning statements in the near condition (Roca et al., 2013). Furthermore, equipment (i.e., standard or vision occluding equipment) and instructions (attention focused on hole or ball marker) affected quiet eye duration and dwell time in a golf putting task (Panchuk et al., 2014). Despite providing evidence that task constraints influence perceptual skills, these studies are limited to acute changes and the long-term impact of practice with different task constraints on perceptual skills remains unclear. Here we examine the influence of extensive practice (i.e., more than a thousand hours of structured practice) with different sport-specific constraints on attention orientation underpinning the passing skill in futsal and soccer.

Futsal is the 5-a-side indoor form of football, whereas association football (also called soccer) is the 11-a-side outdoor form of football, both of which are officially regulated by the Fédération Internationale de Football Association (FIFA). The two sports share many similarities (e.g., the kicking action and the rule permitting the use of the hands other than for the goalkeeper) but various constraints differentiate the two games (see Table 5.1), and could be expected to influence the type of information players become attuned to when performing passes. In this context, several elite soccer players including Cristiano Ronaldo, Messi, and Pele stated that practicing futsal early in their career facilitated the development of decision-making skill. The smaller space, more intense man-marking, and higher opponent pressure in futsal is believed to encourage players to make and execute quicker decisions than soccer (UEFA, 2014). These experiences suggest that differences between futsal and soccer might, indeed, influence the development of perceptual skill.

Table 5.1 *Soccer-specific and futsal-specific constraints with the expected influences on the game.*

Constraint	Sport		Expected influence
	Soccer	Futsal	
<i>Pitch size (m)</i>	100 x 65	40 x 22.5	Higher game intensity
<i>Number of players</i>	11 vs 11	5 vs 5	and more opponent
<i>Individual playing area</i>	295 m ² /player	90 m ² /player	pressure in futsal
<i>Ball: Circumference (cm)</i>	68.5 – 69.5	62.5 – 63.5	More regular and predictable ball bounce
<i>Weight (gr)</i>	420 – 445	410 – 430	in futsal
<i>Height of first bounce</i>	135 – 155	55 – 65	
<i>Surface</i>	Natural or synthetic grass	Flat, typically hardwood or laminated synthetic material	
<i>Rules</i>	Offside 3 substitutions	No offside Unlimited substitutions	

Despite the differences in rules and equipment, passing is the main skill performed in both sports (Mohammed et al., 2014; Rampinini et al., 2009). The passing action is complex as it involves the interception of the ball while making a decision, usually under pressure, about which teammate to pass the ball to. Players are required to switch their attention between information specifying the approaching ball and the behaviour of players around them. While no studies have been conducted in futsal, separate studies have investigated how visual attention underpins decision making and ball control in soccer. The analysis of eye movements is frequently used as proxy for examining attentional processes due to the partial-interdependence of attention and eye movements (Van Gompel et al., 2007). While attention can move independent of the eyes, gaze shifts are strictly correlated with shifts in attention (Henderson, 2003) and gaze patterns provide information on individuals' control of attention (Panchuk et al., 2015). A video-based task showed that high visual scanning behaviours (i.e., attention frequently shifting between different locations in the display) underpinned successful decision making (Vaeyens, Lenoir, Williams, & Philippaerts, 2007), and visual information of ball behaviour and foot-ball interaction supported accurate performance in a ball control task (Williams, Weigelt, Harris, & Scott, 2002). Corrêa et al. (2014a) suggested that futsal players should become attuned to information of their teammates' behaviour early in the execution of the pass; however, they did not examine the attentional processes underpinning such behaviour. As such, it is not known how soccer and futsal players control their attention during games, when they need to couple ball control and decision making, because in situ assessments of attentional strategies, which are required to accurately capture players' behaviour (Dicks et al., 2010) are rarely achieved in sport due to limitations in assessment methods. Even though the skill is the same, it is unclear how extended exposure to the different task constraints in futsal and soccer influences perceptual skills underpinning passes.

The purpose of the present study was to investigate how perceptual skill underpinning the passing action was influenced by domain-specific practice with different task constraints. The orientation of attention when controlling and passing the ball was examined in young, skilled futsal and soccer players during modified games. We hypothesized that, despite performing a similar skill, sport-specific constraints would promote attunement to different information during the execution of the pass. Specifically, the higher game intensity (i.e., higher opponent pressure and quicker passes) and ball characteristics (i.e., more predictable and easier to control) of futsal are expected to promote an orientation of the futsal players' attention towards the behaviour of the players around them and to force quick decisions, relative to soccer players who would mainly orient their attention towards the ball. Furthermore, the players' orientation of attention was also assessed when their team was in possession of the ball. The higher number of players on the pitch in soccer was predicted to encourage soccer players to orient their attention towards teammates' and opponents' movement for a greater period of time than futsal players in this phase.

5.2 Method

5.2.1 Participants

A total of 48 skilled, young, male players were recruited for the experiment. They were divided into two groups based on their domain of expertise: soccer players ($n=24$, 13.6 ± 1.2 years old, 6.8 ± 1.2 years of experience) and futsal players ($n=24$, 13.6 ± 1.2 years old, 7.0 ± 1.6 years of experience). Participants completed a questionnaire on their training history that included the number of training years at club level, and an average amount of training months per season, number of training per week and training duration (Appendix C). The years of experience referred to structured team practice in their domain. Players in both groups, on average, had three 90-minute sessions per week, 40 weeks per year, resulting in approximately 1220 and

1260 hours of domain-specific structured practice in the soccer and futsal group respectively. Furthermore, both groups had participated in approximately 400 competitive games in their respective domain. To control for training and competition time, two squads (U13 and U15) from within one of the most successful Spanish futsal teams and the most successful Australian State representative soccer squads were recruited. Both groups had a similar weekly training schedule that included four 90-minute training sessions and one competitive game. Only outfield players were sampled from the squads. Players that trained at a club level in the 'other' sport were excluded. As such, participants had experience only in their own sport. Technical issues during data collection (e.g., the scene camera moved during the game, the video quality was unreliable, etc.) resulted in a final sample size of 17 futsal players (U13=9 and U15=8) and 20 soccer players (U13=9 and U15=11) being examined.

Prior to the study, participants were fully informed of the risks involved in participating in the experiment and their parents or guardian gave written consent for them to participate. The study was approved by the research team's University Ethics Committee.

5.2.2 Experimental task and procedure

The experimental task was a 6-vs-6 (including goalkeeper) modified game. The game format, the aim (scoring goals to win), and the rules, including no offside rule, were the same for both sports to allow for between-sport comparisons. However, the ball, playing surface, and individual playing area were manipulated to create the two domain-specific tasks. As such, the soccer task (SOC) was performed with a FIFA quality-approved soccer ball, on a synthetic-grass pitch of 36 m x 24 m corresponding to an individual playing area of 86 m²/player, which is representative of an actual soccer game (Figure 5.1B) (Fradua et al., 2013). The futsal task (FUT) was performed with a FIFA quality-approved futsal ball, on a wooden pitch of 24 m x 15 m corresponding to an individual playing area of 36 m²/player, which is the most common density in futsal matches (Figure 5.1A) (unpublished observations). The two tasks were not

simulations of soccer and futsal games but representative of the passing skill in the two disciplines.

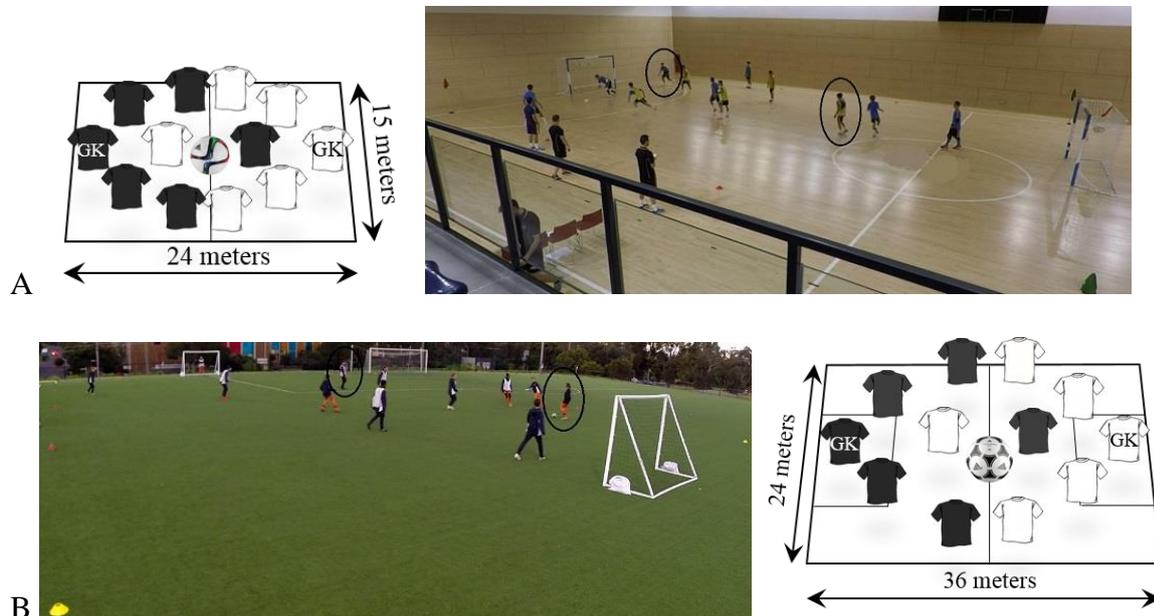


Figure 5.1 Example of FUT task (A) and SOC task (B). The two participants wearing the scene camera are highlighted in the circles. GK indicates the goalkeeper of each team. The goals were futsal-size goals to discourage shooting and encourage passing in the SOC task.

The scene camera of a mobile eye tracking system (Mobile Eye, Applied Sciences Laboratories, Bedford, MA, USA) was used to collect participants' attention orientation. An external camera (GoPro 3+) was placed in one corner of the pitch to record the task.

All familiarization and testing sessions were performed in the participant's regular training environment (i.e., futsal group in FUT and soccer group in SOC). The groups performed a familiarization session which consisted of a shortened version of the experimental task one week prior to the experimental session. The experimental session comprised of six games that were 5 minutes in duration with 5-minute breaks between games to allow players time to recover. Two participants wore the scene camera during each game and the participants rotated between tasks (e.g., participants A and B wore the camera in game 1, then participants

C and D wore the camera in game 2, and so on) to assess all 12 players throughout the session (Figure 5.2). As a result, each player wore the scene camera during one game and participated in 5 games in total, having rested the game prior to wearing the scene camera. Players were instructed to perform the task as they normally would; aiming to win each game, with the only added rule of no slide tackles to the player wearing the eye tracker for safety reasons.

After a standardized, 10-minute warm-up, each group was randomly divided into two teams of 6 players including a goalkeeper. Before each task, two participants were fitted with the Mobile Eye. The task started with the investigator bouncing the ball on the ground. The bounce was used as reference to synchronize the eye-tracker scene camera and the external camera. One of the investigators umpired the games.

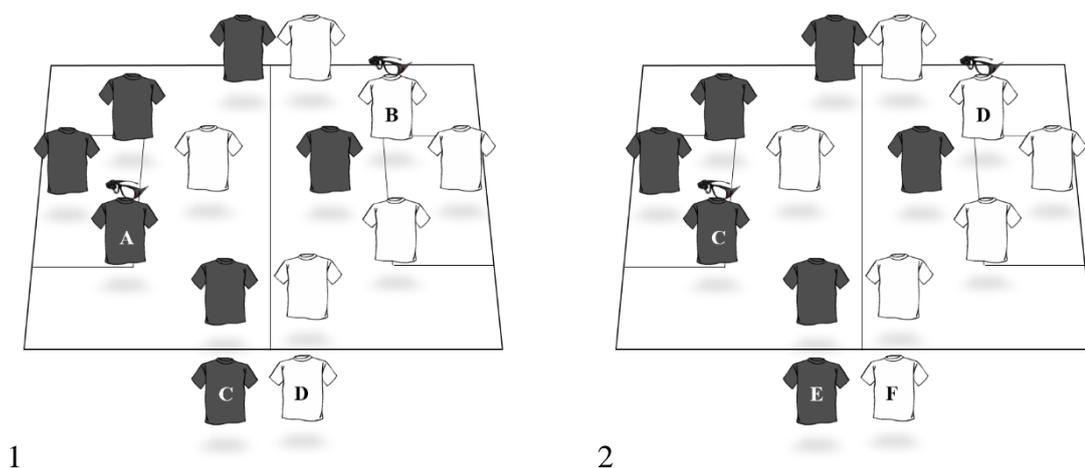


Figure 5.2 Schematic representing the rotation of participants wearing the scene camera throughout the session. In game 1, A and B wore the scene camera while C and D rested; in game 2, C and D wore the scene camera while E and F rested; and so on until all the participants have worn the scene camera.

5.2.3 Data analysis

Attention orientation. The gaze window, developed in chapter 4, was used to classify attention orientation into two areas of interest, namely ball-directed and player-directed. The orientation of attention was classified either as i) ball-directed, when the ball was visible or

when only below a player's knee was visible (i.e., head down), or ii) as player-directed, when above a player's knee was visible (i.e., head up) and the ball was not visible. These two areas are relevant during the passing action as players are required to direct their attention towards other players' behaviour, to inform decision making, and towards the ball, to guide skill execution. Furthermore, players can direct their attention towards either the player in possession of the ball or other areas, when they are not in possession of the ball. Previous research has shown how the ability to alternate attention between ball-related and player-related areas might underpin football expertise and successful passing in lab-based decision-making tasks (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007; Vaeyens, Lenoir, Williams, & Philippaerts, 2007).

The footage from the scene camera and the external camera, both recorded at 30hz, were synchronized using Sports Code to couple the orientation of attention with specific events, consistent with the Vision-in-Action procedure (Vickers, 1996).

The game was divided into three phases, reception, control and team phase (Figure 5.3). The *reception phase* referred to the period from the time the ball left a teammate's foot to the participant's first touch. The *control phase* captured the time in which participant had possession of the ball, from the first touch to the release of the pass. The *team phase* referred to the time the participant's team had possession of the ball minus the previous two phases. Three attention-orientation variables were determined: relative attention-orientation time (AT), attention-orientation switches (AS), and last-attention location (AL). AT and AS were adapted from previous research on visual search strategies (Williams & Davids, 1998; Williams et al., 1994), representing relative viewing time and fixation order, respectively. AT refers to the relative percentage of time the attention was oriented on the two areas of interest during the passing action. AS was calculated as the number of times participants alternated the attention between the two areas of interest per second. AL was specifically designed to capture the

participants' behaviour during the passing action and refers to the location where the head was oriented when the foot made contact with the ball, when controlling the ball (reception phase) or when performing the pass (control phase). These dependent variables were evaluated frame-by-frame using Sports Code. AT and AS were evaluated, separately, in each phase, whereas AL was examined only in the reception and control phases.

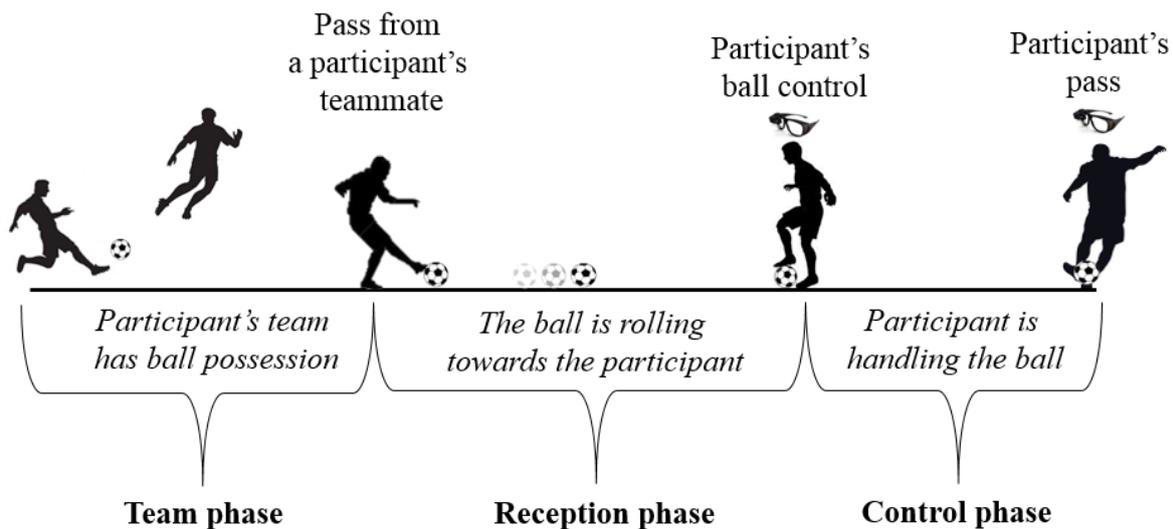


Figure 5.3 Schematic of the three game phases: team, reception and control phase

Passes where the receiving pass (from a teammate) was bouncing and the participant's body was oriented towards the side line (with less than 4 players in front of him) were excluded from the analysis to limit the influence of external factors. Furthermore, only passes that included the control phase were considered (i.e., direct passes were excluded). This resulted in a total of 350 passes analysed, 169 in futsal (10 ± 4 passes per player) and 181 in soccer (9 ± 2 passes per player).

Game dynamics. Three game-related variables were assessed to quantify the context in which the passes were performed. Technical intensity of the game referred to the number of passes performed each minute during the game. Individual playing area (IPA) is a tactical variable that can influence a player's decision (Fradua et al., 2013) and is the playing area the

player was in when performing the pass. To calculate IPA, the pitch was divided into fixed squares of known dimensions (i.e., 108 m² in SOC task and 60 m² in FUT task), using side-line cones as references, and the number of players inside the square the participant was occupying when performing the pass were counted. The dimension of the square was then divided by the number of players to get the individual playing area (e.g., in SOC task, 108 m²/5 players = 21.5 m²/player). Reception time referred to the time it took the ball to travel from the teammate to the participant with the eye tracker (i.e., reception-phase time). This indicates how much time the participants had to prepare the reception and control action.

5.2.4 Coding reliability

Five percent of the total trials were randomly selected for inter- and intra-coder reliability. The trials were recorded and coded by the primary coder a week after the original coding was completed, and by a second coder. Cohen's kappa was 0.94 for intra-coder reliability and 0.93 for inter-coder reliability, all representing perfect agreement (Landis & Koch, 1977).

5.2.5 Statistical analysis

All the attention-orientation dependent variables were analysed separately using generalized linear mixed modelling (Proc Glimmix in Version 3.6 of Statistical Analysis System Studio, SAS Institute, Cary, NC) with domain (soccer, futsal) as a fixed factor and participants as a random factor. The model allowed for overdispersion (i.e., non-uniformity of error). Specifically, Poisson regression was computed to analyse AS as data was expressed as count per unit of time (switches/sec), whereas Logistic regression was computed for AT and AL, being both binary dependent variables. The game dynamics variables were analysed separately using an independent t-test.

Significance was set at $p < .05$ for all the analyses and the magnitude of changes was assessed using Effect Sizes (Cohen's d) with 90 % Confidence Intervals defined as follows: <0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, 1.2-2.0 large, >2.0 very large (Hopkins, 2010a).

The between-subject standard deviation for the standardization of the effect sizes was calculated using the pure observed between-subject variance and the overdispersed sampling variance as follow: $\sqrt{(\textit{Athlete ID variance} + \textit{overdispersed sampling variance})}$.

5.3 Results

5.3.1 Attention orientation

The mean data for attention-orientation variables is presented in Table 5.2.

Reception phase. There was a significant group difference in AL ($p < 0.01$, $ES = 2.03 \pm 0.6$). Prior to their first touch, futsal players oriented their attention primarily towards other players relative to the soccer players (54% of the time vs. 16% of the time). The results also showed a small effect in AS ($p = 0.08$, $ES = 0.22 \pm 0.21$) with futsal players switching their attention between the ball and players more frequently than soccer players. No differences were found in AT ($p = 0.59$, $ES = 0.18 \pm 0.56$).

Control phase. There was a significant group difference in AT ($p = 0.01$, $ES = 0.86 \pm 0.58$). Futsal players oriented their attention towards other players for a longer period of time than soccer players (45% vs. 32%). No differences were found in AS ($p = 0.30$, $ES = 0.30 \pm 0.49$) and AL ($p = 0.43$, $ES = 0.27 \pm 0.57$).

Team phase. There was a significant group difference in AT ($p < 0.01$, $ES = 1.02 \pm 0.57$). Soccer players oriented their attention towards other players longer than futsal players (22% vs. 13%). There was also a significant group difference in AS ($p = 0.01$, $ES = 0.85 \pm 0.57$). Soccer players alternated their attention more frequently between the ball and players than futsal players.

Table 5.2 Mean relative attention-orientation time on player-directed area (AT, in percentage), attention-orientation switches (AS, in switches/sec) and last-attention orientation on ball-directed area (AL, in percentage) \pm SD of the two groups across the three different phases. Significance was set at $p < 0.05$. Effect sizes: *small, **moderate, large***, and very large****.

Phase	Attention-orientation	Group		p value
		Futsal	Soccer	
<i>Reception</i>	<i>AT (%)</i>	17 \pm 12	12 \pm 8.0	p = 0.59
	<i>AS (switches/sec)</i>	1.0 \pm 0.5	0.6 \pm 0.3	p = 0.08*
	<i>AL (%)</i>	54 \pm 21	16 \pm 17	p < 0.01****
<i>Control</i>	<i>AT (%)</i>	45 \pm 18	32 \pm 18	p = 0.01**
	<i>AS (switches/sec)</i>	1.1 \pm 0.4	1.1 \pm 0.4	p = 0.30*
	<i>AL (%)</i>	20 \pm 23	14 \pm 21	p = 0.43*
<i>Team</i>	<i>AT (%)</i>	13 \pm 5.0	22 \pm 10	p < 0.01**
	<i>AS (switches/sec)</i>	0.3 \pm 0.1	0.4 \pm 0.1	p = 0.01**

5.3.2 Game dynamics

There were significant group differences in reception time ($p < 0.01$, ES = 1.69 \pm 0.55), in individual playing area ($p < 0.01$, ES = 2.99 \pm 0.60), and in technical intensity ($p < 0.01$, ES = 6.21 \pm 0.53) (Figure 5.4). The results showed a higher game intensity in futsal with more passes per minute performed (35%), shorter time to organize the controlling action (30%) and lower individual playing area (46%) relative to soccer.

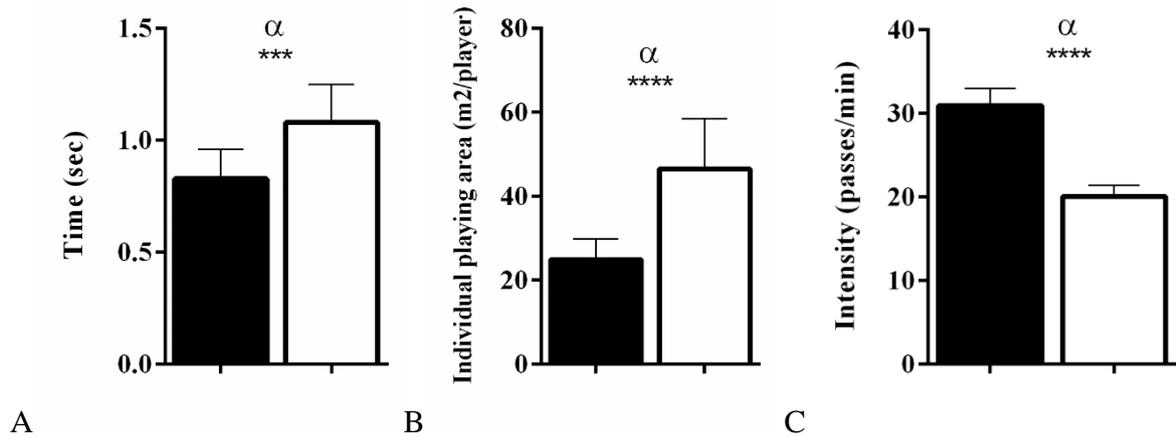


Figure 5.4 Mean reception time (A), mean individual playing area (B), and mean technical intensity (C). The black and white bars represent futsal and soccer group respectively. α : statistically significant, effect sizes: *small, **moderate, ***large, ****very large. Error bars represent ± 1 SD from the mean.

5.4 Discussion

The aim of this study was to investigate how extensive practice with domain-specific task constraints influenced perceptual skills associated with the passing action. It was hypothesized that futsal-specific constraints (e.g., high game intensity, ball characteristics, playing surface, etc.) would promote an orientation of attention towards player-directed areas while soccer constraints would encourage a ball-directed orientation of attention. The results confirmed this hypothesis as futsal players spent more time orienting their attention towards player-directed areas and alternated their attention more frequently between the ball and players during the reception and control phases. Futsal players developed perceptual-motor coordination that allowed them to perform the first touch while orienting their attention towards player-directed areas, and then spent more time attending to players during ball control. On the other hand, soccer players alternated their attention between the ball and players less frequently, and mainly attended to the ball when performing the first touch. Furthermore, they spent less time

orienting their attention towards players during the control phase. It was also hypothesized that the higher number of players on the pitch in soccer would promote a higher frequency scanning behaviour in soccer players during the team phase. This prediction was confirmed as soccer players spent more time orienting their attention towards players and alternated their attention more frequently between the ball and other players than futsal players during the team phase. These findings demonstrate that each group developed unique perceptual strategies to gather information about the ball and other players at different phases during the games. Furthermore, the smaller individual-playing area, shorter reception time and higher technical intensity in futsal, highlighted, as predicted, an overall higher game intensity in futsal.

While this methodology did not allow to evaluate the influence of each sport-specific constraint on the observed behaviours, it can be speculated how the constraints may have influenced the development process. The higher intensity of the futsal game, confirmed in this study (i.e., smaller individual playing area, shorter reception time and technical intensity), is suggested to be the main constraint that led futsal players to scan the environment and focus their attention on player-directed areas just prior to and during ball control. Similarly, it has been suggested that futsal players should detect information earlier during the passing action to make decisions (Corrêa et al., 2014a). Furthermore, it is speculated that the futsal ball, which has a predictable bounce and is easier to handle, contributed to the development of the observed behaviour during the futsal players' first touch. On the other hand, the higher number of players in soccer (i.e., more potential information sources) and the less predictable behaviour of the soccer ball could be the key constraints that led soccer players to scan the environment more frequently when their teammates were in possession of the ball and to orient their attention to the ball when they were controlling it. Previous research has shown that a higher number of players within a player's field of view promoted a higher number of visual fixations (Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). Furthermore, stimuli that are close to the player (i.e.,

ball and other players) promote lower visual search rates than stimuli that are far from the player (Roca et al., 2013). In the team phase, the proximity of stimuli in the two domains could play a role in shaping behaviour as futsal players are accustomed to dealing with stimuli that are closer to them than soccer players, due to the smaller size of the futsal pitch. A potential research direction would be to investigate the influence of these constraints independently.

The last-attention orientation (AL) in futsal players was mainly player-directed in the reception phase indicating that they developed a coordination pattern that allowed them to receive the ball while orienting their attention towards other players, while soccer players' attention was mainly ball-directed. This suggested that futsal players had automated control of the ball as they oriented their attention away from the ball in the last phase of ball flight, which is the moment that requires the highest attentional demands in interceptive actions (Williams et al., 1999). Previous research has shown that modified equipment that simplifies skill performance (e.g., scaled tennis equipment for children) promotes implicit processes that eventually lead to movement automaticity (Buszard et al., 2014b). It is suggested that, in this study, the futsal ball and the hard futsal-court surface were likely to be the constraints that simplified ball control and delivery, potentially promoting more enhanced movement automaticity.

This study is novel, having assessed attentional processes in situ, coupling perception and action, in two team sports. Laboratory-based tasks typically do not include the reception of the ball when examining decision making in team sports. Participants usually watch patterns of play and are required to perform a sport-specific action using a ball positioned at their feet (Helsen & Starkes, 1999; Vaeyens, Lenoir, Williams, & Philippaerts, 2007) or in their hand (Furley, Memmert, & Heller, 2010; Gorman & Farrow, 2009). Interestingly, one of the key findings of this study was the pattern of perceptual-motor coordination developed by futsal players during the reception phase (i.e., AL on player-directed area). This difference in

coordination would not have been captured if we had not designed a task in which players had to receive and pass the ball. This suggests future studies need to consider the inclusion of a ball reception phase when examining decision making in team sport, as it might be critical for players' coupling of perception and action.

This study provides new evidence on the influence of task constraints on perceptual-motor skills. Previous research has been limited to acute changes (Dicks et al., 2010; Panchuk et al., 2014; Timmerman et al., 2015), whereas this experiment examined the long-term effects of practicing with specific task constraints. Players developed patterns of coordination that best suited the different contextual demands, e.g., higher game intensity, different ball, etc. This supports the notion that individuals' coordination is the result of self-organization of interacting constraints, particularly task constraints in the current study (Davids et al., 2008b; Newell, 1986). It also highlights the importance of manipulating constraints on action to better understand human coordination and skill acquisition (Newell, 1986).

The findings of this study also have practical implications for sport practitioners. Researchers have suggested manipulating task constraints, including equipment and rules, to obtain desired changes and adaptations in athletes' behaviour as it allows individuals to find their own preferred pattern of coordination (Araújo et al., 2004; Davids et al., 2008b; Farrow et al., 2016). This study suggests that the type of ball, the number of players and the individual playing area can be manipulated to promote different perceptual skills. The futsal ball could potentially be used on a hard surface to develop automaticity of the kicking skill. Similarly, previous research has showed the benefit of using a futsal ball to acquire ball juggling skill (Button, Smith, & Pepping, 2005). Furthermore, the individual playing area and number of players can be manipulated to constrain the players' visual search for environmental information. The number of players can be increased to promote higher scanning behaviour as indicated by more frequent attention switches and more time spent on players in the soccer

group. Individual playing area can be manipulated to modify opponent pressure when performing passes, which in turn, encourage players to search for decision-making information at key moments. For example, high opponent pressure can be used to promote early and quick detection of environmental information.

The players' behaviours observed in this study has been interpreted as being the result of long-term practice with different task constraints. However, it must be acknowledged that other interpretations cannot be excluded. For example, players might have developed different motor programs in response to the different domain-specific training that have influenced the behaviour. Furthermore, factors other than task constraints might have contributed to the development of the behaviours. Given that participant's performance was captured during a single session it was not possible to determine how these skills developed over time. It could also be possible that only the players that developed the observed behaviours early in practice continued to participate in the sport (i.e., players self-selected to participate in either sport based on these behaviours). Furthermore, it must be acknowledged that the coding window used to classify the participants' orientation of attention may have influenced the results, given its relatively high rate of false positive associated with player-directed area. These limitations should be addressed in future research to further examine how different task constraints influence the development of perceptual skill. Longitudinal studies, with baseline assessment, training and post-training assessment are needed to examine the causal relationship. Furthermore, attention orientation was assessed on a single occasion in this study, and future research could assess the behaviour over multiple occasions to evaluate the adaptability of the skill.

5.5 Conclusions

Despite performing the same skill (passing action), futsal and soccer task constraints shaped athletes' perceptual behaviours. Higher game intensity, higher opponent pressure, an easier-to-handle ball, and a lower number of players in futsal led futsal players to acquire information on other players' behaviour just prior to and during ball control. On the other hand, a higher number of players, lower game intensity and an unpredictable ball behaviour in soccer led soccer players to scan the environment when not in possession of the ball. Despite the limitations highlighted in the previous paragraph, this is the first study showing the influence of task constraints on perceptual skills in sport and a potential future research direction would be to examine the influence of task constraints independently in a longitudinal study.

CHAPTER 6

TASK CONSTRAINTS MODULATE TRANSFER OF PERCEPTUAL- MOTOR SKILL BETWEEN SIMILAR DOMAINS.

6.1 Introduction

The constraints-led perspective contends that an individual's behaviour in goal-directed activities emerges from the self-organisation of interacting organismic, environmental and task constraints (Newell, 1986). Skill learning involves a relatively permanent change in behaviour over time as a result of goal-directed practice with a set of constraints (Kelso & Zanone, 2002; Newell, 1996; Zanone & Kelso, 1997). With practice, individuals become perceptually attuned to environmental information that specifies task-relevant affordances, and develop the ability to organize functional coordination patterns (Davids et al., 2008b). Transfer of learning is the process of adapting that behaviour, previously developed with a certain set of constraints, to a new set of constraints (Newell, 1996; Rosalie & Müller, 2012). Transfer is evaluated on performance achievement, not on an 'idealised' movement reference, as different behaviours can lead to successful performance (Travassos et al., 2017). Transfer is positive when individuals successfully adapt their behaviour and improve their performance. Transfer is negative when performance decreases, or neutral when performance is not affected (Carroll et al., 2001). Despite transfer of learning being recognised as a central issue in motor skill performance (Adams, 1987; Shea, Kovacs, & Panzer, 2011), the practice conditions that foster the transfer process remains an open question (Broadbent, Causer, Williams, & Ford, 2015; Pacheco & Newell, 2015). It has been suggested that practicing with certain task constraints, for example equipment and rules, guides the development of an adaptive behaviour that, in turn, promotes skill transfer (Davids et al., 2008b); however, the relationship between task constraints and transfer of learning in sport is relatively un-explored.

The similarity of information that guides action is what promotes skill transfer between tasks (Pinder, Davids, et al., 2011b; Snapp-Childs et al., 2015). Research in sport has shown that similarity in the information that supports action between domains promoted transfer of perceptual-motor skills, from basketball to darts (Rienhoff et al., 2013) and from baseball to

cricket (Moore & Müller, 2014). However, since the interaction of task constraints shapes information (Newell, 1991), domain-specific task constraints are likely to influence skill transfer. Research in bimanual oscillatory finger movement showed how task constraints during practice influenced transfer. Participants who practiced a bimanual oscillatory finger movement at a 90-degree relative phase demonstrated transfer of the coordination pattern primarily to an untrained, 270-degree symmetrical phase (Zanone & Kelso, 1997). Given this research used a relatively-simple task, it is unclear how practicing a sport skill with different task constraints influences transfer. Here, we investigated this issue evaluating transfer of passing skill between futsal and soccer task constraints.

Futsal is the 5-a-side indoor form of football, whereas association football (also called soccer) is the 11-a-side outdoor form of football, both of which are officially regulated by the Fédération Internationale de Football Association (FIFA). Passing is the main skill performed in both domains (Mohammed et al., 2014; Rampinini et al., 2009) and is a complex perceptual-motor skill that involves the reception of the ball and a pass towards a teammate. Throughout the action, players are required to simultaneously perceive the surrounding environment and to execute the coordinated action to successfully deliver the ball to a teammate. Spatial and temporal information of attacker-defender interactions shapes the emergence of passing affordances during games (Travassos, Araújo, Davids, Vilar, et al., 2012). Specifically, relative angles and distances between the ball carrier and teammates, and the ball carrier and a teammate's nearest defender constrain the passing action. A player's ability to adapt his perceptual behaviour and action to the continuous changes of these relationships underpins successful passing performance (Corrêa et al., 2014a, 2014b; Travassos, Araújo, Davids, Esteves, et al., 2012). As such, players are required to attune their attention simultaneously towards this key environmental information to decide on who to pass the ball to, and towards

the approaching ball to guide the execution of reception and delivery of the ball (Oppici, Panchuk, Serpiello, & Farrow, 2017).

Table 6.1 *Soccer and futsal task constraints.*

Task constraints	Domain	
	Futsal	Soccer
<i>Number of players</i>	5 vs 5	11 vs 11
<i>Pitch size</i>	40 x 22.5 m	100 x 65 m
<i>Individual playing area</i>	90 m ² /player	295 m ² /players
<i>Rules</i>	Offside	No offside
<i>Ball circumference</i>	62.5 – 63.5 cm	68.5 – 69.5 cm
<i>Ball's coefficient of restitution</i> (Peacock, Garofolini, Oppici, Serpiello, & Ball, 2017)	0.51	0.60

The relative similarity of information that guides the passing action in both sports is expected to promote transfer of passing skill to the other domain. However, passing in the two domains is practiced with different task constraints, including the ball, playing surface and individual playing area (see Table 6.1) that influence perception-action coupling, and, in turn, affect the transfer process. The smaller individual playing area in futsal likely leads to more frequent and rapid changes of inter-player relationships (i.e., relative distance and angles) than soccer, which could fast-track players' ability to explore the information that specifies passing affordances. This might be facilitated by the futsal ball's lower coefficient of restitution (Peacock et al., 2017) and flat surface that simplify ball control. It has been shown that futsal players explored different information (i.e., ball & players) more frequently and oriented their attention to players' movement for longer than soccer players when performing passes during games (Oppici et al., 2017). Perceptual-motor exploration during practice has been shown to facilitate skill adaptability and, in turn, transfer of skills (Bennett et al., 1999). Therefore, it is likely that (the magnitude of) transfer will be higher from futsal to soccer task constraints than

vice-versa. However, it is unclear how practicing the passing skill with futsal or soccer task constraints influences transfer.

The aims of this study were i) to determine how learning the passing skill with domain-specific task constraints influenced the transfer to new task constraints, and ii) to explore how perceptual behaviours supported transfer. Passing performance and attention orientation were assessed in young, skilled (i.e., with more than 1000 h of domain-specific experience) futsal and soccer players during modified games. Participants performed a game with their own-domain task constraints and a game with the other-domain task constraints to evaluate transfer. Although a certain degree of transfer in both groups is expected, given the relative similarity of information that guides passing between the learning and transfer tasks, we predicted a higher magnitude of transfer for futsal players. Therefore, it is expected that futsal players would improve their passing performance from futsal to soccer task constraints, while soccer players' passing performance would remain stable across the two modified games.

6.2 Method

6.2.1 Participants

Data collection for this study took place after the study discussed in chapter 5, and the same forty-eight (n=48) skilled, young, male players were recruited. They were divided into two groups based on their domain of expertise: soccer players (n=24, 13.6 ± 1.2 years old, 6.8 ± 1.2 years of experience) and futsal players (n=24, 13.6 ± 1.2 years old, 7.0 ± 1.6 years of experience). The years of experience refer to structured team practice in their domain. Participants completed a questionnaire on their training history, which included the number of training years at club level, and an average amount of training months per season, number of training sessions per week and session duration (Appendix C). Participants had approximately 1220 and 1260 hours of domain-specific structured practice in soccer and futsal, respectively.

Only players that had never practiced the other sport at club level were included in the sample. As such, participants had competitive experience only in their own sport. To control for training and competition time, two squads (U13 and U15) from within one of the most successful Spanish futsal teams and the most successful Australian State representative soccer squads were recruited. Both groups had a similar weekly training schedule that included four 90-minute training sessions and one competitive game. Only outfield players were sampled from the squads. Technical issues during data collection (e.g., the scene camera moved during the game, unreliable video quality, etc.) resulted in a final sample size of 17 futsal players (U13=9 and U15=8) and 20 soccer players (U13=9 and U15=11).

Prior to the study, participants were fully informed of the risks involved in participating in the experiment and their parents or guardian provided written consent for them to participate. The study was approved by the research team's University Ethics Committee.

6.2.2 Experimental task and procedure

The experimental task was a 6-vs-6 (including goalkeeper) modified game. Two tasks were designed sampling the task constraints typical of passing (i.e., playing space, ball and surface) of the two sports. A soccer task (SOC) was performed with a FIFA quality-approved soccer ball, on a synthetic-grass pitch of 24 m x 36 m corresponding to an individual playing area of 86 m²/player, which is representative of playing space during soccer game (Fradua et al., 2013). A futsal task (FUT) was performed with a FIFA quality-approved futsal ball, on a wooden pitch of 24 m x 15 m corresponding to an individual playing area of 36 m²/player, which is the most common density in futsal matches (unpublished observations). These two tasks did not maintain the same number of players and pitch dimension of their relative sport; therefore, they cannot be considered representative of the two games. However, inter-player interactions, which shape the emergence of task-relevant passing affordances, were sampled from the two sports using playing area as key constraint; thus, based on the principles of representative

learning design (Pinder, Davids, et al., 2011b), these tasks can be considered representative of short passing skill in futsal and soccer.

An external camera (GoPro 3+, California, USA) was placed in one corner of the pitch to record the task, allowing the off-line evaluation of pass outcome. The scene camera of a mobile eye tracking system (Mobile Eye, Applied Sciences Laboratories, Bedford, MA, USA) was used to collect participants' attention orientation.

Participants performed two sessions in total; a familiarization session, which consisted of a shortened version of the experimental session, and an experimental session in the other-domain task. The sessions were interspersed by 48 hours. Each experimental session comprised of six games that were 5 minutes in duration with 5-minute breaks between games. Two participants wore the scene camera during each game and the participants rotated between tasks (e.g., participants A and B wore the camera in game 1, then participants C and D wore the camera in game 2, and so on) to assess all 12 players throughout the session. As a result, each player wore the scene camera during one game and participated in 5 games in total, having rested the game prior to wearing the scene camera.

After a standardized, 10-minute warm-up, each group was randomly divided into two teams of 6 players plus a goalkeeper. Before each task, two participants were fitted with the Mobile Eye. The task started with the investigator bouncing the ball on the ground. The bounce was used as reference to synchronize the eye-tracker scene camera and the external camera. One of the investigators umpired the games.

6.2.3 Data analysis

Pass accuracy. Participants' pass accuracy was evaluated as the main performance variable. A pass was considered accurate when the ball reached a teammate (i.e., the teammate made contact with the ball before any opponent), consistent with previous research (Serpiello,

Cox, Oppici, Hopkins, & Varley, 2017). Pass accuracy was evaluated using a commercially-available video analysis software (Sports Code, SportsTec by Hudl, Australia).

Attention orientation. Attention orientation and game dynamics variables are briefly presented as further details are presented in chapter 5 and published elsewhere (Oppici et al., 2017). Participants' attention orientation was classified into two areas of interest, namely ball-directed and player-directed, using the gaze window previously validated. The orientation of attention was classified either as i) ball-directed, when the ball was visible or when only below a player's knee was visible, or ii) as player-directed, when above a player's knee was visible and the ball was not visible. The footage from the scene camera and the external camera, both recorded at 30hz, were synchronized using Sports Code to couple the orientation of attention with specific events, consistent with the Vision-in-Action procedure (Vickers, 1996). The game was divided into three phases, reception (the time from a teammate's pass to participant's first touch), control (from participant's first touch to pass release) and team phase (time of participant's team ball possession minus the previous two phases). Three attention-orientation variables were determined: relative attention-orientation time in the two areas of interest (AT), attention-orientation switches between the two areas (AS), and last-attention location (AL). These dependent variables were evaluated frame-by-frame using Sports Code. AT and AS were evaluated, separately, in each phase, whereas AL was examined only in the reception and control phases.

Passes where the receiving pass (from the teammate) was bouncing and the participant's body was oriented towards the side line (with less than 4 players in front of him) were excluded from the analysis to limit the influence of external factors. Furthermore, only passes that included the control phase were considered (i.e., direct passes were excluded). This resulted in a total of 731 passes analysed, 369 in FUT (169 futsal group, 200 soccer group) and 362 in SOC (181 in both groups).

Game dynamics. Three game-related variables were evaluated to quantify the context in which the passes were performed: technical intensity (i.e., number of passes per minute), individual playing area (IPA) and reception time.

6.2.4 Coding reliability

Five percent of the trials were randomly selected and independently coded by two coders, and then re-coded a week later by the primary coder for inter- and intra-rater reliability. Cohen's kappa was above 0.9 in all dependent variables in both intra- and inter-rater reliability, representing perfect agreement (Landis & Koch, 1977).

6.2.5 Statistical analysis

Pass accuracy and attention-orientation dependent variables were analysed separately using generalized linear mixed modelling with repeated measures (Proc Glimmix in Version 3.6 of Statistical Analysis System Studio, SAS Institute, Cary, NC), with group (soccer, futsal) and task (SOC, FUT) as fixed factors and participants as a random factor. The model allowed for overdispersion (i.e., non-uniformity of error). Specifically, a logistic regression was computed for pass accuracy, AT and AL, being binary dependent variables, whereas Poisson regression was computed to analyse AS as data was expressed as count per unit of time (switches/sec). Furthermore, pass accuracy was adjusted for game dynamics, having compared two different groups' outcome in the same task. The game dynamics variables were analysed separately using an independent t-test for the two tasks.

Significance was set at $p < .05$ for all the analyses and the magnitude of changes was assessed using Effect Sizes (Cohen's d) with 90 % Confidence Intervals defined as follows: <0.2 trivial, $0.2-0.6$ small, $0.6-1.2$ moderate, $1.2-2.0$ large, >2.0 very large (Hopkins, 2010a). The between-subject standard deviation for the standardization of the effect sizes was calculated using the pure observed between-subject variance and the overdispersed sampling variance as follow: $\sqrt{(\textit{Athlete ID variance} + \textit{overdispersed sampling variance})}$.

6.3 Results

6.3.1 Pass accuracy

There was a significant task effect in the futsal group only ($p = 0.046$, $ES = 0.75 \pm 0.61$) (Figure 6.1). Futsal players improved their passing accuracy from FUT to SOC, while pass accuracy of soccer players remained stable across the two tasks. Furthermore, there was a very large, group effect in pass accuracy in SOC ($p = 0.09$, $ES = 2.98 \pm 2.96$). Futsal players performed more accurate passes than soccer players. No difference was found in pass accuracy in FUT.

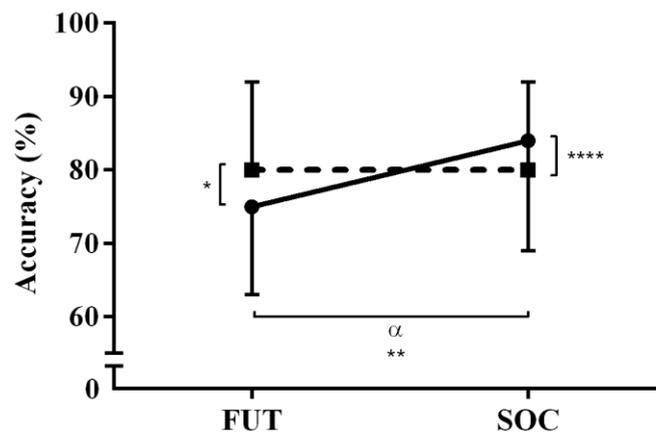


Figure 6.1 Mean pass accuracy in the performance of FUT and SOC task. The futsal group is presented with the solid line, while the soccer group with the dashed line. α : statistically significant, effect sizes: *small, **moderate, ***large, ****very large. Error bars represent ± 1 SD from the mean.

6.3.2 Attention orientation

The mean data for attention-orientation variables is presented in Table 6.2.

Reception phase. In the reception phase, there was a significant group effect in AL in FUT ($p < 0.01$, $ES = 1.35 \pm 0.58$), while there was a small group effect in AL in SOC ($p = 0.07$,

ES = 0.58 ± 0.53). Furthermore, there was a significant task effect in both futsal ($p < 0.01$, ES = 1.41 ± 0.52) and soccer group ($p = 0.02$, ES = 0.62 ± 0.45) in AL (Figure 6.2). Prior to first touch, futsal players oriented their attention towards other players more times than soccer players in FUT, while this difference was smaller in SOC; both groups oriented their attention towards other players more times in FUT than SOC. No group or task effect were found in AS and AT.

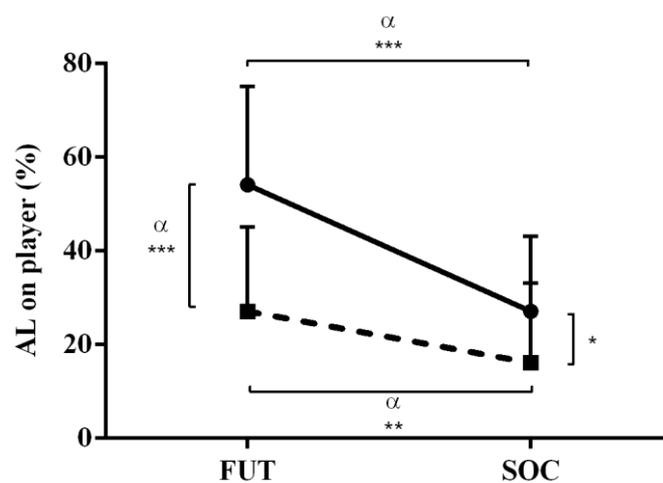


Figure 6.2 Mean AL on player-directed areas in the reception phase. The futsal group is presented with the solid line, while the soccer group with the dashed line. α : statistically significant, effect sizes: *small, **moderate, ***large. Error bars represent ± 1 SD from the mean.

Control phase. In the control phase, there was a significant task effect in the futsal group in AL ($p = 0.048$, ES = 0.57 ± 0.47) and in AT ($p = 0.01$, ES = 0.73 ± 0.45). Futsal players oriented their attention towards the ball more times in SOC than FUT prior to performing the pass, and for a longer period throughout the phase. No group effect or task effect in the soccer group was found in AT and AL, and no group or task effect in AS.

Team phase. In the team phase, there was a group effect in SOC ($p = 0.04$, $ES = 0.73 \pm 0.58$) and a task effect in the soccer group ($p < 0.01$, $ES = 0.54 \pm 0.29$) in AT. Soccer players oriented their attention towards other players for longer than futsal players in SOC, and for longer in SOC than FUT. No group effect was found in FUT, and no task effect in the futsal group. Furthermore, there was a group effect in FUT ($p = 0.01$, $ES = 0.87 \pm 0.54$) and in SOC ($p < 0.01$, $ES = 0.99 \pm 0.60$) in AS (Figure 6.3). Soccer players switched their attention between ball and players more frequently than futsal players in both tasks. No task effect was found in both groups in AS.

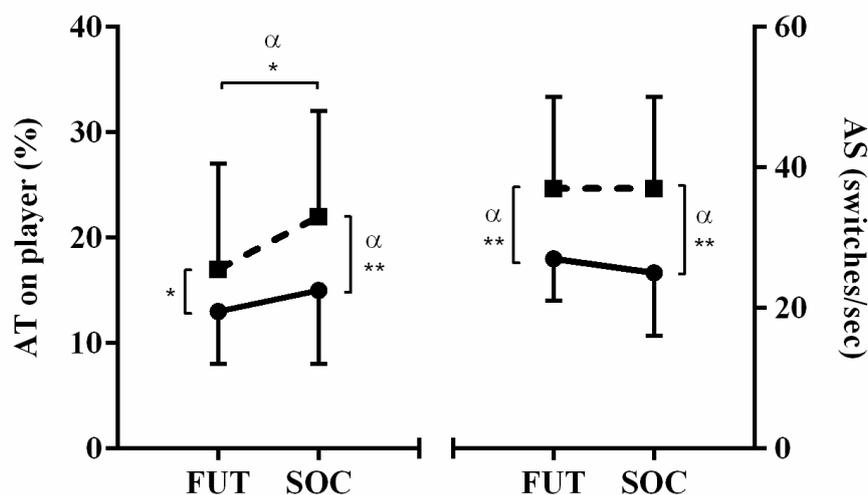


Figure 6.3 Mean AT on player-directed area (left side) and mean AS (right side) in the team phase. The futsal group is presented with the solid line, while the soccer group with the dashed line. α : statistically significant, effect sizes: *small, **moderate, ***large. Error bars represent ± 1 SD from the mean.

Table 6.2 Mean relative attention-orientation time on player-directed area (AT, in percentage), attention-orientation switches (AS, in switches/sec) and last-attention orientation on ball-directed area (AL, in percentage) \pm SD of the two groups across the three different phases in the two tasks. Significance was set at $p < 0.05$. Effect sizes: *small, **moderate and large***.

Phase	Variable	Within-group comparison						Between-groups comparison	
		Futsal group			Soccer group			p value	
		FUT	SOC	p value	SOC	FUT	p value	FUT	SOC
<i>Reception</i>	<i>AT</i>	17 \pm 12	13 \pm 9	0.2*	14 \pm 10	15 \pm 10	0.9	0.4*	0.8
	<i>AS</i>	1.0 \pm 0.5	0.9 \pm 0.5	0.4*	0.6 \pm 0.3	0.8 \pm 0.4	0.4*	0.2*	0.3*
	<i>AL</i>	54 \pm 21	27 \pm 16	<0.01***	16 \pm 17	27 \pm 18	0.02**	<0.01***	0.07*
<i>Control</i>	<i>AT</i>	50 \pm 19	39 \pm 15	0.01**	34 \pm 18	40 \pm 19	0.1*	0.1*	0.5
	<i>AS</i>	0.9 \pm 0.3	0.8 \pm 0.3	0.1*	0.9 \pm 0.3	0.9 \pm .04	0.9	0.3*	0.4*
	<i>AL</i>	20 \pm 23	9 \pm 13	0.05*	14 \pm 21	18 \pm 20	0.5	0.7	0.4*
<i>Team</i>	<i>AT</i>	13 \pm 5	15 \pm 7	0.2*	22 \pm 10	17 \pm 10	<0.01*	0.2*	0.04**
	<i>AS</i>	0.3 \pm 0.1	0.3 \pm 0.1	0.8	0.4 \pm 0.1	0.4 \pm 0.1	0.8	0.01**	<0.01**

Note: the data on groups' attention orientation in their own task (i.e., futsal group in FUT and soccer group in SOC) was collected in the study discussed in chapter 5.

6.3.3 Game dynamics

There was a significant group effect in technical intensity in FUT ($p < 0.01$, ES 3.25 ± 0.48) and in SOC ($p < 0.01$, ES 4.34 ± 0.48). The futsal group performed a higher number of passes per minute than the soccer group in both tasks. There was a group effect in IPA in FUT ($p < 0.01$, ES 0.91 ± 0.54), while there was no effect in SOC. The futsal group had a lower individual playing area than the soccer group in FUT. No group effect was found in reception time in both tasks (Figure 6.4).

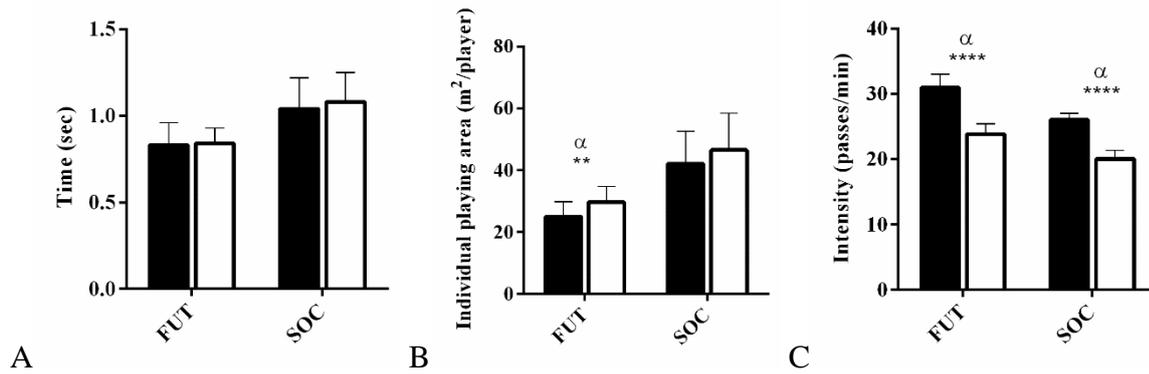


Figure 6.4 Mean reception time (A), mean individual playing area (B), and mean technical intensity (C). The black and white bars represent futsal and soccer group, respectively. α : statistically significant, effect sizes: *small, **moderate, ***large, ****very large. Error bars represent ± 1 SD from the mean.

6.4 Discussion

This study examined how learning the passing skill with futsal or soccer task constraints influenced transfer to the other domain's task constraints. It was hypothesised a certain degree of transfer both in futsal and soccer players, given the relative similarity of information that supported action during practice and the transfer task. However, it was hypothesised that there would be a higher magnitude of transfer from futsal practice to the soccer modified game due to the effect of practicing passes with a smaller individual playing area, shorter reception time and higher technical intensity. The hypothesis was confirmed as the futsal group significantly improved their passing accuracy from FUT to SOC, while the passing accuracy of the soccer group remained stable (Figure 6.1). This indicated positive transfer of passing skill from futsal practice to soccer task constraints, and neutral transfer of the soccer group. Furthermore, the results showed that futsal players performed more accurate passes with higher game intensity than soccer players in SOC, while soccer players performed passes with similar accuracy but lower game intensity than futsal players in FUT.

Transfer is the process of adapting a learned behaviour to new constraints (Newell, 1996; Rosalie & Müller, 2012), and these results indicated practicing the passing skill with futsal task constraints facilitated a higher degree of adaptation to new task constraints than practicing with soccer task constraints. The results on attention orientation during reception and control phases suggest that futsal players' adaptation of perceptual behaviour to the passing affordances that emerged in SOC might have facilitated skill transfer. The recruited participants have practiced passing exclusively with the task constraints sampled in this study in their own domain (i.e., ball, playing surface and individual playing area) for more than 1000 h, thus, the perceptual behaviour of futsal players in FUT and soccer players in SOC could be viewed as a 'desirable' attunement to task-specific passing affordances in FUT and SOC, respectively. For example, information about the ball during the reception and control phases seems to be critical with the soccer task constraints, considering that the soccer group oriented their attention primarily to the ball in SOC (Table 6.2). This might be important to ensure a good impact with the ball both at reception and delivery. Futsal players significantly changed their orientation of attention during the reception and control phases from FUT to SOC, increasing AL and AT to the ball, which resulted in a similar behaviour to soccer players. The higher passing accuracy of the futsal group compared to the soccer group in SOC suggests that futsal players not only adapted their attention orientation according to the emergence of passing affordances in SOC but they were also able to better perceive information that specified affordances and couple a functional passing action. On the other hand, soccer players' orientation of attention remained stable across the two tasks, except for AL in the reception phase that slightly changed, which might explain the group's stable passing performance.

The results of this study have theoretical and practical implications. Researchers have suggested that practicing with a certain set of task constraints develops functional perception-action coupling that, in turn, might promote transfer of skills (Araújo et al., 2004; Davids et

al., 2008b). The results of this study have shown how learning the passing skill with futsal and soccer task constraints affected skill transfer. Skill learning in team sports entails exploring perception-action relations, discovering and stabilising functional solutions, and exploiting affordances and degrees of freedom (Araújo, Davids, Chow, & Passos, 2009). Task constraints that encourage exploration of information during practice can fast-track the stabilisation of functional movement solutions in a transfer task (Pacheco & Newell, 2015). For example, practicing a catching skill with restricted vision encouraged individuals to explore additional task-relevant information, improving a full-vision task (transfer) performance (Bennett et al., 1999). We speculate that practicing passes with the time-demanding futsal task constraints enhanced players' ability to search for and to exploit information that specified affordances in SOC. Futsal requires a continuous (re)attunement to informational constraints that support the passing action, which might have facilitated discovery and stabilisation of functional perception and action couplings with the less demanding soccer task constraints. Conversely, practicing the passing skill in a relatively large space with more time to act did not facilitate soccer player's ability to discover functional movement solutions in FUT, and performance did not improve.

Practitioners should be encouraged to manipulate task constraints during training to expedite their players' learning and transfer of skills. The number of players and pitch dimensions (potentially the main constraints that promote transfer) are typically reduced in small-sided games during training (Davids et al., 2013), and this study demonstrated how the use of a smaller playing area can improve passing performance in a larger playing area. Conversely, practicing within a large playing area may limit performance in a smaller playing area. Furthermore, given its more predictable trajectory and being easier to kick (Peacock et al., 2017), the futsal ball might have also played a role in developing futsal players' ability to explore and exploit the informational constraints that supported the passing action. It has

been recently suggested that futsal practice can fast-track the development of soccer-related skills (Travassos et al., 2017). While being limited to short passing skill with the sample constraints (i.e., ball, playing surface and playing area), the results of this study suggest soccer practitioners to introduce futsal task constraints in their practice to improve their athletes' passing performance.

The results have been interpreted as being influenced by long-term practice with domain-specific task constraints. However, it cannot be excluded that factors other than task constraints contributed to the results, e.g., futsal participants potentially performed more activities or participated in other sports that promoted skill adaptability relative to soccer participants. The questionnaire adopted in this study to collect participants' training history did not allow to record the specific practice activities the players engaged in throughout their career, potentially limiting the interpretation of the results. While logistical issues (i.e., the clubs' tight practice schedule) prevented its use in this study, future research should adopt a validated participation history questionnaire (e.g., Ward et al., 2007) to properly account for the effect of practice activities on transfer of skill. Furthermore, a future research direction would be to conduct a longitudinal study manipulating domain-specific task constraints to evaluate direct correlations between certain task constraints and skill transfer in similar domains.

6.5 Conclusions

This study highlighted how learning a passing skill with futsal task constraints (i.e., small area and short time to act) promotes transfer to soccer task constraints (i.e., larger space and longer time to act) than vice-versa. Futsal players improved their passing performance when they moved to the soccer-like task, while soccer group's passing performance remained stable. The more adaptable perceptual behaviour of the futsal group is suggested to be one of

the main mechanisms promoting skill transfer. Practitioners are encouraged to reduce playing area during training to enhance players' ability to functionally couple perception and action when playing in larger playing area.

CHAPTER 7

THE INFLUENCE OF EQUIPMENT ON TRANSFER OF PERCEPTUAL-MOTOR SKILL

7.1 Introduction

The characteristics of equipment, such as ball compression and bat dimensions can be modified to simplify the execution of sport skills in children or in novices, potentially fast-tracking the learning process (Araújo et al., 2004; Farrow et al., 2016). Buszard et al. (2016b) recently illustrated in their systematic review the psychological, biomechanical, cognitive, and skill performance factors that can be promoted using modified equipment, and also highlighted a lack of transfer studies which limits the current understanding of how modified equipment influences skill learning. Furthermore, previous research has mainly assessed the physical aspects of performance, e.g., number of skill executions (Farrow & Reid, 2010), fluency of movement (Buszard et al., 2016a), while the perceptual side of performance has remained relatively un-explored. As such, it is currently unclear whether skills learned with modified equipment transfer to tasks that employ other equipment (e.g., standard equipment) and how the supporting perceptual behaviour is affected.

Skilled behaviour emerges from the coupling of perception and action under the interaction of organismic (e.g., action capabilities and intentions), environmental (i.e., features of the environment), and task (e.g., equipment) constraints (Araújo & Davids, 2011; Kelso, 1995; Newell, 1986). Opportunities for action (i.e., affordances) emerge from the performer-environment interaction (Gibson, 1979; Newell, 1991). The perception of information specifying affordances regulates decision-making and the self-organisation of coordination patterns (Araújo et al., 2006; Davids et al., 2008b). In this sense, perception, cognition and action are intertwined processes that underpin an individual's skill (Araújo et al., 2006; Araújo, Hristovski, Seifert, Carvalho, & Davids, 2017).

Transfer of skill in this context, refers to how previous exposure to a particular set of interacting constraints influences task performance under different constraints (Newell, 1996; Rosalie & Müller, 2012; Seifert et al., 2016). Skill transfer is evaluated on performance

achievement (i.e., the degree of success when performing a task; Araújo & Davids, 2015), and is considered positive when previous practice leads to a performance improvement under a new set of interacting constraints (Carroll et al., 2001). Positive transfer occurs due to the due to the similarity between a practiced behaviour and the functional perception-action coupling required in a new task (transfer) to achieve the task goal (Newell, 1996; Pacheco & Newell, 2015).

A modification to equipment, which is a task constraint, influences how perception, cognition, and action emerge (Araújo et al., 2004). Practicing with a piece of equipment shapes how individuals educate their attention towards the information that specifies affordances, and how they self-organise coordination patterns (Davids et al., 2008b). The skill learned with a specific piece of equipment can positively transfer if the developed behaviour cooperates with the new task constraints (e.g., different equipment) (Kelso & Zanone, 2002; Zanone & Kelso, 1997). Put simply, an equipment modification that facilitates perception (cognition) and action coupling in a new task promotes transfer. Similarity of the information that guides action between the learning and transfer tasks promotes the transfer process (Pinder, Davids, et al., 2011b; Snapp-Childs et al., 2015). The influence of equipment on the transfer of perception and action is relatively un-explored in the human movement field; the current study examined how modifications to equipment influence the transfer of passing skill from a futsal ball to a soccer ball.

The passing skill in soccer is a complex perceptual-motor skill that involves making a decision, on who to pass a ball to, and kicking the ball towards a teammate (Oppici et al., 2017). Perception, decision-making and the passing action are intertwined and emerge from the interaction of a passer with their environment and the characteristics of the task. A successful pass entails perceiving information specifying affordances (e.g., distances and angles between players; Travassos, Araújo, Davids, Vilar, et al., 2012) and organising a functional kicking

action to successfully kick the ball to the intended player. The analysis of eye movements can be used for examining attentional processes that underpin passing, due to the partial-interdependence of attention and eye movements (Dicks et al., 2010; Van Gompel et al., 2007). Gaze patterns provide information on individuals' attunement to environmental information, and provide insights into changes in perceptual skills (Panchuk et al., 2015). For example, previous research has showed that frequent switches of attention between the ball and players underpinned successful passing performance in soccer (Vaeyens, Lenoir, Williams, & Philippaerts, 2007).

Futsal (FB) and soccer (SB) balls are used in futsal (the 5-a-side form of football) and soccer (or soccer, the 11-a-side form of football) respectively, and they are likely to influence how the passing skill emerges. Both balls (i.e., FB and SB) are spherical but differ in size, circumference of 63 and 69 cm, weight, 420 and 430 gr (FIFA, 2010), and coefficient of restitution, 0.51 and 0.60 (Peacock et al., 2017). While previous research showed that, in a group of young athletes, practicing futsal or soccer exclusively influenced the perceptual skill underpinning passing (Oppici et al., 2017), the effect of the different balls alone on passing is unclear. Futsal balls are thought to be easier to handle due to a higher energy loss during football impact (due to the lower coefficient of restitution) that prevents FB from bouncing off the foot uncontrollably (Peacock et al., 2017). Equipment that simplifies the execution of a skill promotes skill automaticity (i.e., execution with little or no involvement of attention) (Buszard et al., 2014b), which, in turn, can facilitate an efficient allocation of attention towards environmental information (Mackenzie & Harris, 2017). Therefore, practicing the passing skill with a FB is expected to promote the development of more efficient perception-action coupling relative to a SB, and the behaviour developed is expected to transfer to passing with SB due to task similarity. While, previous research (Travassos et al., 2017) and anecdotes from elite

soccer players (UEFA, 2014) have suggested that practicing with a FB fosters the development of passing skill in soccer, implying the transfer of skill, this issue has not been investigated.

The aim of this study was to determine the transfer of learning of passing skill from a FB to a SB, and the perceptual behaviour supporting it. The passing-skill learning of adult novices, who trained with a FB for 3 sessions, was evaluated against a control group who trained with a SB. Pre- and post-training assessments were performed using a SB in both groups to evaluate transfer. It was hypothesised that positive transfer of passing skill from a FB to a SB would be indicated by higher improvement in passing performance for participants training with a FB relative to the SB group, due to the FB's properties and task similarity. The superior performance improvement was hypothesised to be underpinned by development of an efficient perceptual attunement to task-relevant information, encouraged by a higher level of skill automaticity. FB was predicted to facilitate skill automaticity that, in turn, would promote higher attention alternations between ball and players, lower attention time on ball and higher attention time on players.

7.2 Method

7.2.1 Participants

A total of 24 adult novices (n=18 females and n=6 males, 24 ± 4.8 years old) were recruited for the study. The required sample size was calculated a-priori using G*Power (version 3.1), with a repeated-measures test (within-between interaction), with $\alpha = 0.05$, power $(1 - \beta) = 0.95$, and an effect size of $f = 0.42$ (derived from similar studies with a similar design; Abernethy, Schorer, Jackson, & Hagemann, 2012; Broadbent, Causer, Ford, et al., 2015), resulting in a total sample size of 22 with an actual power of 0.96. Two extra participants were recruited (9% of calculated sample size) to account for attrition.

Participants had no prior experience in organised soccer or futsal (i.e., in a sport club), and their experience in recreational soccer (i.e., kicking with friends or at school) and in other team sports was collected using a customised questionnaire (Appendix F). The participants were divided into two groups, a futsal-ball experimental group (FUT) and a soccer-ball control group (SOC), after the pre-intervention test using the minimisation procedure, which randomises the allocation of participants minimising group differences in the variables of interest (Hopkins, 2010b). Following this procedure, the two groups were matched for their pre-test performance outcome, previous experience in soccer and other team sports (Table 7.1).

Table 7.1 *Characteristic data (mean \pm SD) for the two groups in relation to age and sport participation experience*

	FUT	SOC	p value
<i>Age</i>	24.6 \pm 4.2	23.5 \pm 5.5	0.59
<i>Performance accuracy (AU)</i>	0.10 \pm 0.03	0.09 \pm 0.05	0.92
<i>Soccer experience (hours)</i>	115.8 \pm 119.5	124.8 \pm 96.5	0.84
<i>Team-sport experience (hours)</i>	100.8 \pm 89.9	97.5 \pm 94	0.93

Prior to the study, participants were fully informed of the risks involved in participating in the experiment and they provided written informed consent to participate. The study was approved by the research team's University Ethics Committee.

7.2.2 Experimental design

The experimental design comprised of a pre-test, three training sessions, and a post-test (Figure 7.1). The sessions were interspersed by 48 h, and the time of each session was kept consistent throughout the study. Participants were not practicing any team sports at the time of recruitment and were instructed to refrain from engaging in team-sport activities or any additional kicking practice.

Both pre- and post-test sessions were performed with SB in both groups, while the two groups used a different ball in the training sessions (i.e., FUT used FB and SOC used SB). Only FIFA-quality approved balls were used. The SB was a ‘Match’ (Select Sport A.S., Copenhagen, Denmark), inflated at 0.85 atmosphere; while the FB was a ‘Conext15’ (Adidas, Herzogenaurach, Germany), inflated at 0.75 atmosphere. Ball inflation was checked at the beginning of each session, and the inflation values corresponded to the range midpoint specified in the FIFA guidelines (FIFA, 2010).

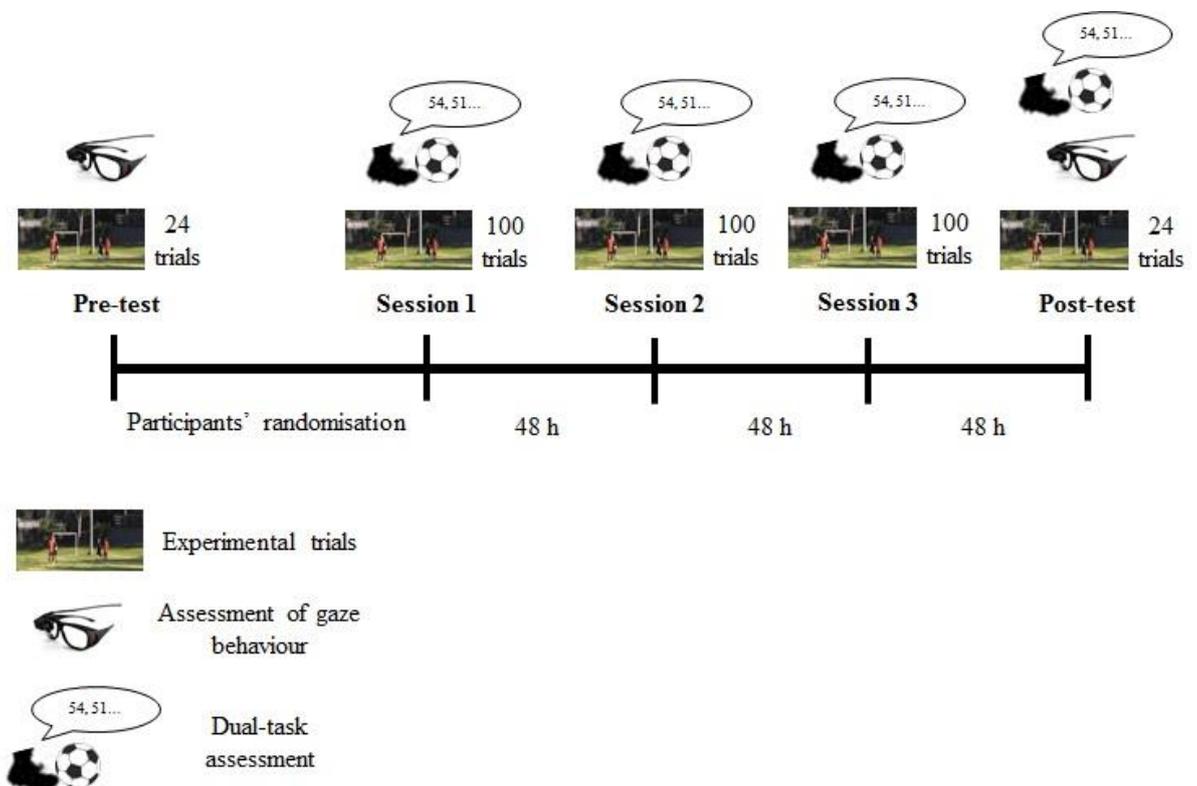


Figure 7.1 Schematic of the study design.

7.2.3 Test and training stimuli constructions

Eight male soccer players (24.4 ± 4.4 years old), who regularly played in regional soccer competitions, were filmed while performing soccer-specific movements on an outdoor pitch to create the experimental video stimuli. A video camera (Panasonic HC-V380K Full HD, Osaka, Japan) was positioned 20 m away from the players, at a height of 1.75 m to approximate a

soccer player's field of view during games. The players were divided in two teams, a red-uniform attacking team and black-uniform defending team, and three different scenarios were created, including 2v2, 3v3 and 4v4. The players, organised in red-black pairs, were instructed to perform set movements, with the red players moving to receive the ball from the investigator positioned behind the camera, and the black players tightly marking their direct opponent. Each trial ended with one of two potential outcomes, either one of the attacking players was unmarked (i.e., his direct opponent stopped following him) or all attacking players were tightly marked. An investigator's verbal signal started the trial, while a second verbal signal indicated the type of outcome.

The footage was then edited using Windows Media Player (Microsoft, Washington, USA) to create decision-making video clips lasting 2.5 s. In each scenario, three different types of clips were created, namely early decision, late decision and no decision. The timing of the attacking player becoming free to receive a pass was between 1.5-1.7 and 2.0-2.1 s for the early- and late-decision clips, respectively, while no attacking player was free in the no-decision clips. The early-decision clips represented an easier challenge than late-condition clips as the teammate was free for a longer period and participants had more time to organise their passing action. Each video clip included, in the following order, a 2-s image of the first frame, a 3-2-1 countdown, the video and then a black screen with red vertical lines corresponding to the final position of the attacking players (Figure 7.2).

7.2.4 Apparatus and procedure

The experimental task involved the participant making a direct pass of a moving ball in response to the video stimuli using the inside part of the dominant foot. The video clips were projected, using a roof-mounted front projector (Mitsubishi XD550U, Tokyo, Japan), onto a screen (4 x 2.5 m). To ensure consistency, the ball was delivered to the participants along the ground through a hole at the bottom of the screen, via a custom-made ramp, positioned

behind the screen, that allowed speed to be approximately $2 \text{ m}\cdot\text{sec}^{-1}$ (Button et al., 2005).

This task was designed to improve the representativeness of the passing skill in a laboratory setting. While previous research did not consider it (e.g., Helsen & Starkes, 1999; Vaeyens, Lenoir, Williams, & Philippaerts, 2007), the reception phase of a pass (i.e., when the ball travels towards the person making a pass) is critical as it challenges an individual's perception of information about ball's and player's behaviour (Oppici et al., 2017; Oppici, Panchuk, Serpiello, & Farrow, 2018).

Pilot trials, where ball speed was indirectly calculated by measuring (from video) the time from the ball exiting the ramp to reaching the spot where participants stood, showed consistency in ball speed in both balls, being 1.96 ± 0.04 and $1.95 \pm 0.04 \text{ m}\cdot\text{sec}^{-1}$ in FB and SB, respectively. The ball delivery and the start of the video were manually coupled, i.e., the ball was released on the '1' of the countdown, with the video starting when the ball passed through the screen hole. The similarity of trial duration in the two groups (2342 ± 123 and $2366 \pm 132 \text{ ms}$ in FUT and SOC, respectively) indicated consistent video-ball coupling across the two groups.

Participants were instructed to stand on a specific spot, 5 m in front of the screen, wait for the ball and pass it directly (i.e., without controlling it) along the ground towards the free teammate (i.e., red attacking player). The pass had to be directed to the teammate's current position, not to the end-run trajectory. However, participants had to hold the ball when they thought that no teammate was free. After each trial, participants were asked to verbalise their decision saying out loud the number (counting the red lines left to right) corresponding to the teammate they intended to pass the ball to. This was included to assess participant's decision independently from the accuracy of the kick.

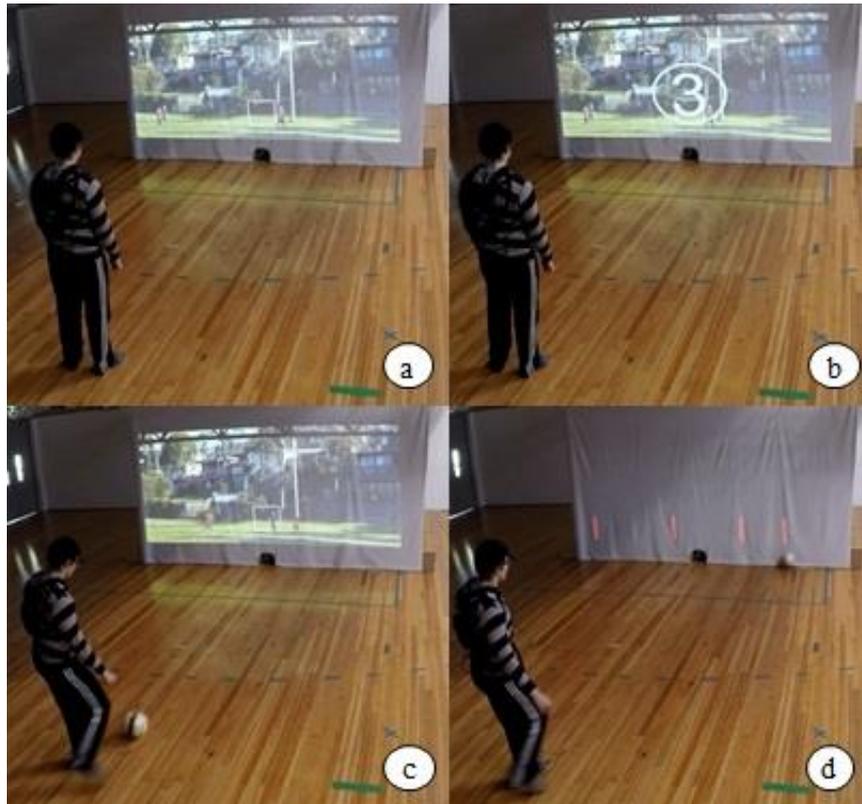


Figure 7.2 Sequence of the video stimuli, including image of the first frame (a), 3-2-1 countdown (b), video (c) and black screen with vertical red lines (d).

A Mobile Eye system (Applied Sciences Laboratories, Bedford, MA, USA) was used to collect participants' gaze behaviour at 30Hz during the testing sessions. The Mobile Eye uses an eye-tracking technique known as 'Pupil to CR' which correlates pupil and corneal reflection features to compute gaze within the scene being viewed. An external camera (GoPro Hero4, California, USA) was placed in a corner to record participants' performance at 30Hz.

Pre-and post-test. The testing sessions comprised of 24 trials, divided into two blocks of 12, including twelve 2v2 and twelve 4v4 scenarios, in a sequence that was consistent in both sessions across participants. Each scenario included 5 early, 5 late and 2 no decision conditions. The trials were interspersed by approximately 30 s, and no feedback was provided throughout the session.

The sessions started with 20 warm-up kicks towards vertical red lines projected onto the screen. Participants were then fitted with the eye tracker and the system was calibrated using a 9-point reference grid. The calibration was checked between the two trial blocks.

In the pre-test, before the experimental trials, participants were provided with instructions projected onto the screen that explained the task in detail, and then provided with 10 practice trials to become familiar with the video stimuli and with wearing the Mobile Eye unit.

In the post-test, participants also performed a dual-task kick assessment before the decision-making trials. The dual-task condition involved 10 kicks towards red lines projected onto the screen while simultaneously counting back-wards out loud in 'threes' as quickly as possible from a number indicated by the researcher. In each trial, the researcher provided a different number (e.g., 54 or 76) and, after a 3-2-1 countdown, on the 'go' signal the ball was released and participants started counting until the ball was kicked. Counting back-wards is a valid stimulus to overload individuals' attention while performing movements (Buszard et al., 2014b). Participants were instructed to perform accurate kicks while counting quickly and accurately, prioritising kick accuracy. Before the dual-task condition, participants performed 10 single-task kicks (i.e., kicking only) and 5 single-task counting (i.e., counting only). The red line positions and number order were consistent across participants.

Intervention. The 3 training sessions comprised of, in the following order, 20 warm-up kicks, a dual-task assessment (same procedure as post-test) and 100 trials, divided in six blocks of 15 trials and one block of 10 trials. The order of trials was different in each session but consistent across participants. The trials included thirty-six 2v2 (16 early, 15 late and 5 no decision), thirty-two 3v3 (13 early, 15 late and 4 no decision) and thirty-two 4v4 trials (9 early, 19 late and 4 no decision). Feedback on decision accuracy was provided after each trial. The sessions were filmed using the external camera.

7.2.5 Data analysis

Performance accuracy. Considering that all trials involved a decision but not all of them required a pass, a performance variable was created to capture participant's performance accuracy. Performance accuracy was evaluated by combining decision accuracy and pass accuracy. Performance accuracy provided a measure of performance that balanced potential correct decisions ending with bad kicks, and passes that were accidentally accurate (i.e., participant meant to kick to the wrong teammate but the ball hit the correct player). Decision accuracy was evaluated by comparing the participant's verbal response with the correct decision, while pass accuracy was evaluated in terms of proximity of ball end-point and the free-teammate final position (i.e., correct decision). The distance between the ball when it hit the screen and the free-teammate position was evaluated by superimposing a grid onto the external-camera video using a free-to-use video-player software (Kinovea 0.8.15). Reference points on the projected video were used to calibrate the grid, which contained 16 spaces, at the beginning of each evaluation. One end of the grid was placed on the final ball position (in the middle of the ball) and the spaces between the ball and free-teammate red line were counted. As such, the lower the distance the more accurate the pass. Performance accuracy was calculated multiplying the participant's decision accuracy by the inverse of average pass accuracy:

*performance accuracy (AU): decision accuracy * 1/average pass accuracy.*

Dual-task performance. Kick accuracy in single- and dual-task conditions was evaluated by superimposing the grid onto the external-camera video, as described in the previous paragraph. As such, the lower the value the more accurate the kick. In both conditions, counting performance was evaluated as quantity of counted numbers and number of errors in counting, using the video from the external camera. Dual-task cost was calculated in kicking and counting:

dual-task cost (%) = (dual-task performance – single-task performance) / dual-task performance.

Gaze data. The video from the eye tracker and the external camera, both recorded at 30hz, were synchronised using a commercially-available coding software (Quit Eye Solution, QES) to couple gaze with specific phases during the task (Vickers, 1996). The first frame of the video stimuli was the trial onset and the participant's first contact with the ball (either passing or holding the ball) was the trial offset.

Four gaze behaviours were then coded as fixation, saccade, blink and other. Fixation was coded when the gaze was stable, within 3 degrees of visual angle, on a location for a minimum duration of 100 ms (Panchuk & Vickers, 2006), which corresponds to 3 video frames. Saccade was coded when the gaze shifted to a different area, moving for more than 3 degrees of visual angle, with a minimum duration of 66 ms, while blink was coded when gaze cursor disappeared for a minimum of 100 ms. Lastly, gaze was coded other when vibration of the eye tracking made coding impossible.

Six fixation locations were identified: teammate-opponent pair, ball, free space (area between players, below players' head), free teammate, non-marking opponent (free teammate's direct opponent) and other (area outside the screen or above players' head).

Number of fixations, average fixation duration, fixation order (i.e., the number of fixation alternations between ball and other areas) and relative viewing time (%) in each area of interest were evaluated in each trial.

Percentage transfer. The percentage transfer, from FB training to SB, was calculated for performance accuracy with the formula:

*experimental group – control group / experimental group + control group * 100* (Magill, 2011), applied to this study:

$$FUT - SOC / FUT + SOC * 100.$$

7.2.6 Coding reliability

Five percent of the trials were randomly selected and independently coded by two coders, and then re-coded a week later by the primary coder for inter- and intra-rater reliability. Intra-class correlation R values, calculated for performance accuracy, number of fixations and average fixation duration, ranged from 0.93 to 0.98.

7.2.7 Statistical analysis

Performance accuracy, fixation duration, fixation count and relative viewing time were analysed separately using linear mixed modelling with repeated measures (Proc Mixed in Version 3.6 of Statistical Analysis System Studio, SAS Institute, Cary, NC), with group (SOC, FUT) and session (pre, post) as fixed factors and participants as a random factor. The analyses were performed across all scenarios (overall) and in each individual scenario (2v2, 4v4, early, late). The model allowed for overdispersion (i.e., non-uniformity of error). Fixation order was analysed using generalized linear mixed modelling (Proc Glimmix in SAS Studio) with Poisson regression analysis. Dual-task performance across the intervention was analysed using linear mixed modelling with repeated measures, with group (SOC, FUT) and session (S1, S2, S3, post) as fixed factors and participants as a random factor.

Correlations of pre-to-post changes between performance accuracy and gaze variables, and between performance accuracy and dual-task performance, were evaluated separately performing correlation analysis (Proc Corr in SAS Studio).

Significance was set at $p < 0.05$ for all the analyses and the magnitude of changes was assessed using Effect Sizes (Cohen's d) with 95 % Confidence Intervals defined as follows: <0.2 trivial, $0.2-0.6$ small, $0.6-1.2$ moderate, $1.2-2.0$ large, >2.0 very large (Hopkins, 2010a). The between-subject standard deviation for the standardization of the effect sizes was calculated using the pure observed between-subject variance and the overdispersed sampling variance as follow: $\sqrt{(\textit{Athlete ID variance} + \textit{overdispersed sampling variance})}$.

7.3 Results

One participant in FUT did not complete the study and the final sample size included 23 participants, FUT (n=11) and SOC (n=12). Both groups performed the same number of decisions, 300 trials, and kicks throughout the intervention, including warm-up, single-task, dual-task and decision-making kicks, 363 ± 13 and 363 ± 17 for FUT and SOC, respectively. The variability in number of kicks depended on participants' decision, i.e., holding or kicking the ball.

7.3.1 Performance accuracy

There were no statistical differences in pre-test performance accuracy (Table 7.1). The analysis of the fixed effects showed a significant session effect overall and in all scenarios ($p < 0.01$); no group effect in overall but a significant group effect in the late scenario ($p < 0.01$); a group \times session effect overall ($p = 0.08$) and a significant group \times session effect in the late scenario ($p < 0.01$). The analysis of least square means differences showed that pre-to-post improvements had a larger effect size in FUT than SOC in all scenarios except the early scenario (Table 7.2). In the post-test, FUT performance was higher than SOC, moderately and largely in the overall and late scenario, respectively. A similar trend was observed when decision accuracy and pass accuracy were analysed separately.

Table 7.2 *Analysis of least square means differences in performance accuracy of FUT (i.e., group that trained with futsal ball) and SOC (i.e., group that trained with soccer ball). Pre-to-post within-group differences and between-group differences at pre-test and post-test are presented as p value (effect size \pm confidence limits). Significance was set at $p < 0.05$.*

Scenario	Pre-to-post		Between-group	
	Within-group differences		differences	
	FUT	SOC	Pre-test FUT/SOC	Post-test FUT/SOC

<i>Overall</i>	p < 0.01 (2.06 ± 0.86)	p = 0.02 (1.03 ± 0.82)	p = 0.95 (0.03 ± 1.10)	p = 0.06 (1.07 ± 1.10)
<i>2v2</i>	p < 0.01 (1.71 ± 0.86)	p < 0.01 (1.21 ± 0.83)	p = 0.71 (0.18 ± 1.00)	p = 0.16 (0.69 ± 1.00)
<i>4v4</i>	p < 0.01 (1.34 ± 0.87)	p = 0.10 (0.70 ± 0.84)	p = 0.78 (-0.14 ± 1.01)	p = 0.32 (0.50 ± 1.01)
<i>Early</i>	p = 0.03 (0.96 ± 0.86)	p = 0.02 (1.03 ± 0.83)	p = 0.81 (0.12 ± 1.00)	p = 0.93 (0.04 ± 1.00)
<i>Late</i>	p < 0.01 (2.61 ± 0.87)	p = 0.07 (0.76 ± 0.83)	p = 0.97 (-0.02 ± 1.07)	p < 0.01 (1.83 ± 1.07)

7.3.2 Gaze data

The gaze videos of three participants, one in FUT and two in SOC, were not reliable and they were excluded from the analysis. This resulted in 20 participants (10 per group) included in the analysis of the gaze data.

Fixation count. The analysis of fixed effects did not show any significant session, group or group x session effects. The analysis of least square means differences only showed a session effect in SOC in the 2v2 scenario ($p = 0.08$, $ES = 0.84 \pm 0.94$), with the group decreasing the number of fixation pre to post.

Fixation duration. The analysis of fixed effects only showed a significant session effect in the 2v2 scenario, while the analysis of least square means differences did not show any group or session effect. Both groups increased the fixation duration pre to post in the 2v2 scenario.

Fixation order. The analysis of fixed effects showed a significant session effect in all conditions ($p < 0.01$); a group x session effect in overall ($p = 0.08$) and significant group x session effect in the early scenario ($p = 0.04$); no significant group effect in any condition. The analysis of least square means showed small significant session effects in all conditions in FUT

($p < 0.01$), while there were no significant session effects in SOC. FUT increased the number of ball-other locations fixation alternations from pre to post.

Relative viewing time. The analysis of fixed effects showed a significant session effect in ball ($p = 0.01$); a significant group x session effect in teammate-opponent pair ($p = 0.04$) and a group x session effect in non-marking opponent ($p = 0.09$). The analysis of least square means difference showed a significant session effect in FUT ($p = 0.02$, $ES = 1.16 \pm 0.94$) in ball; moderate session effects in FUT in teammate-opponent pair ($p = 0.09$, $ES = 0.67 \pm 0.79$) and in non-marking opponent ($p = 0.06$, $ES = 0.91 \pm 0.94$). FUT decreased the time spent fixating teammate-opponent pairs and increased the time spent fixating ball and non-marking opponent. Furthermore, there was a moderate group effect in the post-test ($p = 0.12$, $ES = 0.99 \pm 1.31$) in free teammate. FUT spent more time fixating free teammate than SOC (Figure 7.3).

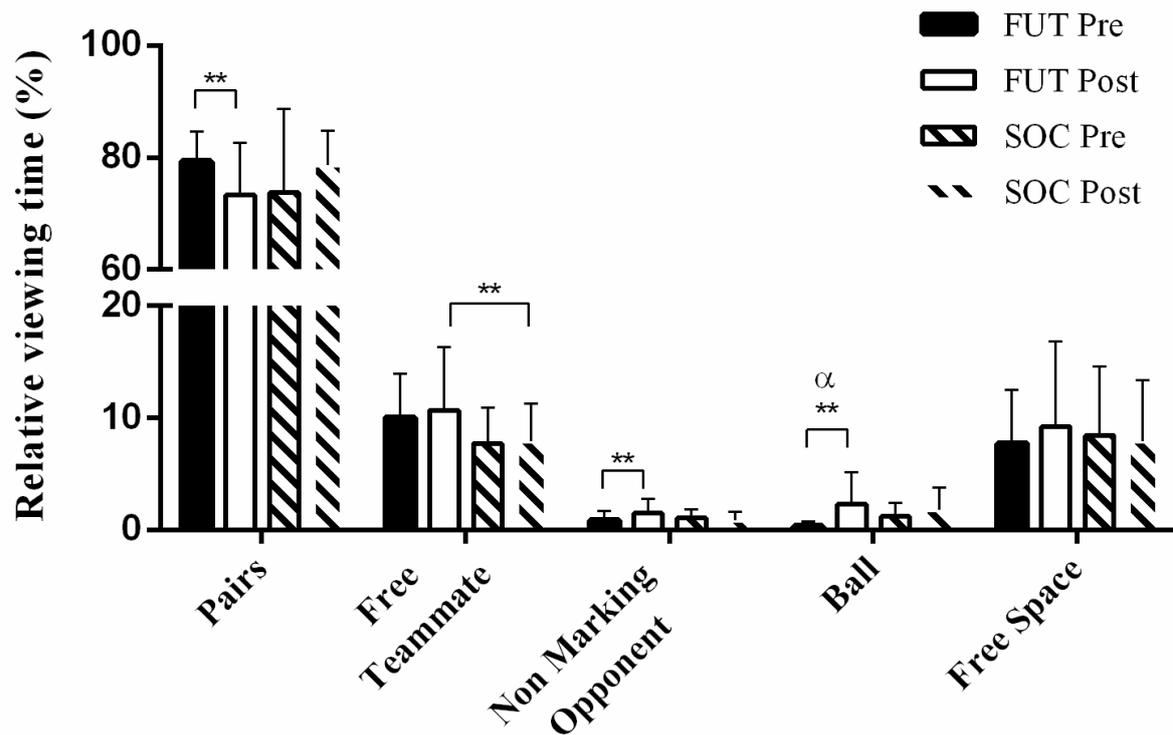


Figure 7.3 The groups' relative viewing time on the different areas of interest in pre- and post-test are presented. α indicates statistical significance ($p < 0.05$) and ** indicates moderate effect size.

7.3.3 Dual-task performance

The analysis of fixed effects showed a significant session effect in single-task ($p = 0.02$) and dual-task kick performance ($p < 0.01$), while there was no significant effect in dual-task cost. There were no group or group by session effects in any of the dual-task conditions. Both groups significantly improved single-task and dual-task kick performance throughout the study. The analysis of least square means showed a significant improvement in dual-task kick performance from session 1 to post-test in FUT ($p = 0.02$, $ES = 1.08 \pm 0.88$) and in SOC ($p < 0.01$, $ES = 1.14 \pm 0.82$). Both groups developed similar level of skill automaticity.

7.3.4 Percentage transfer

The percentage transfer, from FB to SB, was 16% and 29% in the overall and late condition, respectively.

7.3.5 Correlations

There were large correlations between gaze data (fixation duration and count) and performance accuracy in overall ($r = 0.51$, $p = 0.13$; $r = -0.50$, $p = 0.14$), 2v2 ($r = 0.60$, $p = 0.07$; $r = -0.59$, $p = 0.07$) and early condition ($r = 0.54$, $p = 0.11$; $r = -0.57$, $p = 0.08$) in FUT, while there were no significant correlations in SOC. In FUT, increases in fixation duration and decreases in fixation counts were correlated with improvement in performance accuracy. There were large correlations between dual-task kick and performance accuracy in 4v4 ($r = 0.50$, $p = 0.14$) and late condition ($r = 0.58$, $p = 0.08$) in SOC, while there were no significant correlations in FUT. In SOC, increase in dual-task kick error was correlated with improvement in performance accuracy.

7.4 Discussion

The aim of this study was to investigate the transfer of passing skill from a FB to a SB, and the perceptual behaviour underpinning the process. It was hypothesised that positive transfer of passing skill from FB to SB would be indicated by greater improvements in passing performance of FUT relative to SOC. The results confirmed this hypothesis as FUT showed higher pre- to post-test improvement (i.e., larger effect sizes) and higher post-test passing performance than SOC in all conditions, except the early condition. Practicing with a FB promoted a functional coupling of task-relevant affordance perception and coordination patterns that, when adapted to a SB, improved performance. Particularly, the large between-group difference in performance in the late condition showed that FB fostered the development of participants' ability to functionally couple perception and action in a time-constrained

situation, i.e., the teammate was free for a shorter period of time and participants had less time to organise the passing action.

The superior performance in FUT was hypothesised to be underpinned by development of an efficient perceptual attunement to task-relevant information, i.e., higher fixation alternations between ball and other areas, lower fixation time on ball and higher fixation time on players. The results confirmed that higher passing improvement in FUT was underpinned by significant changes in their gaze behaviour, while SOC only slightly modified their perceptual behaviour. Despite minimal changes in fixation duration and count in both groups, the results of relative viewing time and fixation order indicated that changes in perceptual attunement started to appear in FUT but not in SOC. The changes in gaze behaviour in FUT partially confirmed the hypothesis as they increased the number of fixation alternations between the ball and other areas (i.e., fixation order). FUT also increased the fixation time on ball (contrary to predictions), increased fixation time on non-marking opponent, and decreased fixation time on teammate-opponent pairs. Changes in both groups' viewing time resulted in FUT fixating free-teammates for longer than SOC. In addition, changes in fixation duration and count were correlated with passing improvements in FUT but not in SOC. Despite not entirely confirming the hypothesis, the perceptual modifications coupled with a larger improvement in FUT, indicate that FB facilitated the development of an efficient perceptual attunement to task-relevant information that supported passing performance.

It was hypothesised that changes in perceptual behaviour would be promoted by higher skill automaticity in FUT. The results did not confirm this hypothesis as both groups showed similar improvement in skill automaticity throughout the intervention. Despite being easier to kick (Peacock et al., 2017), the FB did not fast-track the development of skill automaticity compared to SB. These results seem to contradict previous research that showed that easy-to-handle equipment places fewer attentional demands on performer, in turn, facilitating skill

automaticity (Buszard et al., 2014b). However, a higher skill automaticity in FUT might have been masked by the design of the dual-task assessment. Both dual-task kicking and counting cost did not improve throughout the study in both groups suggesting that, potentially, counting backwards and kicking did not challenge participants' allocation of attention. Participants perhaps focused their attention on counting when the ball was rolling towards them and then switched attentional focus on kicking once the ball was close to them. Therefore, participants' attention was slightly affected during the kicking action, and skill automaticity was not evaluated properly in the two groups. Therefore, the changes in perceptual behaviour in FUT might have actually been promoted by participants' skill automaticity that was not captured with the adopted dual-task assessment. A potential research direction stemming from these results would be to use a probe dual-task (Abernethy, 1988; Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007), where participants respond to a secondary task during the execution of the pass, instead of a continuous dual-task, as adopted in this study.

Mechanisms other than skill automaticity might have encouraged the development of the observed behaviours. Previous research highlighted that equipment scaled to the participants' characteristics facilitated the execution of a skill, skill accuracy and encouraged more opportunities to execute a skill (Buszard et al., 2016b). This suggests that modified equipment might reduce movement variability, which would explain skill accuracy and easiness in executing a skill, and, in turn, might promote the repetitions of a small number of movement solutions, which was suggested to fast-track the development of functional coordination patterns (Ranganathan & Newell, 2013). In addition, haptic information changes when properties of equipment are modified, and these changes in information likely play a role in the learning process. Kicking a futsal or a soccer ball provides different haptic information to the person performing the kick due to differences in the balls' coefficient of restitution. While previous research focused on visual information, haptic information has been argued to

be important for coordinated movement as much as, if not more, than vision (Turvey, Burton, Amazeen, Butwill, & Carello, 1998), and an enhanced sensitivity to haptic information has been suggested to fast-track learning (Davids, Button, & Bennett, 2008a). Therefore, a futsal ball might have reduced movement variability and/or improved participants' sensitivity to ball touch during practice, and, in turn, encouraged the development of the observed gaze behaviour. A potential future direction would be to assess movement variability and participants' sensitivity to haptic information when equipment is modified.

Previous research showed that futsal task constraints, including the ball, influenced the orientation of attention underpinning passing, i.e., higher attention alternations between ball and other areas, and lower attention time on ball relative to soccer task constraints (Oppici et al., 2017). These results were partially confirmed in the current study as FUT showed higher alternations between ball and other locations than SOC but FUT also increased fixation time on ball. However, participants in Oppici et al. (2017) were skilled junior players, while participants in this study were novices and the different skill levels might have influenced attentional focus on ball. It is possible that individuals' perceptual attunement to the FB, as a source of information, follow an inverted-U-shape along the expertise continuum. Typically, novices mainly rely on visual information to guide action but as they progress through the expertise continuum they increasingly learn to use haptic information (e.g., foot-ball contact) (Misceo & Plankinton, 2009). In this context, FB might promote the use of haptic information over visual information on ball only in experts, who are able to exploit FB properties (e.g., regular ball bounce and trajectory), being at the skill level (Handford et al., 1997). Future research direction would be to evaluate the influence of modified equipment on an individual's ability to use haptic information to guide action, and to examine how the learning process is affected. An individual's level of expertise likely influences how equipment modification

shapes skill learning and transfer. Therefore, future research could examine how equipment modification shapes the behaviour of individuals at different expertise levels.

A constraints-led approach, where constraint modification guides learning, as opposed to the traditional coach-led approach, where the coach guides learning, has been suggested to facilitate functional movement adaptations (Davids et al., 2008b). Task constraints, including equipment, have been the focus of this approach as they can be readily manipulated by practitioners. For example, sport programs, such as Tennis Australia's Hot Shots program, have recently started to scale equipment and playing area to the children's physical characteristics to encourage their engagement, enjoyment and development of sport skills (Tennis Australia, 2018). The results of this study provide new insights supporting this approach. Although constraints- and coach-led approaches were not compared, this study showed that practicing the passing skill with the same instructions but with a different ball influenced the learning process. Practicing the passing skill with FB was more beneficial than SB in improving passing skill with SB, as previous research (Travassos et al., 2017) and anecdotes suggested (UEFA, 2014). Practitioners working in soccer are encouraged to use FB in their training sessions to fast-track learning, particularly in novices.

Despite coupling the perception of information specifying task-relevant affordances and the kicking action, the representativeness of the passing task adopted in this study could be improved in future research. Rather than projecting players on a video screen and kicking to a target placed at a fixed distance, the passing task could be performed with live players moving to receive the pass. The representativeness of the task would improve, and participants would perform passes to players positioned at different distances in each pass. Therefore, they would need to appropriately change the speed of their pass to accurately reach the intended teammate. Furthermore, future research could examine the transfer of passing skill using a soccer game as transfer task and improve the generalisation of the findings to the game.

7.5 Conclusions

This study investigated issues that were relatively un-explored in the human movement field, providing results that extend the current understanding of the impact of modified equipment on skill learning. The results showed that practicing a passing skill with a modified ball promoted positive transfer to performing passes with another ball. The participants that practiced with the futsal ball showed greater improvement in passing accuracy than participants who practiced with the soccer ball. Furthermore, the results showed that the equipment participants trained with influenced the perceptual attunement to environmental information. Practicing passes with the futsal ball promoted the education of attention towards information specifying task-relevant affordances, i.e., teammate-opponent relationships. In summary, this study confirmed that modified equipment influences the self-organisation of perception-action coupling, which, in turn, shapes the development of a behavioural repertoire that can positively transfer to another equipment improving learning of a perceptual-motor skill (Araújo et al., 2004; Farrow et al., 2016).

CHAPTER 8

GENERAL DISCUSSION

This thesis aimed to examine the relationship between task constraints and transfer of perceptual behaviour in sport. The task constraints of futsal and soccer, and the skill of passing were used as vehicles to examine the issue. Specifically, the aims were:

- i) To investigate the influence of long-term practice with different task constraints on the development of perceptual behaviour supporting the passing skill.
- ii) To determine how task constraints influence the transfer of passing skill, and to explore how perceptual behaviour supports the transfer process.
- iii) To determine how manipulation of equipment promotes the transfer of passing skill, and how perceptual behaviour facilitates transfer.

It was hypothesised that:

- i) futsal and soccer task constraints would encourage the development of different strategies to perceive task-specific affordances to guide passing,
- ii) futsal task constraints would promote a higher magnitude of transfer of passing to soccer task constraints than vice-versa, and
- iii) the futsal ball would promote positive transfer of passing skill to the soccer task, underpinned by an efficient perceptual attunement to environmental information.

8.1 Main findings

Chapters 3 and 5 examined how futsal and soccer task constraints influenced the emergence of task-specific passing affordances and, consequently, how players became perceptually attuned to the domain-specific passing affordances during games. Chapter 3 showed differences in passing execution time and the type of passes performed between adult, elite futsal and soccer players during games. Passing, which comprises ball control and kicking phases, was quicker in futsal, while soccer players performed more direct passes and fewer one-touch passes

relative to futsal players (Figure 3.1 and Figure 3.2). This suggests that task-specific passing affordances might emerge during or immediately after ball control in futsal, and before or after ball control in soccer. Using head-mounted cameras, chapter 4 developed a method to approximate a player's orientation of attention during games to examine how futsal and soccer task constraints affected the development of perceptual behaviour supporting the passing skill. Chapter 5 showed how futsal and soccer players oriented their attention towards ball-directed and player-directed areas at different key moments during modified games that were representative of the passing skill in the two sports. Futsal players oriented their attention towards other players, to gather information to support decision-making, at the first touch of the ball, and frequently alternated their attention between the ball and players during the reception phase. Together with the results of chapter 3, this indicates that task-specific passing affordances in futsal emerge during ball control, and players need to perform the first touch with their head up to perceive the movement of other players. Conversely, soccer players spent less time looking at player-directed areas during ball control and had fewer attention alternations during reception. Soccer players also oriented their attention towards players for longer and had more attention alternations than futsal players when their team was in possession of the ball (Table 5.2). Furthermore, this chapter showed how task constraints influenced the context in which passes were performed in the futsal and soccer modified games. The interaction of futsal task constraints, namely higher pressure from the direct opponent, shorter reception time and higher technical intensity relative to soccer task constraints (Figure 5.4) resulted in higher passing demands. Together, the results of chapters 3 and 5 highlighted how the different task constraints of futsal and soccer influenced when task-specific passing affordances emerge during games, the contextual demands of the two domain-specific tasks, and the players' perceptual attunement to environmental information that specified task-specific passing affordances.

Chapter 6 examined how task constraints influenced the transfer of passing skill, and the perceptual skill underpinning it, between futsal and soccer. Similar to chapter 5, players' orientation of attention and pass accuracy were evaluated during modified games that were representative of the passing skill. In addition to performing in their own game, futsal players performed in a modified soccer game and soccer players performed in a modified futsal game. The results showed that futsal players improved their pass accuracy from the futsal to soccer game, resulting in higher pass accuracy than soccer players in the soccer task, while soccer players' pass accuracy remained stable across the two games, and their pass accuracy in the futsal task was similar to futsal players (Figure 6.1). As such, the soccer group's transfer of passing skill can be considered neutral, as their passing performance did not change, and the futsal group's transfer was positive, as they improved their passing performance. This demonstrated how task constraints during practice affected the magnitude of skill transfer to a new set of constraints, and it suggested that practicing futsal could be beneficial for the development of passing in soccer. Futsal players adapting their perceptual skill to passing affordances with soccer task constraints was considered one of the mechanisms that promoted positive transfer, as their orientation of attention significantly changed from futsal to soccer, resulting in similar behaviour to soccer players. On the other hand, soccer players only slightly adapted to the futsal task constraints. Lastly, it was speculated that learning the passing skill with more-demanding task constraints (i.e., smaller individual playing area, shorter reception time and higher technical intensity) encouraged the exploration of environmental information during practice, which facilitated skill adaptation to new task constraints.

Chapter 7 focused on the effect of ball properties on promoting transfer of passing and perceptual skill. In a randomised controlled study, a group of adult novices practiced passing with a futsal ball, while another group practiced with a soccer ball. Between-group changes in passing performance and perceptual skill were assessed pre- and post-intervention using a

soccer ball in both groups. The futsal-ball group showed a higher pre- to post-test improvement and higher post-test pass accuracy than the soccer-ball group, which indicated positive skill transfer. The development of a ‘stronger’ attunement to environmental information that specified affordances underpinned the higher performance of the futsal-ball group, which was indicated by significant changes in the group’s gaze behaviour, while no changes were seen in the soccer-ball group. The futsal-ball group increased the time spent fixating areas of the visual display that specified affordances, such as non-marking opponent and free teammate (Figure 7.3), increased the number of fixation alternations between ball and other areas, and changes in gaze behaviour positively correlated with improvement of passing performance. This chapter presented the benefits of practicing the passing skill with equipment that facilitated the execution of that skill.

8.2 Theoretical implications

8.2.1 Constraints on perceptual behaviour

The findings of this thesis extend current knowledge on the influence of task constraints on perceptual behaviour. Current evidence on how task constraints influence an individual’s behaviour is primarily derived from studies that have assessed the outcome of a movement, such as the number of skill executions (e.g., Owen et al., 2011; Timmerman et al., 2015), skill accuracy (e.g., Buszard et al., 2014a; Dellal et al., 2011) and inter-player coordination (e.g., Silva, Duarte, et al., 2014; Torrents et al., 2016). Only a limited number of studies have directly evaluated the acute changes in perceptual behaviour when task constraints were modified (Dicks et al., 2010; Roca et al., 2013; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). Typically, participants performed sessions with different task constraints, with one session per set of constraints, and between-sessions changes were assessed. As such, it remained uncertain how task constraints affected perceptual behaviour more longitudinally.

Chapter 5 showed how practicing passing for more than 1000 h with different task constraints influenced the development of perceptual skill. The interaction of futsal or soccer task constraints shaped the perception of passing affordances during different moments during the game. Futsal and soccer players developed different strategies to perceive environmental information that specified those affordances. Furthermore, chapter 7 showed how learning the passing skill over three practice sessions with different equipment (i.e., futsal and soccer ball) affected the development of gaze behaviour underpinning decision making. Being easier to kick, the futsal ball fast-tracked participants' attunement to task-relevant information. While previous research has shown temporary changes in perceptual skill (Dicks et al., 2010; Roca et al., 2013; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007), these findings provide new insights into the long-term effect of practicing with different task constraints on perceptual skill.

8.2.2 Information similarity promotes and task constraints modulate transfer

Previous research has indicated that the similarity of information that guides action between learning and transfer task encouraged transfer of perceptual skill (e.g., Roca & Williams, 2017; Rosalie & Müller, 2014), and that task constraints influenced the emergence of an individual's behaviour (e.g., Buszard et al., 2016b; Davids et al., 2013). However, it was unclear how task constraints affected skill transfer between tasks that share similar information. The results of this thesis confirmed that similarity of information that guides action promotes skill transfer, and indicated that task constraints modulate the magnitude of transfer. Information that specifies passing affordances is relatively similar between futsal and soccer, namely the ball and players' behaviour (see section 2.5.2). This similarity facilitated soccer players transferring their perceptual behaviour and passing skill from soccer to the futsal modified game. Their transfer was neutral as their passing performance did not change between the soccer and futsal modified game. However, the differences between futsal and soccer task constraints influenced the emergence of passing affordance in their respective games (chapter

3) and how players perceptually attuned to information that specified those affordances (chapter 5). The perceptual skill of futsal players, developed with higher contextual demands than soccer (i.e., short reception time, high technical intensity and high opponent pressure) and positively transferred to the soccer modified game. Futsal players improved their passing performance from the futsal to soccer modified game, resulting in higher passing performance than the soccer group. Learning the passing skill with futsal task constraints promoted a higher degree of transfer to soccer task constraints than vice versa.

The results of chapters 6 and 7 provide new insights into ‘what’ needs to be similar to promote skill transfer. Identical-elements theory (Thorndike, 1906) contends that positive transfer occurs when similar elements (e.g., movement kinematics) are present between a learning task and the transfer task. If similarity in task elements was the main driver for transfer, the same magnitude of transfer would have been detected both ways (i.e., futsal to soccer and vice versa), given the same number of similar task elements. However, futsal and soccer players having a different magnitude of transfer suggests that the key to promoting transfer was the similarity between an individual’s behaviour and the requirement of a new task, rather than similarity in task elements. The two main theoretical approaches used in the motor learning field (i.e., information-processing and ecological dynamics) differ in the explanation of human behaviour and, consequently, transfer of learning. The transfer appropriate-processing framework (Lee, 1988) argues that transfer is promoted by the similarity of cognitive processing elicited during learning and the processing required in the transfer task. On the other hand, ecological dynamics conceptualises an individual’s behaviour as the fit between perceived affordances and the emergence of coordination patterns (Araújo et al., 2006; Davids et al., 2012), and transfer occurs due to similarity between the practiced perception-action couplings and the coupling required in a transfer task to achieve the task goal (Davids et al., 2008b; Pacheco & Newell, 2015). Despite these two approaches were not directly compared,

the results of this thesis seem to support the ecological dynamics approach to skill transfer. In chapter 6, the soccer game required an orientation of attention primarily towards the ball during the reception and control phases to perceive passing affordances, while the futsal game required an orientation of attention primarily towards player-directed areas at the first touch and during the control phase. The futsal players showed a higher magnitude of transfer than soccer players due to their perceptual (and likely motor) behaviour being similar to the requirement of the transfer task (Table 6.2). In chapter 7, the futsal-ball group developed superior passing skill than the soccer-ball group that transferred to the soccer task. The futsal ball fast-tracked the attunement to information that specified affordances in the soccer task. As such, these results suggest that futsal task constraints promoted transfer to the soccer task constraints due to the similarity of behaviour they afforded and the requirements of the soccer tasks.

8.2.3 Specificity of learning

Chapter 7 showed how practicing passes with a futsal ball fostered the development of functional perception-action couplings that resulted in a higher performance with a soccer ball than practicing with a soccer ball. Put simply, training with a futsal ball was more beneficial than training with a soccer ball in developing passing skill in soccer. These results have implications for the specificity of learning hypothesis (Proteau, 1992) and for the representative learning design (Pinder, Davids, et al., 2011b).

The specificity of learning hypothesis contends that learning is specific to the visual information sources present during learning, and skill performance deteriorates if the information changes in a transfer task (Proteau, 1992). This hypothesis has been questioned as studies have shown how proprioceptive information supported accurate performance in a transfer task where visual information differed from the learning context (Bennett et al., 1999; Tremblay & Proteau, 1998). It has been argued that learning is specific to the sensory information sources, not only visual, present during learning (Mackrout & Proteau, 2007).

However, the information sources learning is specific to is still debated (Tremblay, 2010), and the results of chapter 7 provide new insights to the debate.

Based on learning specificity, passing would be domain specific, and practicing with domain-specific task constraints would confer the greatest learning benefits. In other words, practicing with soccer task constraints would improve passing in soccer. However, the results of chapter 7 challenge this hypothesis. The learning condition of the soccer-ball group was specific to the transfer task (i.e., passing with the soccer ball), as information sources were the same during practice as in the transfer task. On the other hand, the futsal-ball group practiced with a different ball, which afforded different information to participants relative to the transfer task. The visual information available to guide passing was the same in both experimental groups during practice (i.e., they watched the same video clips at the same distance from the video screen), while the haptic information from the ball differed between the two groups, due to the different futsal and soccer ball coefficient of restitution. Therefore, no between-groups difference in passing performance would have been detected if learning was specific to visual information. Furthermore, the soccer-ball group would display superior performance if learning was specific to haptic information. However, the results showed the opposite, as the futsal-ball group had a higher performance improvement in the transfer task than the soccer-ball group. This indicated that learning the passing skill with the futsal ball was more beneficial than learning with the soccer ball. While specificity of learning contends that learning a skill with reduced or extra information reduces performance (Proteau et al., 1992), these results suggest that learning a skill with different information sources might actually be beneficial and improve the learning (and transfer) process. This finding seems to contradict the idea of learning specificity; however, when interpreted using a dynamical systems theory the findings are somewhat more parsimonious.

In dynamical systems theory, practice is conceptualised as the search for a movement solution in the perceptual-motor workspace that emerges from the interaction of constraints (Newell, 1991, 1996). Pacheco and Newell (2015) showed that the exploration and stabilisation of the perceptual-motor workspace during learning facilitated transfer to a different perceptual-motor workspace. The ability to explore different movement solutions and stabilise functional ones promoted accurate performance in a new task, which required the same processes (i.e., exploration and stabilisation), despite information sources being different. In this context, specificity of learning is viewed as specificity of the practiced regions of the perceptual-motor workspace (Ranganathan, Mussa-Ivaldi, Scheidt, Wieser, & Mosier, 2014). This would explain skill transfer from one set of constraints to a new set of constraints due to the similarity of strategies required to find functional movement solutions. This approach better contextualises the results of chapter 7 in regard to an explanation of the specificity of learning. The transfer task with the soccer ball required making a decision and kicking the ball towards the free teammate. Perception of information about the players in the video stimuli was required to make accurate decisions, and perception of visual and haptic information about the ball was required to control and direct the kick towards the intended teammate. It can be speculated that the futsal ball fostered the participants' ability to search for task-relevant visual and haptic information, and to exploit the combination of haptic and visual information that specified affordances and guided successful passing performance. While participants' sensitivity to haptic information was not measured, results showed that participants who practiced with the futsal ball changed their visual strategy to perceive information that specified affordances (e.g., free teammate and non-marking opponent). On the other hand, the visual strategy of the soccer-ball group did not change. The futsal-ball group having a higher performance than the soccer-ball group in the transfer task suggests that learning was specific to the strategy of exploiting a combination of visual and haptic information. As such, based on dynamical systems theory,

this thesis might suggest that learning is specific to the strategies adopted to perceive, combine and exploit the array of information sources available to guide action, and learning transfers to tasks that require a similar strategy.

Representative learning design (RLD) advocates the replication of constraints interaction that athletes typically experience in competition during training, as learning is specific to the information that emerges from the interaction of constraints (Davids et al., 2012; Pinder, Davids, et al., 2011b). Specifically, the degree in which movement is guided from comparable information sources in training as in competition (i.e., functionality) and the degree in which the athlete's movements during training compare to competition (i.e., action fidelity) are critical concepts. They are measured to verify the correspondence of an athlete's behaviour between the constraints of training and competition. The higher the similarity in functionality and or action fidelity, the higher the transfer predicted (Pinder, Davids, et al., 2011b). While previous research has mainly focused on the correspondence of an individual's movement kinematics between tasks (Barris et al., 2013; Pinder, Davids, et al., 2011a; Travassos, Duarte, et al., 2012), these results suggest a need to equally consider the functionality of the information specifying affordances between contexts to predict skill transfer. The futsal ball fast-tracked participants' ability to functionally couple affordance perception and coordination patterns, and, in turn, transfer improved. Despite haptic information being different to the soccer ball, the futsal ball encouraged participants to attune to the information that specified affordances and supported accurate passing performance in the soccer task. Interestingly, a constraint (i.e., the futsal ball) not sampled from the environment towards which the passing skill was generalised (i.e., the soccer task) improved functionality. Similarly, novice goalkeepers who practiced penalty kick performance facing three players running-up to execute a kick had higher anticipation performance and more saves when facing one player, relative to the group that faced one player only during practice (Dicks, Pocock, Thelwell, & van der Kamp, 2017).

The three-players condition fast-tracked participants' ability to attune their attention towards reliable information of the kicking action that specified task-specific affordances and, in turn, transfer improved. This highlights the importance of considering functionality when designing experimental and training tasks. Practitioners should not merely replicate in training the constraints of the competition, but they should sample the constraints that are functional to the achievement of the task goal in competition. In this context, the Representative Practice Assessment Tool (RPAT; Krause, Farrow, Reid, Buszard, & Pinder, 2017), which is based on RLD and developed to help practitioners designing representative tasks, encourages coaches to consider the functionality of a task to competition performance. The results of chapter 7 supports RLD and the use of RPAT to maximise skill transfer to competition, and encourage practitioners to scrutinise the constraints that are functional to the coupling of perception and action in competition, even if the constraints differ to the competition constraints.

8.2.4 Preferred pathway to promote the development of sport expertise

The transfer of perceptual and passing skill between futsal and soccer presented in this thesis has implications for the issue of sport specialisation. While specialisation in one sport is required for the attainment of sport expertise (Baker & Young, 2014), the timing of specialisation is debated (Baker et al., 2009). Early specialisation entails practicing one sport from a young age with a large volume of deliberate practice and a focus on acquiring sport-specific skills (Ward, Hodges, Williams, & Starkes, 2004). While linked to the development of sport expertise (Ericsson, 2003), specialising in one sport at an early age has been argued to increase children's drop-out rates and to exclude potentially talented individuals who mature late (Côté & Erickson, 2015). Conversely, two different approaches emphasise engagement in a variety of sports (early diversification pathway; Côté & Erickson, 2015; Güllich, 2016) and in domain-related playful activities (early engagement hypothesis; Ford et al., 2009) to overcome the issue of early specialisation and, in turn, promote the development of

psychological and inter-personal skills (Côté & Erickson, 2015). Based on these approaches, the Developmental Model of Sport Participation (DMSP; Côté & Fraser-Thomas, 2007) and the Athletic Skills Model (ASM; Wormhoudt, Savelsbergh, Teunissen, & Davids, 2017) have been proposed to guide sport programs with a holistic approach on sport expertise that considers the development of an individual's psychological, inter-personal and perceptual-motor skills.

The assumption of DMSP and ASM is that engagement in a variety of playful activities and sports at an early age provides the foundations for the later development of sport-specific skills, which implies transfer between sports and activities. In this context, it has been recently argued that futsal practice can be beneficial for the development of soccer skills (Travassos et al., 2017). However, evidence on the benefits of sport diversification on expertise has been mainly derived from studies that analysed the activities expert athletes engaged in during their career (Côté & Erickson, 2015), typically through retrospective questionnaires which assessed the volume and type of training activities (e.g., Berry, Abernethy, & Côté, 2008; Güllich, 2016). How skills transfer between sports in young individuals has not been directly investigated. While not specifically addressing the benefits of DMSP and ASM, the results of this thesis showed transfer of skills between two sports, which encourage a sampling approach to athletic development. Young futsal and soccer players were able to accurately perform passes with the constraints of the other sport. Furthermore, futsal and soccer task constraints encouraged the development of different perceptual behaviours (chapter 5); hence, practicing both sports at an early age could enrich an individual's behavioural repertoire. As such, these findings suggest that children should be encouraged to sample different sports (e.g., futsal and soccer) to diversify their experience and promote the acquisition of adaptable perceptual and motor skills. Given their similarity, futsal and soccer could be considered complementary to

each other and could represent a sport-related activity, which would mainly support the early-engagement hypothesis.

8.3 Practical implications

The results of this thesis suggest that manipulating task constraints in practice can encourage the development and transfer of perceptual behaviour. Traditional approaches to sport coaching position the coach at the centre of the learning process whereby the coach leads the training session providing feedback and specific instructions to guide learners towards the acquisition of cognitive and perceptual skills (Schmidt & Lee, 2011). For example, coaches can provide explicit instructions regarding relevant information that guides anticipation and decision-making skills to channel an athlete's development of perception (e.g., Abernethy, Schorer, et al., 2012; Williams et al., 2011). In contrast to this approach, the constraints-led approach to coaching advocates the manipulation of constraints to allow learners to explore informational sources and become attuned to the information that specify opportunities for action in relation to their action capabilities (Chow, Davids, Hristovski, Araújo, & Passos, 2011; Davids et al., 2008b). While this approach values the role of instructions and feedback in assisting the process, the main driver of learning is the interaction of constraints that sets the affordances and encourage individuals to organise functional coordination patterns to achieve the task goal (Newell, 1991; Renshaw et al., 2010).

The results of chapter 7 indicated how a ball's properties influenced participants' gaze behaviour and passing performance. Instructions and feedback were the same for the experimental and control group, and the observed differences in perceptual behaviour and performance resulted from the manipulated task constraints. Furthermore, chapters 5 and 6 highlighted how the interaction of futsal and soccer task constraints influenced the development and transfer of perceptual behaviour underpinning passing. The manipulation of task constraints in practice is not a new concept – junior sport programs, such as the Tennis

Australia's Hot Shots program (Tennis Australia, 2018) and the Italian Football development program (Italian Football Federation, 2018), scale equipment and playing area to the children's physical characteristics to encourage their engagement, enjoyment and development of sport skills. The results of this thesis support these junior programs, showing how task constraint manipulation promotes skill performance and learning. Chapter 7 showed how the properties of equipment, such as size and coefficient of restitution can be manipulated to facilitate the execution of a skill and, in turn, fast-track the learning (and transfer) process. Furthermore, a skilful coach can play with task constraints to encourage players to look at certain environmental information (i.e., ball and other players) that, depending on the game scenario, may specify affordances in competition. For example, the number of players can be increased during small-sided games to promote higher scanning of environmental information in search for task-relevant affordances; individual playing area can be reduced to increase pressure from a direct opponent and promote early and quick detection of environmental information; passing space and time can be reduced to promote transfer to passing with larger space and longer time. With specific reference to futsal and soccer, this thesis would advise soccer coaches to introduce futsal constraints into their practice to expedite their athletes' learning.

Practitioners in other sport fields should consider the main constraints that affect their athletes' behaviour and should manipulate them to encourage the development of functional and adaptable behaviours. Growing evidence is indicating that expert athletes typically practice different sports early in their career (Güllich, 2016; Rees et al., 2016). Therefore, selecting task constraints that facilitate the acquisition of adaptable behaviours is critical for the development of sport expertise as it allows learners to transfer their skills to different sport domains. Importantly, the manipulation of task constraints needs to be tailored to the environment to which the practiced behaviour is intended to be applied. Representative learning design encourages practitioners to select task constraints during practice that specify information

available in competition (Pinder, Davids, et al., 2011b). In addition, this thesis recommends practitioners considering constraints that improve the functionality and adaptability of perception and action required in competition, even if constraints differ to the constraints that athletes typically experience in competition. As chapter 7 indicated, a slight modification of informational constraints due to different ball properties fast-tracked learning of the passing skill.

8.4 Strengths of this thesis

This thesis has two main strengths: first, perceptual behaviour was assessed while maintaining the perception-action coupling of the passing task, and second the effect of task constraints on perceptual learning and transfer was examined using a randomised controlled study. The assessment of perceptual behaviour has always been challenging in sport science, as researchers need to balance the advantages and disadvantages of laboratory-based and in situ study designs (Mann & Savelsbergh, 2015). Perceptual skill in sport has mainly been assessed in the laboratory, using tasks that de-coupled perception and action (Travassos et al., 2013), which is known to affect the measurement (Farrow & Abernethy, 2003) and the generalisation of the observed behaviour to competition (Brunswik, 1955). Assessment of perceptual skill has rarely taken place *in situ* (Dicks et al., 2010). In this thesis, perceptual skill was assessed both in situ and in the laboratory to maximise the benefits of the two approaches whilst limiting the issues that might arise (e.g., technological issues in measuring perceptual skill in situ and de-coupling perception and action in the laboratory). Chapters 5 and 6 examined the effect of practicing with different interacting constraints on the development and transfer of perceptual skill in young skilled futsal and soccer players. The interaction of constraints typical of passing in futsal and soccer (i.e., ball, surface and players) were represented, and a method was validated to evaluate participants' orientation of attention during games. A trade-off of this design was that the developed method only allowed classification of attention orientation on

two areas of interest. Considering the low specificity in discriminating locations of interest with this method, chapter 7 was conducted in the laboratory to improve the analysis of participants' gaze behaviour. A task was developed to represent the information that guided passing, i.e., the coming ball and players' movements, and the action of passing. As opposed to a static positioning of the ball as used in previous research (Helsen & Starkes, 1999; Vaeyens, Lenoir, Williams, & Philippaerts, 2007), the ball was delivered to the participants while a video showed players simulating soccer movements. A trade-off of this task was a relatively low representativeness of players' movements, being on a video as opposed to 'real-life'.

Chapter 7 employed a randomised-controlled study design to examine the effect of task constraints on transfer of perceptual skill. Randomised controlled studies where groups of participants receive an experimental (or control) intervention are considered the best research design to examine the effect of a treatment on an individual's behaviour (Creswell, 2014; Sibbald & Roland, 1998). However, there is a lack of longitudinal studies in sport science mainly due to cost, drop-out rate and the need to control for confounding variables that somewhat limits current understanding of learning (and transfer) processes (Abernethy, Thomas, & Thomas, 1993; Farrow & Baker, 2015). In fact, current literature on the effect of task constraints on an individual's behaviour is mainly limited to acute effects. In chapter 7, participants were randomly allocated into two experimental groups and underwent a training period, which allowed examining how ball properties promoted the transfer of perceptual skill, in turn, extending current knowledge on this issue.

8.5 Limitations of this thesis

This thesis has some limitations that impacted the findings. The gaze coding window developed in chapter 4 to approximate a participant's orientation of attention discriminated only between

two areas of interest, i.e., ball-directed and player-directed. While this method allowed the examination of futsal and soccer groups' attention orientation during modified games, it did not allow to assess what specific information participants directed their attention to and supported the passing skill in futsal and soccer. For example, the player-directed area included different potential attention locations, such as teammate, opponent, and free space. Therefore, this method did not allow to examine in depth a participant's perceptual behaviour and some difference in the futsal and soccer groups' visual attention may have been missed.

The training history of participants in chapters 5 and 6 was not assessed in detail. Participants were recruited from elite clubs in two different countries (i.e., Spain and Australia) and the time available to perform skill assessment was very limited due to the squads' congested calendar. Therefore, it was decided to use a brief questionnaire to collect the main information on domain-specific practice (see Appendix C), and to maximise the available time for the assessment of perceptual behaviour. Only players with no experience in the other sport at club level were included in the sample, so previous practice on the other domain was not included in the questionnaire. An in-depth questionnaire on the specific activities participants engaged in (e.g., Ward et al., 2007) that requires the experimenter's supervision (Hopwood, 2015) could not have been administered. Additional information on previous practice activities would have strengthened the results. For example, differences in training activities other than task constraints potentially influenced the observed behaviours in chapter 5, or playful activities in the other domain and structured practice in other sports could have affected results of chapter 6.

Given that the futsal and soccer groups were recruited from two different countries, there might have been a difference in the groups' expertise level that could potentially have influenced the results of chapter 6. The futsal group could have not been recruited in Australia because futsal players in this country typically play both futsal and soccer. This cross-sport

participation would have biased the results. Therefore, it was decided to recruit futsal players in a country (i.e., Spain) where young futsal players play futsal exclusively. While the soccer and futsal groups had the same years of experience in their relative sport (6.8 ± 1.2 and 7.0 ± 1.6 years of experience respectively), the same hours of domain-specific structured practice (1220 and 1260 hours respectively), the same weekly training schedule (four 90-minute training sessions and one competitive game), and very similar socio-economic contexts (the groups were recruited from one of the richest areas of Australia and Spain), the futsal group's expertise level may have been higher than the soccer group's, due to the higher competitive level in Spain relative to Australia. It is difficult to speculate on how this potential difference may have influenced the results (given the limited evidence on the influence of expertise on skill transfer), but it is important to acknowledge this potential limitation.

The experimental tasks of chapter 5 and 6 were designed to represent the interaction of constraints during passing in futsal and soccer. The ball, playing surface, movement of other players, and inter-player distance are key information sources that specify passing affordances (Corrêa et al., 2014a), and these were sampled from futsal and soccer to create two domain-specific modified games. As such, the observed behaviour could be generalised to passing with those constraints. However, soccer is played 11-vs-11 and futsal is played 5-vs-5, and the designed 6-vs-6 game might have influenced the players' behaviour as the number of passing options were modified. A trade-off had to be made as games with similar number of players were required to allow a between-groups comparison. A 6-vs-6 scenario was chosen for two main reasons: a game with 5 teammates, as opposed to 7 or 9 teammates, affords a higher number of passes, hence, a reasonable amount of trials for the analysis; futsal squads are typically composed of 12 players, so a 6-vs-6 game was logistically preferable. As a result, the findings of chapters 5 and 6 cannot be generalised to the entire game, and, being played in relatively short spaces, the findings can be mainly generalised to short passing.

The dual-task assessment designed to evaluate skill automaticity may have limited some of the conclusions of chapter 7. Dual-task assessment involves the performance of a secondary task in addition to the main skill, to assess the attentional resources placed on executing the primary skill. The timing of the secondary task is critical as it needs to correspond to the period where the primary task requires an individual's focus of attention (Abernethy, 1988; Abernethy et al., 2007). In chapter 7, a continuous secondary task was adopted (i.e., counting backwards in 'threes', consistent with previous research; Buszard et al., 2014b) to overload participants' allocation of attention throughout the whole trial which comprised of ball delivery and kick. However, both single-task and dual-task kicking improved throughout the study in both groups, and counting performance was not affected in the dual-task, suggesting that, potentially, counting backwards did not challenge participants' allocation of attention. Participants might have focused their attention on counting at the beginning of a trial and then switched attention to kicking when the ball was closer to them. This design issue did not allow a proper examination of skill automaticity and, consequently, limited conclusions on the potential role of skill automaticity in promoting transfer.

8.6 Future directions

The findings of this thesis lead to relevant questions for future research. Chapters 6 and 7 showed how futsal task constraints promoted transfer of skills, and it would be interesting to further examine the mechanisms that underpin skill transfer when task constraints, such as equipment and playing area are modified. How does modified equipment that facilitates the execution of a skill, or a reduction of space and time that increase the demands of a skill facilitate transfer? In chapter 7, skill automaticity was examined as potential mechanism that encouraged transfer from futsal to soccer ball. While the abovementioned methodological issues prevented proper assessment of skill automaticity, future research could use a probe dual

task, as opposed to the continuous dual task used in chapter 7, to examine the potential role of skill automaticity in promoting transfer. A probe dual task would place a secondary stimulus when a participant is executing a skill (Abernethy, 1988). For example, a sound pitch could be played during the kicking action and a participant would need to verbalise as quickly as possible whether the pitch was high or low frequency, similar to previous research (Beilock, Bertenthal, McCoy, & Carr, 2004). This task should challenge a participant's allocation of attention between primary and secondary task when the execution of the skill places high attentional demands to achieve a successful outcome. Furthermore, future research could examine other mechanisms that might facilitate learning (and transfer) when equipment is modified, such as reduced movement variability and increased sensitivity to haptic information. Furthermore, Gibson (1979) argued that people continuously exploit haptic and visual information to guide action, and future studies could examine how attunement to haptic and visual information develop and interact when equipment is manipulated.

In chapter 6, it was speculated that the reduced space and time during practice in futsal encouraged players to explore different information sources and to exploit the information that specified passing affordances, which facilitated adaptation and transfer to passing with soccer task constraints (i.e., larger space and longer time to perform passing). Previous research showed how restricted vision in one-handed catching (Bennett et al., 1999) and changes in holes orientation in climbing (Seifert et al., 2015) encouraged perceptual-motor exploration which then facilitated skill adaptability to new task constraints. Future research could examine how the manipulation of the number of players and space influence the exploration of environmental information and movement solutions, and how this behaviour promotes transfer. The measurement of visual exploration will be challenging (McGuckian, Cole, & Pepping, 2018); however, an inertial sensor placed on a participant's head during games could provide

indication on the number of head turns, which could be a proxy for exploratory behaviour (McGuckian & Pepping, 2016).

Future research could also adopt methods to capture skill adaptability on several occasions to examine how the adaptation process that underpins transfer evolves. Perceptual and passing skill were evaluated on a single occasion in chapters 6 and 7, which potentially did not entirely capture how an individual adapted a learned skill to a new task. Similarly, other studies that evaluated transfer of skills or skill adaptability in sport assessed a participant's skill in a transfer task on a single occasion, and the performance of various trials was typically averaged (e.g., Abernethy et al., 2005; Müller et al., 2015). Future research could assess skill on several occasions and/or analyse data in time-series rather than averaging a participant's performance across all trials (an example; Zanone & Kelso, 1997). This would provide insights into how adaptation occurs and how task constraints influence the adaptation process. For example, does adaptability typically occur on a second session, and skill assessment on a single occasion misses it? Would averaging the first or last 10 trials, or using a rolling average every 5 trials be best to capture the adaptation process? Do certain task constraints promote a quick or slow adaptation?

While a generic participation history questionnaire was used in chapters 5 and 6, future research examining skill transfer could adopt a validated sport-specific questionnaire to gather detailed information about an individual's previous experience. For example, Ford, Low, McRobert, and Williams (2010) developed a participation history questionnaire in cricket, which can be adapted to other sports (for an example in soccer see Roca, Williams, & Ford, 2012). The questionnaire was comprised of three main sections: the first two sections contained questions about the age an individual reached certain milestones (i.e., first experience, supervised training, competition in an organised league and at a semi-professional level) and the average hours per year they engage in certain activities (i.e., play, practice, and competition)

in their primary sport; the third section recorded information on an individual's engagement in other sports. This detailed information on an individual's practice history would allow to properly account for the influence of different experiences on skill transfer, and to examine how a specific type of activity (e.g., structured) with a certain set of constraints influences skill transfer.

Lastly, future research could examine how the interaction of expertise and task constraints influences transfer of learning. Previous research has shown that expertise promotes transfer of anticipation skill to a similar sport domain (Moore & Müller, 2014; Rosalie & Müller, 2014). For example, Rosalie and Müller (2014) expert taekwondo athletes were superior than 'near-expert' taekwondo athletes in transferring their ability to anticipate an opponent's action to karate. In this study, the higher level level of expertise allowed the athletes to perceive task-specific affordance and act accordingly. Furthermore, it has been shown how soccer players with different skill levels (i.e., national- and regional-level) behaved differently when the size of a soccer pitch was modified (Silva, Duarte, et al., 2014). Future research could combine these two approaches and examine how an individual's skill level influences skill transfer when task constraints are modified. Participants can be stratified into different skill levels and they can undertake a cross-sectional or longitudinal examination of their skill transfer. In this context, it would be critical to design a proper assessment of an athlete's skill level, and a participation history questionnaire can certainly provide relevant information that can contribute to the skill evaluation.

8.7 Concluding remarks

This thesis examined the role of task constraints in promoting development and transfer of perceptual behaviour supporting a perceptual-motor skill. It is known that the interaction of task constraints influences the emergence of task-specific affordances (Araújo et al., 2006;

Gibson, 1979; Newell, 1986); however, previous research was limited to the acute effect of task constraints modification on an individual's perception of affordances (Roca et al., 2013; Vaeyens, Lenoir, Williams, Mazyn, et al., 2007). The first step of this thesis was to examine how task constraints influenced perceptual skill in the long term (i.e., after 1000 hours of practice), and results showed that practicing passing with different task constraints influenced how participants oriented their attention towards environmental information to perceive affordances.

The second step was to evaluate how learning a skill with different task constraints promoted transfer to new constraints. Previous research indicated how similarity of information between learning and transfer tasks facilitated transfer of perceptual skill (Snapp-Childs et al., 2015); however, it was unclear whether task constraints modulated skill transfer between tasks that shared similar information to guide action. Results showed that learning the passing skill in a reduced space with reduced time to perform the skill promoted a higher magnitude of transfer to a task with larger space and longer time than vice-versa. As such, similarity of information to guide action between tasks facilitates transfer, and task constraints influence the magnitude of transfer. Practitioners are encouraged to design training drills that present similar information to competition and to manipulate task constraints to improve the magnitude of transfer.

Finally, it was investigated how modified equipment facilitated transfer and, in turn, expedited the skill learning process. Properties of equipment can be modified to facilitate the execution of a sport skill (Buszard et al., 2016b); however, it was unclear how modified equipment influenced the development and transfer of perceptual skill to the standard equipment. Practicing the passing skill with the futsal ball fast-tracked learning of soccer passing. The properties of the futsal ball encouraged the development of participants' gaze behaviour that underpinned the positive transfer to soccer ball. These results indicated that the

perceptual strategies developed with the futsal ball were functional to passing performance with the soccer ball. Practitioners are encouraged to select training constraints that promote behaviours that are functional to competition, even if training constraints are slightly different to the constraints of the competition.

In conclusion, this thesis extends current knowledge on the role of task constraints in promoting skill learning. The manipulation of task constraints during practice has an effect on the development and transfer of an individual's ability to perceive task-relevant affordances. The findings of this thesis provide new insights into the literature on skill transfer, and encourage practitioners, who regularly manipulate task constraints, to select training constraints that facilitate the development of behaviour required in competition.

CHAPTER 9

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(APA 6 GUIDELINES WERE FOLLOWED)

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CHAPTER 10

APPENDICES



CONSENT FORM FOR PARENT/GUARDIAN OF PARTICIPANTS AND PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite your son to be part of a study entitled: 'Investigating the transfer of skills between futsal and soccer representative tasks'.

The research aims to investigate whether the equipment and rules unique to futsal and soccer help skills transfer between each game. Where you look and your passing skills will be assessed during soccer and futsal activities (5 vs 5 games). There are small, foreseeable risks related to the execution of the tasks. One task will be performed on a surface (grass or gym floor) which you are not accustomed to, potentially increasing the lower body injury risks due to the different foot-surface grip. However, a proper warm-up and familiarization session will minimize this risk.

CERTIFICATION BY SUBJECT

I, _____

Parent/guardian of _____

certify that I am voluntarily giving the consent for the participation of my son in the study:

Investigating the transfer of skills between representative tasks in futsal and soccer,

being conducted at Victoria University by:

Prof Damian Farrow, Dr Fabio Serpiello, Dr Derek Panchuk and Mr Luca Oppici.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me and my son by:

Mr Luca Oppici and Dr Fabio Serpiello

and that I freely consent to my son participation involving the below mentioned procedures:

- Performance of a warm-up activity and the soccer and futsal 5 vs 5 tasks.
- Assessment of gaze behaviour using the eye tracking system.
- Assessment of technical execution via video coding.
- Being filmed during the assessment. The footage will be seen and analysed only by the research team for the research purpose.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

Any queries about your participation in this project may be directed to the researcher

Prof Damian Farrow

Dr Serpiello Fabio

Mr Oppici Luca

Damian.Farrow@vu.edu.au

Fabio.Serpiello@vu.edu.au

luca.oppici@live.vu.edu.au

(03) 9919 5001

(03) 9919 4736

0452 662 909

If you feel distressed about the participation in the project, psychologist Dr Janet Young is available for counselling:

Dr Janet Young

Janet.Young@vu.edu.au

(03) 9919 4762

I have been informed that the information I provide will be kept confidential.

Parent signature:

Participant signature:

Date:

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.



INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

Your son is invited to participate

Your son is invited to participate in a research project entitled 'Investigating the transfer of skills between representative tasks in futsal and soccer'.

This project is being conducted by the student researcher Mr Luca Oppici as part of a PhD study at Victoria University under the supervision of Professor Damian Farrow and Dr Fabio Serpiello from College of Sport and Exercise Science; Institute of Sport, Exercise and Active Living; and Dr Derek Panchuk from the Australian Institute of Sport.

Project explanation

Transfer of learning is how previous learning influences new learning. Or, more specifically, the influence of previous experiences on performing a skill in a new context (e.g., a different place) or on learning a new skill (e.g., how does soccer experience influence basketball skills). Teachers and coaches are able to promote this process by designing effective training activities. They may manipulate the equipment and rules characteristics of tasks to facilitate the transfer of skills. However, to date there is a lack of research investigating this issue.

Consequently, this study will investigate how the equipment and rules unique to futsal and soccer facilitate the transfer of skills between these different tasks. Do the different ball and player density, characteristic of the two disciplines, help players adjust to the other game quicker?

To help us understand what goes on when we play games that are similar, we are going to assess where you look (your gaze behaviour) and your passing ability (your technical skills) while you play small games in these tasks.

This will help understand the transfer and it will help develop guidelines for coaches.

What will your son be asked to do?

If your son chooses to volunteer for the study, he will be asked to attend three sessions lasting approximately 120 minutes each. In the first session he will be asked to perform a

familiarization session in the “other” discipline (futsal or soccer); in the second and third sessions he will be asked to perform the game in futsal and soccer. Before each session he will have a ten-minute warm-up.

The futsal task will be performed in an indoor court at the Victoria University campus, while the soccer task in an outdoor ground yet to be determined. During the 24 hours prior the testing session he will be asked to refrain from vigorous activity.

During the game activities, he will be asked to wear an eye tracking device which is a pair of safety glasses with two cameras that assess where you look, for a period of time during the session. We will also film his performance and measure his passing skills during the games.

If he feels distressed about the participation in the project, he and you can contact psychologist Dr Janet Young for counselling.

What will he gain from participating?

He will have the unique opportunity to participate in an original research, conducted by a world-leading University in sport science, using the latest available technology.

Once all testing sessions are completed, he will be provided with a detailed report including information relating to his technical skills and to his ability to visually scan the environment and to make decisions. Furthermore, he will receive a report on his ability to transfer those skills performing the task in another environment.

How will the information he gives be used?

The information collected in this study will be used by Mr Luca Oppici for the purpose of completing his PhD thesis. Data will also be used for preparing journal articles for scientific publications and conference presentations by Mr Luca Oppici. At no time will he be personally identifiable in the presentation of these results.

What are the potential risks of participating in this project?

His participation in this research involves small risks related to the procedure. However, if at any time he feels uncomfortable with any procedures, he is free to withdraw from the study free from any repercussions.

He will be asked to perform physical exercise at an intensity which he is already accustomed to. However, performing a session of a different sport, in particular the court surface used may

slightly increase the risk of injuries in the lower body due to the different foot-surface grip. The familiarization session is aimed to help him gradually become familiar with the new environment and reduce this risk. Furthermore, he will be asked to wear appropriate shoes according to the surface he will perform the task on.

The eye tracking device that he will be asked to wear during the sessions may cause a physical risk if he runs into another player or are hit by a ball. However, the goggle lenses which make up the eye tracker are made of a high resistant plastic material which is safe in case of collision or being hit by a ball. Furthermore, specific rules, prohibiting physical tackles and keeping the ball down, will be used during the tasks to minimize the potential risks.

How will this project be conducted?

The activities consist of 5 vs 5 games aiming to replicate futsal and soccer environments. The game will be made of four intervals of ten minutes each, interspersed with ten minutes break.

Session 1 (familiarization): he will gradually become familiar with the new environment and the equipment, performing different run speed, change of direction and a game similar to the assessment wearing the eye tracker.

Session 2: he will perform the game in his discipline.

Session 3: he will perform the game in the other discipline.

Skill assessment:

His gaze behaviour will be assessed via an eye tracking system, consisting of goggles with two mounted cameras, during one interval in each task. This device allows the assessment of his gaze behaviour without interfering with his normal field of view and freedom of movements.

Cameras will be placed around the pitch, filming the task performance. The analysis of the footages will allow the evaluation of his technical skills. The footage will be seen and analysed only by the research team for the research purpose.

Who is conducting the study?

This project is being conducted by Victoria University, College of Sport and Exercise Science; Institute of Sport, Exercise and Active Living.

For further information regarding this study please contact the Principal Investigator, Prof Damian Farrow, phone: (03) 9919 5001, email: Damian.Farrow@vu.edu.au

Investigators:

Prof Damian Farrow – Principal Investigator

Mr Luca Oppici – Student Investigator, mobile: 0452 662 909, email: luca.oppici@live.vu.edu.au

Dr Fabio Serpiello – Associate Investigator, phone: (03) 9919 4736, email: Fabio.Serpiello@vu.edu.au

Psychologist:

Dr Janet Young, phone (03) 9919 4762, email: Janet.Young@vu.edu.au

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461

Training History Questionnaire

Name _____

Age _____

Sport _____

Dominant foot (circle) right / left

Insert in the table below an average amount of months, hours and competitions you engaged in since you started playing futsal or soccer.

What age did you start playing in a club?	
Average number of months per season	
Average number of training sessions per week	
Average duration of a training session	
Average amount of competitive games per season	



CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite you to be a part of a study entitled “How do ball properties influence the transfer of kicking skill?”

The study aims to investigate the influence of two different balls in developing decision-making and kicking skill in soccer. You will practice the kicking skill with either a futsal or a soccer ball for 3 sessions and your abilities to kick a soccer ball while making a decision will be assessed before and after the practice to evaluate the effect of training. Specifically, where you look during the kicking action, your kicking accuracy and your decision-making accuracy will be assessed in the laboratory.

Low risks are associated with the study as practice and testing are performed at low intensity, after proper warm up.

CERTIFICATION BY PARTICIPANT

I, (name and surname) _____

of (suburb) _____

certify that I am at least 18 years old and that I am voluntarily giving my consent to participate in the study:

How do ball properties influence the transfer of kicking skill?

being conducted at Victoria University by:

Prof Damian Farrow, Dr Fabio Serpiello, Dr Derek Panchuk and Mr Luca Oppici.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by:

Mr Luca Oppici and Dr Fabio Serpiello

and that I freely consent to participation involving the below mentioned procedures:

- Assessment of gaze behaviour, decision and kicking accuracy for 3 sessions.
- Practice of the kicking skill for 3 sessions.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher

Prof Damian Farrow

Damian.Farrow@vu.edu.au

(03) 9919 5001

Dr Serpiello Fabio

Fabio.Serpiello@vu.edu.au

(03) 9919 4736

Mr Oppici Luca

luca.oppici@live.vu.edu.au

0452 662 909

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.



INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled “How do ball properties influence the transfer of kicking skill?”

This project is being conducted by a student researcher Mr Luca Oppici as part of a PhD at Victoria University under the supervision of Prof Damian Farrow and Dr Fabio Serpiello from the College of Sport and Exercise Science, and Dr Derek Panchuk from the Australian Institute of Sport (AIS).

Project explanation

This project will investigate how the type of ball influences decision making and kicking skill in soccer.

You will be part of one of two groups that will practice a soccer kicking action for 3 sessions with either a futsal ball or soccer ball. The changes in your performance will be measured before and after training. We will measure how accurately you make decisions and kick the ball in response to moving players displayed on a video screen or who will perform the movements in real-life.

What will I be asked to do?

If you volunteer to take part in this study, you will be asked to attend the laboratory at Victoria University on 6 occasions to practice your kicking skills (3 sessions) or to measure your kicking abilities (3 sessions).

Before the skill tests we will give you the opportunity to learn how to use the equipment and practice, so you know what to expect.

Each skill testing session will last approximately 45 minutes and you will be asked to perform kicks in response to a video or to real players. In session 1 and 5, you will kick a soccer ball in response to videos that will show players moving to receive your pass. In session 6, you will perform a similar task but in this session real players will move in the laboratory and you will

kick the ball to them. In these tests, you will be asked to wear an eye tracking device which is a pair of safety glasses with two cameras that assess where you look.

Each practice session will approximately last 45 minutes and you will practice a kicking task using either a futsal or soccer ball. The session will start with a five-minute warm up to prevent potential injuries. You will then perform a total of 100 kicks in response to video clips displaying moving players (similar to the testing session).

What will I gain from participating?

You will have the opportunity to participate in an original research, conducted by a world-leading University in sport and exercise science, using the latest available technology (e.g., eye tracking technology).

Once the study is completed you may gain information on your kicking skill and you will also have access to the group (mean) results.

Furthermore, you will receive a financial reimbursement of 50\$ in the form of shopping voucher as compensation for your time and effort.

How will the information I give be used?

The information collected in this study will be used by Mr Luca Oppici for the purpose of completing his PhD thesis. Data will also be used for preparing journal articles for scientific publications and conference presentations by Mr Luca Oppici. At no time will you be personally identifiable in the presentation of these results.

What are the potential risks of participating in this project?

The potential risks associated with your participation in the project are low. The intensity of the exercise, both in the practice and assessment sessions, is low. You will never be asked to perform a kick with maximum force, the instructions will always focus on accuracy.

However, there is always the chance of injury when performing physical tasks and we will provide you with a proper warm up at the beginning of each session to help prevent potential injuries.

How will this project be conducted?

If you volunteer to take part in this study, you will perform different assessments and training that involve the kicking action. All the sessions will be performed in the motor learning lab at Victoria University, Footscray Park campus.

Session 1 (pre-test): in this session you will perform 24 kicks in response to a video showing moving players. Different number of players and patterns of movement will be displayed and you will need to kick the ball accordingly. Kick accuracy, decision accuracy and where you look when kicking will be measured. The procedure will be explained to you in details before the test and you will have the opportunity to practice the kicks and ask questions.

Then a 5-minute warm up will precede the testing trials.

You will perform all testing sessions with a soccer ball.

Session 2 – 4 (training): you will practice the kicking action in response to videos showing players that move to receive your pass. You will perform a total of 100 kicks divided in 10 blocks of 10 kicks each. Before these kicks you will perform a 5-minute warm up and 20 assessment kicks to measure how naturally you can kick the ball. The assessment kicks will be divided in 10 kicks towards a fixed target and 10 kicks towards the fixed target while counting backwards. Each training session will approximately last for 45 minutes. In training sessions, you will use the assigned ball, either a futsal or soccer ball.

Session 5 (post-test): you will perform the same procedure as pre-test.

Session 6 (transfer test): you will perform a task similar to pre and post-test but this time there will be real players in the laboratory moving to receive your pass. You will perform a total of 24 trials.

Who is conducting the study?

The study is being conducted by

Prof Damian Farrow – Principal Investigator, phone: (03) 9919 5001, email:

Damian.Farrow@vu.edu.au

Mr Luca Oppici – Student Investigator, mobile: 0452 662 909, email:

luca.oppici@live.vu.edu.au

Dr Fabio Serpiello – Associate Investigator, phone: (03) 9919 4736, email:

Fabio.Serpiello@vu.edu.au

Any queries about your participation in this project may be directed to the Investigators listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Participation History Questionnaire

Name _____

Sex _____

Age _____

Dominant foot (circle) right / left

Current sport _____

1. Experience in soccer/futsal

Your previous experience in soccer and futsal:

	Games during PE classes	Games with friends
Number of years		
Hours per week		

2. Experience in team-sport activities

Insert in the table below your current engagement in sport and previous engagement in team-sport activities (from newest to oldest):

Organised: you played in a club for at least one season.

Non-organised: you played only with your friends.

Current Sport	

Engagement (organised/non-organised) and competition level	
Number of seasons	
Hours per week	
Sport	
Engagement (organised/non-organised) and competition level	
Number of seasons	
Hours per week	
Sport	
Engagement (organised/non-organised) and competition level	
Number of seasons	
Hours per week	
Sport	
Engagement (organised/non-organised) and competition level	
Number of seasons	
Hours per week	
Sport	
Engagement (organised/non-organised) and competition level	
Number of seasons	
Hours per week	