PRIMING MOTOR-VISUAL SKILLS FOR FOOTBALL:

AN ASSESSMENT OF THE *4-BALL* METHOD

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ABSTRACT

Sports vision training that claims to enhance the basic *visual functions* of athletes (in the optometric sense) has been largely discredited. By contrast, perceptual training that aims to improve *visual skills* has shown more significant and beneficial results. In view of this consensus, the lack of studies on perceptual skills conditioning applied as a warm-up is surprising. This study is an attempt to redress this scarcity. It will assess the effects of a novel multi-ball method (*4-ball*) applied in football (soccer) as a motor-visual warm-up prior to competitive performance.

The results presented in this study, despite acknowledged limitations, indicate substantial gains on a range of performance indicators in football, following the introduction of a *4-ball* warm-up. Further research at an outcome and process level is required to support these findings, as well as to clarify the underlying factors that help explain specific training effects.

In light of this preliminary study, a number of suggestions for future research are set out as well as practical recommendations for implementing this method for football coaches and players.

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CHAPTER 1: INTRODUCTION

1.1 Background to this applied study

Advances in video and computing technology over the past twenty-five years have helped stimulate a wide range of research on perceptual-cognitive skills in sport (for overviews see Williams *et al.,* 1999; Hodges *et al.,* 2006; with respect to football, see Williams and Ward, 2007). Many lines of enquiry have developed drawing upon discoveries in movement and vision science, sport psychology and neuro-anatomy. This process has led to an interest in the development of dedicated perceptual training programmes that aim to improve performance in sports (see Mann *et al*., 2007).

Within professional football there is an increased awareness of the potential benefits of this research on perception, although little evidence that any practical initiatives have been fully implemented (Ford *et al*., 2010). However, the game is going through a period of rapid change. Due largely to the exorbitant sums involved in the purchase and sale of players, the quality of 'in-house' talent development at football clubs and academies has come into sharp focus. As a result, existing methods as well as styles of coaching and conditioning have come under increased critical scrutiny, (see Williams and Reilly, 2000; Ford *et al.,* 2010).

Against a background of an influx of foreign players and coaches into the domestic game and the repeated failure of the England national teams (from U-17's to senior level) to win major tournaments, the Football Association have recently conducted a thorough review of best practice in football development. In 2010 they launched the The Future Game, which sets out their blue-print to “produce technically excellent and innovative players”, with exceptional “awareness and vision to formulate the ‘pictures’ of what they are going to do next.” (The Future Game, 2010, P.11).

Viewed from this context, specialized perceptual training programmes have a clear potential to gain a wider application in elite football, at least where there is evidence that these programmes can provide players with a significant competitive advantage. However, to achieve this, a sustained effort must be made to communicate new research initiatives and findings to coaches and coach educators (see Bishop *et al*., 2006). In this way, new and effective methods can be properly applied, thereby encouraging coaching practice to evolve and player performance levels to further improve (see Farrow *et al*., 2008).

1.2 Introduction to the chapter

This study will assess the effects on performance in football following the introduction of a novel motor-visual warm-up described as *4-ball.* The *4-ball* protocol used here was designed to function:

1) As a pre-competition warm-up aimed at priming the player’s perceptual system for optimal performance.

2) As amenable to athletes in team sports such as football, warming up in groups or individually.

3) As a practical method that can be applied by athletes performing in the field.

To this author’s knowledge, there are no existing studies focused on assessing a specific motor-visual warm-up applied in the immediate lead up to competitive play. Furthermore, a majority of research on perceptual skills training has focused on:

A) Athletes involved in *individual* sporting disciplines such as tennis (Farrow & Abernethy, 2002).

B) Discrete events encountered by athletes in team-based sports, for example, goalkeepers facing a penalty kick in football (Savelsbergh *et al*., 2002).

Very few, if any, studies have assessed a dedicated perceptual conditioning protocol applied simultaneously to a *group* of athletes (i.e. relevant to team-based sports such as football or rugby etc.). Ripoll et al., (2005) provide a notable exception, with their study on team tactical perceptual training in football. However, the group interventions adopted, were not applied as a pre-competition warm-up as proposed in this study.

A third limitation stems from the fact that a majority of studies on perceptual training in football have been laboratory-based (e.g. Williams & Grant, 1999; Williams & Ward, 2003). Such controlled research has advanced knowledge, and suggested new training possibilities, but this has come at the expense of realism and ecological validity. The use of video and software technology to create simulated environments has been effective in examining constructs such as anticipation and decision-making (e.g. Williams *et al*., 2004). However, such constructs are difficult to measure directly since changes in behaviour can only be inferred over time (Williams *et al*., 2005). Furthermore, subsequent assessment of skills transfer into applied and competitive settings has largely been omitted as will be further discussed below. Hence, while interest in perceptual training has flourished over the past twenty-five years, this interest has remained largely confined to academia. It is yet to make any widespread impact within professional sport in general, and, football in particular (Ford *et al*., 2010; Williams *et al*., 2005).

In an attempt to address these three key limitations, this applied study will focus on the team-sport of football (soccer), assessing outcome scores on a range of performance indicators following the implementation of a practical *4-ball* pre-competition warm-up.

The research model adopted here has undoubted limitations of its own and these are discussed in section 5.6 below. Hence, the purpose of this study is largely preliminary. It aims to provide some initial data as well as possible perimeters for further more detailed outcome and process-orientated research.

1.3 A brief introduction to *4-ball*

A detailed description of the *4-ball* constraint will be set out in the Training Procedures section (see 3.5). However, to help establish a premise for the literature review, a brief outline of the *4-ball* method is necessary.

As developed for this research project, the *4-ball* warm-up consists of a novel sequence of practical task constraints that combine 3-ball "cascade" juggling using the upper limbs with simultaneous ground-ball drills using both lower limbs to control and pass a regulation size football. This method compels players to execute precise interceptive, ball striking and throwing actions by means of integrating all four limbs to fulfil a single, more complex "unitary task" (Hirst, 1986). Subsequent drills extend the perceptual and coordinative challenge, with the player required to identify static and dynamic visual cues, for example, different coloured cones raised by a coach. The player is asked to give an immediate verbal response to these visual stimuli while simultaneously controlling the four balls as described above.

1.4 *4-ball* applied as a motor-visual warm-up

Applied as a motor-visual warm-up, the purpose of *4-ball* is as follows: to help prime the player to rely more on peripheral vision and on kinaesthetic information in the immediate run up to competitive performance. More precisely, that *4-ball* seeks to encourage a decoupling of the player's point of gaze and the movements of the ball, allowing for increased sensitivity and adaptability to other effective sources of sensory information (proprioceptive, haptic etc.). This approach is theorized as freeing foveal vision to focus on potentially earlier and more decisive visual cues, for example, "reading" early movements of teammates or opposition players in externally paced sports (for an overview on visual search strategies in football see Williams & Davids, 1998). .

1.5 Outline of the study

This applied study will begin by defining a theoretical context for an assessment of the *4-ball* method. Chapter 2 will review the main lines of contemporary research on perceptual-motor skill acquisition with a focus on the following relevant areas:

- studies assessing perceptual training programmes.
- visuo-motor investigations of three ball "cascade" juggling.
- implicit experimental and instructional techniques such as secondary and distracter task paradigms.
- constraints-led coaching methods.
- the critique of specificity of practice

These research areas have all helped provide a conceptual and methodological framework for the current study. With the focus here on performance outcomes in football, relevant research from this domain will be emphasised. Research in sports other than football will also be considered where pertinent. Chapter 2 concludes with an outline of a typical structured warm-up protocol as applied in football.

Chapter 3 will outline the methodology adopted in this study, with the focus on research design, experimental procedures and data analysis. Chapter 4 will provide quantitative results followed by a discussion in chapter 5 with an account of the research limitations. The aim is to link the findings presented here to recent studies and to the theoretical context as set out in the literature review. Proposals for future research will also be outlined as well as practical implications for implementing the *4-ball* constraint in football.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to cognitive research on perception in sport

The aim of improving perceptual skills is an integral part of any comprehensive, sport-specific training initiative. However, interest in developing specialized perceptual training programmes only gained momentum from the early 1990's (see Williams, 2002; Williams *et al*., 1999; Knudson & Kluka, 1997). This section will look at how contemporary research on perception in sport has helped encourage new methods aiming to improve motor-visual expertise in football.

Converging evidence from research across a range of sports, suggests expert performance is not dependent on above-normal visual function, i.e. the quality of eyesight as measured by standard optometric tests (Helsen & Starkes, 1999; Starkes & Allard, 1993). This is now widely accepted including by optometrists specializing in sports vision (Knudson & Kluka, 1997).

Four examples across a range of sports help substantiate this consensus view. Garner (1977) discovered elite athletes display a high incidence of uncorrected visual defects, indicating that below average vision is not inconsistent with superior sports performance. Applegate (1992) found that a progressive blurring of visual acuity had no noticeable impact on motor performance in basketball free-shooting. Helson and Starkes (1999) found no consistent differences between expert and intermediate level football players in various non-specific visual and information processing abilities (for example, visual reaction times, static and dynamic acuity and peripheral range). Similarly, Ward and Williams (2003), found no consistent differences in 200 elite and sub-elite footballers on standard measures of visual function.

In light of these findings, researchers working from a cognitive perspective have shifted focus to examine perceptual skill as a function of expert knowledge or ‘software’ acquired through years of active participation (Abernethy, 1987). Much of this research has sought to compare expert and novice performers, with elite athletes typically seen as more effective in their selective use of visual information to aid decision-making (e.g. Savelsbergh *et al.,* 2002).

Research focused on perceptual skills acquisition often cites a lineage back to Gibson (1966), who described perceptual learning as founded on the “education of attention”. In this view, learning involves the attunement of perceptual systems (visual, auditory, haptic etc.) to the most essential information for performing a certain task. Much of the subsequent research in the sports science domain has elaborated on this perspective by investigating game-specific perceptual skills. This literature is by now substantial, with studies in basketball (Vickers, 1996), baseball (Burroughs, 1984), golf (Steinberg *et al*., 1995), tennis (Abernethy & Wollstein, 1989; Moen, 1989), table tennis (Hughes *et al*., 1993) and football (Williams *et al*., 1994; Helsen & Starkes, 1999) to cite just a few examples. A majority of these studies have focused on what distinguishes expert from novice performers (Abernethy *et al*., 1993; Williams *et al.,* 1994). In the case of research on football, this approach has provided valuable insights on skills acquisition and related topics such as talent identification and development (Williams & Reilly, 2000).

2.1.1 Perceptual experiments using video and video simulation.

Cognitive studies in motor-perception have tended to be laboratory-based, making innovative use of new digital recording and monitoring technology (for a review of available methods, see Carling *et al*., 2008). Participants are wired up to portable, head-mounted eye-tracking systems that record their visual reactions to real-time sporting actions projected on a large video screen (for example see Williams & Davids, 1998). This controlled experimental approach provides information on the participant's point-of-gaze and the saccadic eye movements separating each visual fixation (for a detailed review see Williams *et al.,* 1999). In conjunction with this technology, the so-called "occlusion paradigm" using liquid crystal devices has been extensively adopted (see also 2.2.1). Using such methods, researchers have reported substantial support for anticipatory expertise in sports (see for example, Abernethy and Russell, 1987; Salmela and Fiorito, 1979). Constructs such as "advanced cue-utilization" have been examined, comparing novice and expert visual reactions to an opponent's postural orientation (see Starkes *et al*., 2001). These lab-based studies have focused on "closed skill" events such as the return of serve in tennis (Farrow and Abernethy, 2002). Similarly, in football (an open-skilled sport), perceptual research has focused on interceptive tasks, investigating visual reactions during "set play" (i.e. closed skill) scenarios such as the penalty kick (Savelsbergh *et al*., 2002). Controlled experiments of this sort aim for reliability of results, however they also raise many implications with regard to ecological validity that will be discussed shortly.

Where more open-skill scenarios have been explored - such as are typically encountered in football- research has made use of video simulation of evolving game situations (Williams *et al.,* 1994; Williams, 2002). Again, much of this research has focused on monitoring differences between the visual search strategies of novices and experts. Using the "situational probability paradigm" (Ward & Williams, 2003), participants are presented with filmed sequences representative of their customary view of the action and asked to predict the outcome of these observed sequences. The filmed clips are edited to give varying degrees of information regarding the movement of active players and the flight of the ball with participants asked to predict "the next best move" etc. (see Williams, 2002). As with the research on advance cue-utilization, studies focused on game intelligence (such as recognition of evolving patterns of play), have helped yield significant insights on the perceptual and cognitive processes involved in playing football (Ward and Williams, 2003). A summary of these insights is presented below. However, as is often acknowledged, these controlled experiments typically lack multi-factorial realism and ecological validity. Partly as a result of such limitations, many of the findings presented have largely been ignored outside of academia (Ford *et al*., 2010).

2.1.2 Summary of key findings on visual performance in football

Research from the cognitive perspective points to the following key findings that help define perceptual skills in football (see Williams, 2000):

(1) *Elite performers have more success anticipating the actions of their opponents through greater awareness of advance or partial visual cues* (see Williams *et al.,* 1999; Savelsbergh *et al.,* 2002, Williams and Burwitz, 1993). For example, skilled players are quicker at anticipating an opponent's postural

orientation or the movements of players off the ball. (Abernethy, 1987)

(2) *Elite performers are quicker and more precise in both the recognition and recall of decisive patterns of play* (Williams and Davids, 1995). This cognitive facility is considered vital for enhanced anticipatory skill in competitive team ball sports such as football.

(3) *Elite performers are more efficient and effective in their visual search behaviour.* Research suggests elite players display more pertinent search strategies. These typically involve fewer but longer visual fixations (Williams, 2002; Williams *et al.,* 1999; Abernethy, 2001). Such an approach allows these players to extract better quality information per foveal fixation. This acquired ability is vital as saccadic (or ballistic) eye movements have been shown to compromise visual acuity, so the more information extracted per fixation may confer a performance advantage (see Williams & Davids, 1998). In addition, expert performers also use their peripheral vision more effectively to anticipate play. By comparison, less skilled players are far more liable to 'ball watch' and hence show far less alertness to positions and movements of players off the ball (Williams *et al.,* 1994).

(4) *Elite performers show greater awareness of situational probabilities*. Elite players are more precise in assessing the probability value of unfolding patterns of play, another vital cognitive skill underlying anticipation (Williams *et al.,* 2004). For example, in football, the best passing option, or understanding which players are in threatening and non-threatening positions.

(5) *Elite performers are less susceptible to alterations in emotional state*. Research across a number of sporting domains indicates that the visuo-motor responses of expert players tend to be more consistent under pressure

(Janelle, 2002). By comparison, novices when performing under stressful conditions will tend to increase their saccadic search rate and focus on more peripheral, less informative areas of the display (Williams & Ward, 2003).

2.1.3 Limitations of cognitive studies on visual perception in sport

Convergent findings largely from an information-processing perspective, suggest future perceptual training interventions should focus on developing game-specific knowledge structures underlying skilled perception (Williams & Ward, 2003). Such initiatives are likely to prove more effective than the more generalized visual training programmes offered by optometrists specializing in vision training and therapy such as the *Eyerobics* programme (Abernethy & Wood, 2001).

As previously highlighted, the key concern with a majority of the cognitive studies cited above regards their lack of ecological validity and the lack of data on skills transfer into competitive, real-time, sporting environments (Williams *et al.,* 1999; Williams and Hodges, 2004). These limitations are well recognized, as is the likelihood that coaches and practitioners assessing such research may struggle to draw effective lessons that they can apply in a practical setting (Bishop *et al.,* 2006; Ford *et al.,* 2010).

2.1.4 Implications for future research on perceptual training

The key concerns identified above have helped inform the preliminary research design adopted here. The aim, as further defined below, is to maintain a strong functional link between perception and action, focusing on the proposed perceptual training intervention (*4-ball*) and assessments of its impact in terms of skills transfer into a real-time competitive environment. As emphasized above, relevant findings from a review of visuo-motor research in sport indicate the vital importance of maintaining a realistic degree of action/perception coupling as well as game-specificity when examining motor-perceptual training initiatives (Hodges and Franks, 2004).

2.2 Introduction to visuo-motor research on cascade juggling

As outlined in the introduction, the *4-ball* task involves juggling three balls using the hands while simultaneously controlling a ground ball using the feet (see procedures in 3.5). The rationale for combining hand-juggling together with football skills is discussed in more detail in 5.2 and section 2.3 on the specificity of practice. However, to provide a foundation for this discussion, a brief overview of research on the component act of juggling (principally the basic three ball "cascade" pattern) becomes relevant. Three key findings from this research have a bearing on this study:

1) Juggling is more than simply a visual task. As well as an optical input, proprioceptive and haptic flow fields are also implicated (Van Santavoord and Beek, 1994, pp. 241-242).

2) Only certain segments of the ball flights are attended to, segments which provide more valuable optical information than others (see Haibach *et al.,* 2004, p. 204)

3) Experts more often adopt a so-called "gaze through", where behavioural point-of-gaze remains bounded within a very small area within the juggling pattern (Van Santavoord and Beek, 1996).

2.2.1 The complex perceptual challenge of multi-ball juggling

In an early study on juggling, Van Santvoord and Beek (1994) tried to determine what information sources (e.g. optical, haptic etc.) were necessary to juggle a three-ball cascade pattern (as used in *4-ball*). The focus of their investigation was on the way three intermediate participants phased their hand movements in conjunction with the pick-up of optical information. Crystal occlusion glasses were used that opened and shut at pre-set intervals to create intermittent viewing conditions. A general preference for seeing the flight of the ball just after its zenith was reported. However, although optical information is paramount, other sensory and coordinative mechanisms are implicated. Huys *et al., (*2004), conclude that extended practice by experts "promotes reliance on multiple sources of information, allowing the proficient juggler to switch adaptively between functional organizations involving distinct perceptual systems" (p. 315). In other words, foveal, parafoveal and peripheral aspects of the visual system, as well as haptic and auditory information sources all contribute to successful juggling (Van Santvoord and Beek, 1994; Haibach *et al., 2004*; Dessing *et al.,* 2007).

2.2.2 Visual search and the attunement of perceptual systems

Research across a range of sports including football, indicate that even in circumstances that allow for the continuous tracking of an approaching object (e.g. catching, hitting), experienced athletes do not continually keep their eyes on the object (Goulet *et al*., 1989; Abernethy, 1990; Amazeen *et al*., 2001). Instead observations made using head-mounted eye-tracking devices, suggest athletes tend to look at only a part of the trajectory. Such trajectory segments appear to provide information about the future position of the object, at least enough to guide the athlete to intercept it successfully (see Huys and Beek, 2002).

In an exploration of the relationship of point-of-gaze and ball movements as a function of expertise, tempo and pattern, Huys and Beek (2002) applied advanced tools for the analysis of time series and their correlations. Their findings suggested proficient jugglers will reduce the extent to which they visually track balls. In addition, the tempo and specific pattern of the throws (i.e. the cascade or reverse cascade), will determine what visual search patterns are used. As noted above, jugglers tend to fixate on the balls as they reach their zenith or just following their zenith. Huys *et al*., (2004), acknowledge the "special importance" of the zenith, but qualify this by concluding, "many parts of the ball trajectories are sufficiently informative to sustain juggling" (p.329).

2.2.3 Point-of-gaze and the concept of "gaze-through"

Another intriguing finding from the substantial research on juggling relates to the issue of so-called "gaze through" or the "distant stare" as it is also known. In their 2002 study on intermediate level cascade juggling, Huys and Beek monitored the juggler's line of gaze continuously with an eye tracking system mounted on a helmet equipped with a video camera. This camera recorded the scene from the juggler's perspective. Superimposed on the recorded scene, a cursor indicated the performer's line of gaze. Participants began by making relatively large point-of-gaze movements, but in some trials this was followed by a "sudden, marked drop in amplitude of the point-of-gaze movements….resulting in distant stare" (p.175). Huys and Beek (2002), describe this process as follows:

"In the gaze-through, the line of gaze stays bounded within a small, but economically chosen, region of the pattern" (p.174).

The recorded eye movements suggest this is achieved by means of a decoupling of behavioural point of gaze and ball movements (see Huys *et al.*, 2004), with a diminished role assigned to foveal vision. An increased reliance on peripheral vision, kinaesthetic and haptic information is implicated: "Ultimately, successful reliance on several sources of information may allow for dynamically distinct organizations among which the juggler flexibly switches" (Huys *et al.*, 2004, p.333). However, the ways in which these perceptual modalities evolve in the course of learning, and their relative importance, remains open for future research to determine.

The "gaze-through" construct as outlined here is similar to the definition of the "visual pivot" as proposed by Williams and Davids (1998), that is, where attention is diffused or shifted across the periphery without changing point of gaze. The relevance of the above findings will be further explored in the discussion in chapter 5. However, bearing in mind the focus of this study, why should incorporating three-ball cascade juggling improve perceptual skills in football?

2.3 Specificity of practice

As outlined in the introduction, the *4-ball* constraint involves a number of integrated and simultaneous components. The *primary* task relates to the control and passing of a football with a trajectory confined at ground-level. The *secondary* task involves simultaneous hand-juggling using three balls. In addition, there are the simultaneous progressions involving "cue spotting" with participants required to verbally identify coloured cones raised from varying distances near and far (see 3.5). This process is hypothesized as a practical means to simulate key aspects of the motor-visual challenge as encountered in competitive football (for an overview of visual search behaviour in football see Williams and Davids, 1998). However, from the point of view of maintaining specificity of practice, the *4-ball* protocol is recommended as a specialized motor-visual warm-up best deployed prior to a more general and game-specific warm-up. This will be further discussed in sections 2.6 and 5.8.

From the point of view of maintaining "specificity" in practice, the rationale for incorporating the hand-juggling component of *4-ball* clearly warrants closer scrutiny (see Proteau's review of the literature on specificity of practice in sport, 1992). According to Proteau's hypothesis, "learning must be specific to the sources of afferent feedback used to guide one's movement during practice" (Trembley & Proteau, 1998). Applied to competitive football, Proteau's theory interprets actions as typically unique to that domain. As a team-based, open-skilled, contact sport, football requires players to produce specific movements, some of which will be familiar, while others may not have been exercised in a similar way before (see Davids *et al.*, 2000; Button *et al.,* 2005 for a non-linear, ecological perspective). Hence, practice conditions should reflect this specificity, as a means to allow skills and movements previously practiced, to be effectively modified where necessary. In this way, players enrich their ability to achieve the outcome goals of each given situation (Magill, 2001). To support this view, Proteau (1992) cites research indicating that skill acquisition is undermined in learning environments where relevant visual cues have been added or removed.

At a practical level, this emphasis on specificity of practice is widely endorsed within football. For example, elite players in Belgium rated competitive games and tactical activity as most important for improving performance (Helsen *et al*., 1998). Similarly, Ward *et al*., (2007), confirmed such activities were the most commonly used during practice by elite youth players in England. According to Ford *et al*., (2010), drills and exercises that do not reflect the unique perception/action challenges specific to the sport may not represent an optimal use of practice time:

"In summary, training form type activities [i.e. drills] may not engage the same perceptual, cognitive, and motor skills as are engaged during a match. In contrast, playing form activities [i.e. small-sided games] may do so, thereby facilitating the transfer of skills acquired in these practice activities to match-play and ensuring that such activity is more relevant to competitive performance" (p. 485).

This view aligns with a more ecological perspective. For example, Araujo *et al*., (2004), explored the continual perception-action coupling implicated in one-on-one basketball dribbling, where the goal was to score a basket. The continual movement of the attacker and defender provided information on how to achieve their goals relative to the opposition player's movement; similar findings were made in a study of bowling and batting in cricket by Renshaw *et al*., (2007). For an overview see Savelsbergh and van der Kamp, (2000).

2.3.1 Critique of Proteau's theory

However, the specificity of practice theory has come under increasing criticism recently (see Davids *et al*., 2008). For example, there have been equivocal findings on perceptual skills acquisition in specific practice environments where visual stimulus is manipulated. Williams *et al*., (1999) compared skilled and unskilled catchers and found that while vision was helpful for the skilled performers, it was not essential, whereas the visual stimulus was essential for the unskilled performers. Robertson & Elliott (1996a) reported similar findings in a study in which vision was occluded during the task of crossing a balance beam. The visual constraint caused less disruption to experts when compared with the performance of novice performers (see also Robertson & Elliott, 1996b).

According to Davids *et al*., (2008), such findings suggest that "experts have a broader base of learning which encompasses a range of sensory experiences that assist in completion of the task" (p.170). We shall examine these issues in more detail below. With regard to specificity of practice, this critique has a number of practical implications for those devising effective perceptual training methods. Principal amongst these is that, while conditioning vision is vitally important to learning, other sensory components of a skill must also be carefully addressed (see also Williams *et al*., 1999).

Another perspective that challenges aspects of the specificity of practice theory centres on how best to structure an effective practice environment to optimize learning. Very little research has been undertaken on this issue (Ward *et al*., 2004). The few studies conducted have focused on the relative effectiveness of blocked and variable practice. Blocked or constant practice is when a skill is practiced in a similar way continuously with no variability of the conditions, whereas variable practice incorporates variety in the practice of a skill across many differing conditions. The benefit of variable practice is that a performer develops the ability to perform the skill in a variety of future competition situations. A study by Schoenfelt *et al.*, (2002), supported this view in their assessment of the relative benefits of blocked and variable practice on the basketball free-throw. Two trial groups were involved over a three week period and although both groups improved with practice, the variable practice group performed better during the post-test compared to their pre-tests. The constant practice group however regressed back to their pre-test level of performance.

This finding resonates with increasing evidence that the process of learning motor skills is more explorative in nature than traditionally thought (Araujo *et al.*, 2004). Active exploration of a motor skill will allow a greater amount of success in performance of the skill (Savelsbergh and van der Kamp, 2000). Furthermore, practice of the skill under highly variable conditions allows multiple information-movement couplings to be developed (Savelsbergh & van der Kamp, 2000). The more variable and specific practice is, the greater number of information-movement couplings that can be developed for use in a variety of conditions.

The practical implications of this critique for coaches and practitioners will be discussed in more detail below in the review of constraints-led coaching. In summary, from this critical viewpoint, there is clearly potential for more innovative approaches to targeting and training sport-specific skills. Where the goal is to help develop perceptual expertise, the aim should be "to support the search process by manipulating constraints so that exploratory activity occurs over an optimal area of the perceptual-motor workspace" (Handford *et al.*, 1997 p. 632).

This is a view further developed by Davids *et al*. (2008), in their advocacy of constraints-led “practice simplification”, defined as a means of promoting a more effective and ecologically valid training approach:

“Simplification means that practice conditions should simulate natural performance conditions, but key performance variables such as velocities of objects and people, distances between surfaces and objects, and forces of moving people and objects should be reduced to simplify the task”. (p. 167). In other words, the key specifying information sources within a performance environment - such as the velocity of balls and opponents, number of players in the game as well as the size of the playing area - are reduced to simplify the task. This provides athletes with opportunities to learn and produce distinct perceptual and movement solutions of their own (see Renshaw *et al*., 2009). This concept of task simplification opens up an intriguing perspective on the *4-ball* practice format. As will be further discussed in 2.3.2 and 2.5, the purpose of the multi-ball method is hypothesized as follows: to create an exploratory environment in which the player can experiment with a range of more complex visual, proprioceptive and haptic responses potentially applicable in competitive football.

2.3.2 *4-ball* perceptual conditioning as task simplification

Three key task simplifications are potentially implicated in the *4-ball* conditioning process. Firstly, the highly variable motor-visual challenge of competitive football (an *open-skilled,* reaction sport), is simplified (re-presented) in the form of a more *self-paced, closed-skill* constraint using the *4-ball* technique. In competitive football the perceptual task-load of simultaneously maintaining control of the ball with the feet while maintaining awareness of the surrounding play, requires a highly complex and variable combination of motor-visual skills (see Williams *et al*., 2004; and section 2.1.2). Two opposing teams with a total of up to twenty-two players moving independently and often at high intensity, represents a formidable and highly dynamic perceptual workspace. In the case of *4-ball* however, key performance variables such as perceiving the foreground movements of teammates or opposition players are simulated (physically schematized) by the self-paced circulation of the three juggling balls (for a review contrasting self-paced and externally-paced sports, see Singer 2000 and Williams *et al*., 1998). The player is compelled by this juggling constraint to keep the head and eyes raised in order to effectively monitor and control the circulation of the three balls (Van Santvoord and Beek, 1994). The participant may rely on foreground visual tracking to achieve this or more peripheral visual skills (see discussion on juggling in 2.2).

Concurrent with undertaking this “secondary” juggling task, the player is required to monitor and effectively control or pass a football over varying distances. A further condition is set that this football must remain strictly confined to the ground thereby reinforcing the technical merits of a groundball game, (see Hughes and Franks, 1997). This entire motor-perceptual conditioning process is self-paced, in other words, controlled by the participant (see 3.5), whereas in competitive football the key “specifying information” for action is largely externally-paced, that is, dictated by other performers on the field of play (Williams *et al*., 1998).

Viewed in this way, the *4-ball* constraint is designed to simplify the participant’s perceptual workspace (while requiring them to maintain control of a ground ball). The aim here is to potentially facilitate the discovery of more advanced visual (foveal and parafoveal), proprioceptive and haptic skills functionally relevant to expert performance in football (see, for example, the discussion of the so-called “visual pivot” as used by more experienced and elite performers in Williams and Davids, (1998).

A second form of practice simplification potentially implicated in the use of *4-ball*, concerns the vital area of improving player awareness of teammates making supporting runs in the background (i.e. “specifying information” at a distance). Again, in the case of *4-ball*, accurate and speedy alertness to such important visual cues in football may arguably be conditioned through a form of task simplification. The supporting runs of teammates are represented or physically schematized with the use of coloured cones raised in the distance by the coach, with the participant required to verbally identify their colour. Can the player maintain control of the football at his feet, while concurrently monitoring the three juggling balls in his immediate visual foreground, and also remain alert to informational sources emerging at a distance (for example ten to twenty metres away).

Such multiple and concurrent perceptual task constraints are likely to require sophisticated foreground and background visual tracking skills (see discussion on juggling in 2.2 and section 2.5.3). However, in the case of *4-ball*, the motor-visual task is largely *self-paced*, with the player’s movements controlled in order to ensure successful visual tracking and successful physical coordination of the four balls (with one on the floor, three in the air). Again, this form of task simplification is hypothesized as a means to encourage the participant to explore and develop a range of more complex motor-perceptual responses potentially applicable in competitive football.

A third form of practice simplification that may be implicated in the *4-ball* constraint, relates to the issue of energy demands. In competitive football a player's perceptual and cognitive response is often constrained by the deleterious physiological effects of aerobic and anaerobic exercise (Bandelow *et al*., 2010). Juggling, by contrast, represents a low-intensity aerobic form of exercise (Huys *et al*, 2003) and, by extension, the same may arguably be the case with *4-ball*. This may encourage the participant to explore and develop more complex visual search behaviour (while in control of a ball using the lower limbs) unburdened by the energy-demands typically encountered in competitive football. In this way, the *4-ball* practice technique further aims to simplify the motor-perceptual workspace, facilitating a more sustained form of exploratory learning with regard to encouraging advanced visuo-motor skills. This is also an argument in favour of its use as part of a pre-competition warm-up. While intensively conditioning motor-visual skills, the introduction of *4-ball* (as part of an existing dynamic warm-up), is unlikely to have an adverse impact on energy reserves prior to football.

The task simplifications identified above are suggested as a means to condition players to minimise the extent to which they restrict their visual tracking to their immediate foreground when in control of, or in proximity to, the ball. This is typically described as "ball-watching" by football coaches. Such visual search behaviour is characteristic of less experienced or less expert players (Williams *et al*., 1994). Widely considered to inhibit effective performance in football, ball-watching results in players failing to pick up early visual cues from the surrounding play, both near and far (Williams *et al*, 1994).

By way of contrast, experienced/elite players will typically exhibit more complex and variegated visual and proprioceptive skills (Williams *et al*, 1994).

2.4 Training perceptual skills: Implicit versus explicit approaches

The preceding review raises some fundamental questions for researchers in the fields of motor learning and perceptual training. For example, should learners/performers be explicitly instructed as to what specific information sources to search for and respond to? Alternatively, is it more effective for them to learn the meaning of this perceptual information for themselves, with formal and verbal instruction kept to a minimum (see for example Smeeton *et al*., 2005).

Williams (1995) has argued that in order to enhance a player's attentional capacity to pick up advance visual cues in open play, the aim should be to emphasise general rules and relationships as opposed to prescribing a specific response behaviour to a specific cue. However, there are those who argue that perceptual-motor skills learning may be considered to be largely implicit because the role of explicit knowledge (and hence explicit instruction) during learning is limited. According to Beek (2000) the acquisition of many perceptual-motor skills draw heavily upon functional levels of coordination that are cognitively inaccessible (see Bernstein, 1967). From this perspective, explicit learning is the exception rather than the rule in the perceptual-motor domain. For coaches and players interested in improving motor-perceptual skills in football, this debate on implicit versus explicit learning is important (although too often neglected - see Williams and Hodges, 2005), and hence warrants a brief overview here.

2.4.1 The critique of explicit learning

Implicit learning emerged as a research paradigm in the 1960's and refers to how performers develop intuitive or unconscious knowledge of the underlying structure of complex stimulus environments (see Jackson & Farrow, 2005). According to Reber (1989) implicit learning is the "default mode" for the acquisition, retention and automation of information essential for effective performance. Reber's focus was on the acquisition of "deep information" relating to event sequence structure in perception and cognition. This he argued is often difficult to communicate by explicit verbal instruction. The more implicitly or unconsciously the subject acquires complex information about the environment and/or task, the deeper it is encoded in memory (for a review see Cleeremans, 1997).

Research interest on implicit learning soon extended into the motor skills domain and has flourished over the past two decades. As a result of this effort, coaching practices that valorise explicit cognitive learning - with directed cuing to key information sources- has come under increasing critical scrutiny. Green and Flowers (1991) conclude that explicit learning interventions may actually impede more effective and preferred unconscious learning processes. Similarly, Masters (2000) argues explicit knowledge can have a degrading effect on skill acquisition by forcing the learner to take conscious control of his actions, where unconscious-learning processes might be more effective (see also Jackson *et al*., 2006).

In terms of motor-perceptual performance gains, there is increasing evidence that training that encourages more implicit modes of learning (i.e. that minimize recourse to conscious processing of anticipatory information), is more successful than training utilizing more explicit and intentional cognitive interventions (Masters, 1992; Hardy *et al*., 1996; Jackson and Farrow, 2005). In a study on anticipation in tennis, Farrow and Abernethy (2002) compared implicit and explicit learning approaches and found critical improvements in prediction accuracy regarding service action amongst implicit learners. These improvements were not replicated in the control, placebo or explicit learning trial groups. Beek (2000) however, offers an alternate perspective, concluding that the development of explicit knowledge does not necessarily disrupt performance. Indeed it may be advantageous for performers to learn to override automatic motor processes by developing an alternative strategy based on explicit knowledge.

2.4.2 Implicit learning using the secondary task paradigm

A broader assessment of implicit learning is beyond the scope of this review (see Cleeremans, 1997). However, one experimental method often utilized to facilitate implicit learning and / or "automaticity" is of particular interest in the current context. This method involves the use of a secondary task load and warrants a brief discussion in helping theorize the potential training effects associated with *4-ball*.

Researchers commonly use a secondary task intervention as a means of drawing an athlete's attention away from the performance of a more established primary task. For example, in field hockey an athlete would be asked to dribble a ball while performing a verbal dual-task such as random letter generation (Jackson *et al*., 2006). For a football study using the secondary task method (Beilock *et al*., 2004). The use of such "dual-cue" conditions is hypothesized as a means to compel the athlete to minimize recourse to conscious processing, encouraging him instead to rely on potentially more effective, unconscious or 'automatic' learning (Cleeremans, 1997; Jimenez and Mendez, 2001). In this way, it is hypothesized that complex stimulus information is encoded at a deeper level, enhancing the retention of that information for longer periods post intervention (Allen and Reber, 1980). Information acquired in this way is considered more 'adaptive' and hence more resistant to the effects of psychological stress (Gray, 2004; Masters, 1992).

The first attempt to teach motor skills implicitly using the dual task method was made by Masters (1992). This study examined the performance of novices attempting to putt a golf ball. With one trial group, no explicit instruction were given, instead participants were required to perform a concurrent secondary task while attempting to putt balls into a hole. The secondary task involved them randomly generating letters at a specific rate. Masters found the implicit learners generated significantly less verbal rules than the other two trial groups, one of which learned without use of a dual task, the other by means of explicit instructions. In principle, this demonstrated learning can take place without awareness of what is learned. Hardy *et al.,* (1996) corroborated these findings, suggesting the use of a dual-task is a reliable method for inciting implicit motor learning.

As will be outlined in more detail below (see 3.5), the *4-ball* method assessed in this study combines football passing and control drills using both dominant and non-dominant feet (the primary task), with three-ball juggling using the hands and additional visual response cues (secondary tasks). The juggling and response cues are designed to draw the performer's attention away from the primary task, namely, controlling and passing a football. The aim to this constraint is to facilitate the implicit learning of more complex and flexible perceptual skills. Once these perceptual skills are assimilated (Fitts' autonomous phase), the *4-ball* method is hypothesized as a means to encourage higher degrees of "automaticity" in the execution of these skills with all the putative benefits associated with this performance state (e.g. Jackson and Csikszentmihalyi, 1999). By providing some initial outcome data, this study aims to incite further process-orientated research to test such hypotheses and determine any notable effects on performance in sport-specific contexts (see Future Research 5.7).

2.4.3 Summary and practical implications

The past thirty years has seen considerable research undertaken on forms of implicit learning from the perspective of ecological psychology. In the same period non-linear studies on skills acquisition have also flourished. Findings and implications from these research areas have to some extent dovetailed and helped define something of a paradigm shift from earlier more cognitive approaches (for an overview see Davids *et al*., 2008).

The challenge of building on this recent body of research has helped focus attention on constraints-led coaching methods. In light of the ecological critique of explicit learning, the use of constraints is increasingly viewed as a means to designing more effective training programmes (see Button *et al*., 2005). Rather than rely on overly prescriptive verbal instruction, coaches should focus on the design and use of intelligent constraints that encourage athletes to solve complex motor-perceptual tasks for themselves. The implications of this strategy on skills acquisition, transfer and retention are discussed in 2.5.

In light of the substantial evidence that questions more explicit forms of coaching, a number of practical techniques have been adopted to promote implicit learning such as incidental and analogy learning (Liao *et al*., 2001; Jackson and Farrow, 2005). Similarly, in relation to the current study, the practical implications of the research on implicit learning are of primary interest. This is in line with Renshaw *et al*., (2009), who argue that "coaches need to go 'back to the future' and promote natural implicit learning by creating environments that typify the exploratory behaviour of young children who learn to crawl, walk and run without recourse to verbal instruction" (p.31). The novel perceptual workspace afforded by the *4-ball* method, by combining hand-juggling with football skills, aims to encourage such exploratory behaviour. Applied as a warm-up prior to football, the *4-ball* constraint aims to condition more advanced motor-perceptual skills, minimising the need for the coach to rely on more explicit forms of instruction during coaching and competition (for example, calling from the touchlines: "keep your head up" or "look for a passing option" when the player is running with the ball etc.).

2.5 The emergence of constraints-led coaching

Although the amount of practice has been identified as a major predictor of expert performance (Ericsson *et al*., 1993), very few studies have examined the most effective ways to enhance performance, in particular with respect to improving motor-visual expertise through efficient learning (Starkes *et al*., 2001; Williams and Grant, 1999; Williams and Ward, 2003).

The role of the coach is to develop a practice environment that improves a player's skill to perform specific tasks at an optimal level in competition (Davids *et al*., 2008). This perspective has led to considerable interest recently in assessing to what degree coaches should rely on verbal, prescriptive methods in achieving their coaching goals, or should a greater reliance be placed on setting intelligent constraints to help guide players to discover effective performance solutions for themselves (Button *et al*., 2005).

2.5.1 Constraints-led coaching in football

Manipulating task constraints to help facilitate learning is common practice in football (Davids *et al.,* 2008). Coaches will often implement specific "conditions" such as restricting the number of touches each player is permitted (one or two touches only). The aim in this specific example is to encourage better technique and tactical anticipation as a means to promote quick combination passing etc. The size of the playing area (Nakayama, 2007) or the rules of the game can also be modified, for example, no off-side in small-sided games etc.

Such constraints-based practice forms a vital part of mainstream football training, to aid perceptual/cognitive skills development. It has become an increasingly popular means of encouraging players into a mode of discovery learning. This approach favours a more hands-off attitude on the part of the coach. Instead of overburdening players with complex and prescriptive verbal instructions, players are led largely by the constraints to solve the motor-perceptual problems for themselves (Ford *et al*., 2010; Williams and Hodges, 2005).

2.5.2 Training aids and the method of visual occlusion

More innovative and targeted constraints are also used although to a far lesser extent. Such constraints aim to manipulate perceptual information in the environment to advance or accelerate skill acquisition. For example, in football and basketball, the use of training aids such as molded plastic spectacles with protruding surfaces below each eye have been introduced (Williams *et al*., 1999). These aids prevent vision of the hand or foot as well as the ball when the player attempts to dribble. The aim is to encourage players to rely on other sources of sensory information (proprioceptive, haptic, auditory) as they undertake the task (see Davids *et al*., 2008). Williams *et al.,* (1999), describe these training aids as “popular”, however evidence of existing practices, at least at elite level, cite no example of their use (see Reilly and Gilbourne, 2003; Ford *et al*., 2010). To this author’s knowledge, the use of visual-occlusion goggles and blindfolds etc., is far from common practice in mainstream football training. However, as will be discussed shortly, several studies have produced data to support the practice of occluding various information sources during learning (see Bennett *et al.*, 1999; Williams *et al.*, 1999). For a critique of the occlusion paradigm see Van der Kamp *et al*., (2008).

2.5.3 Rationale for implementing perceptual constraints

Williams *et al*., (1999) cite the following reasons for manipulating perceptual information in the environment during skill acquisition in sport:

- To improve sensitivity to other potentially useful sources of information (i.e. proprioceptive, haptic and auditory) to aid response organization.

- To encourage the athlete to become less reliant on central vision for determining movement during learning.
- To look away from the ball while in flight (i.e. when dribbling or passing) to search for information to assist further response organization and decision-making.
- In team games, to visually scan defensive patterns or check positions of team-mates for a pass when in possession of the ball.

Occlusion devices such as blindfolds, plastic bibs that protrude around the chest or waist as well as so called "dribble aids" worn under the eyes as described above, are all examples of training aids used to promote the acquisition of specific motor-perceptual skills. Applied in football for example, dribble aids aim to "direct players to raise their heads and search for visual information in the environment as they dribble the ball. The key point is that practitioners can remove or add information to help learners develop appropriate information-movement couplings" (Davids *et al*., 2008, p.161).

2.5.4 Summary of constraints-led coaching

In summary, the use of constraints such as modified games and modified rules as well as the use of training aids is an increasingly popular approach to coaching football. Although more research is required, there is evidence that constraints, when appropriately applied, can effectively enhance performance (Williams and Ward *et al*., 2002). The purpose here according to Davids *et al*. (2008), is to "temporarily constrain the performer-environment system to encourage an appropriate focus on certain perceptual variables or the emergence of key information-movement couplings" (p.210).

Much of the preceding research on the use of constraints has focused on the potential benefits in terms of learning and early skills acquisition by beginners. By contrast, studies on the use of constraints as applied by skilled performers and specifically as part of a preparatory routine remains, at least to this author's knowledge, minimal if not non-existent. Hence the final section of this review will summarise research on the use of warm-ups in sport, drawing on findings relevant to this applied study.

2.6 4-ball and the use of structured warm-ups.

As outlined above, *4-ball* is conceived as a pre-game warm-up. It aims to condition motor-visual skills prior to training and competitive performance in football. In this study *4-ball* is applied in isolation as a preparatory protocol. However, it is recommended as a specialized routine, one that should be introduced prior to a more comprehensive and sport-specific warm-up (see 5.8).

Undertaking structured warm-ups prior to sporting activity is commonly, if not universally, accepted (Nelson *et al*., 2005; Young *et al*., 2002). The warm-up prepares players physically as well as mentally with the aim of enhancing subsequent competitive performance (Warren *et al*., 2002). Warm-ups are also seen as an effective means to help minimize the risk of injury (Mandelbaum *et al.*, 2005).

The typical structured warm-up applied in contemporary football involves three key activities (see Critchell, 2002; Jeffreys, 2008). The following summary is in line with recommendations made as part of A) the FIFA 11+ programme, and B) the influential so-called RAMP protocol (Raise/Activate-

Mobilise/Potentiate) produced by the UK Strength and Conditioning Association (UKSCA) and supported by considerable research.

1) The first phase of a warm-up should focus on low intensity activities (e.g. jogging and other fundamental performance movements) to elevate core body temperature, increase heart and respiration rates, as well as blood flow and joint fluid viscosity. Ideally, sport-specific movement patterns and techniques should be identified and used wherever possible as part of this initial warm-up phase (see also Warren *et al*., 2002).

2) The second phase of a warm-up should aim to activate key muscle groups relevant to the sport as well as to mobilize key joints and ranges of motion used in the sport (e.g. involving multi-directional movements etc.). According to the RAMP protocol the key emphasis here is to avoid static stretching and ensure a dynamic and variable approach throughout (see also Little *et al*., 2006).

3) The final phase should involve high-intensity exercises to facilitate subsequent performance (e.g. short sprints and quick agility drills). In this phase, certain key skills should be executed at an intensity that equals or exceeds the level expected in competition. Again, the emphasis is on maintaining sport-specificity in the choice of exercises (see also Gilchrist *et al*., 2008). Such a warm-up protocol aims to encourage optimal preparation for competition and is commonly used within professional football academies (see Dolan, 2008).

The basis of the current study is to assess the potential of incorporating an additional activity prior to performance in football, in the form of a specific motor-visual conditioning protocol. According to Jeffreys (2009), "warm-ups have traditionally focused on energy system and muscular aspects of the physiological processes, the neurological aspects of warm-up have often been overlooked. For optimal effectiveness, a warm-up needs to provide optimum preparation in all aspects of performance" (P.16). This is in line with Critchell (2002), who recommends that effective warm-ups should also aim to condition the athletes balance, as well as eye-hand and eye-feet co-ordination to help condition awareness of time, space and proprioceptive reactions.

As outlined in 2.5.1, the emphasis with *4-ball* is to specifically condition perceptual-cognitive response using a constraints-based approach. Section. 3.5 outlines the training procedures adopted here and provides practical recommendations for the implementation of *4-ball*. However, in view of the multi-factorial nature of this protocol applied prior to competitive football, gathering reliable data to help define best practice represents a substantial challenge (see 5.7). This is compounded by the fact that, to this author's knowledge, there is no existing research assessing warm-up interventions that specifically target visuo-perceptual response in football (see 1.2). Hence, while the literature on warm-ups has helped define the current research design, it remains of limited value in terms of providing a theoretical context for rationalising the *4-ball* protocol.

2.7 Chapter summary

This review has outlined a theoretical context for an applied study of the *4-ball* constraint. It began with a summary of cognitive research on visual skills acquisition focusing on (the primary task of) football. Key findings from perceptual research on juggling (the secondary task) were then considered. Such research has helped illuminate the complex "coupling" of perception and action in sport, highlighting certain processes that may be implicated in the execution of the *4-ball* constraint.

In order to provide a broader conceptual framework and rationale for the current study, the issue of specificity of practice was then addressed with an emphasis on recent critiques of Proteau's hypothesis. This fed into a review of implicit methods of skill acquisition with a particular focus on the secondary task paradigm. An appreciation of the complexity of the perceptual process has helped encourage researchers and practitioners interested in perceptual training to explore more implicit forms of learning. This in turn has fostered increasing interest in the use of constraints-led coaching methods, for example, using "task simplification" as a means to encourage discovery learning. Findings from the above research areas have helped define key parameters underpinning the current study.

In view of the use of *4-ball* as a motor-visual warm-up in this study, the review concluded with a summary of research on the use of warm-ups in sport. The lack of studies focused on pre-competition perceptual priming was noted. In addition, the case was made for the use of *4-ball* as a preparatory protocol in conjunction with a more sport-specific warm-up.

As shall be discussed in more detail in section 5.8, *4-ball* is hypothesized as a novel dual-task constraint that aims to perceptually prepare or "attune" players in the run up to training or competitive performance in football. This review has attempted to put this hypothesis into a theoretical context to help provide a platform for a quantitative study.

CHAPTER 3: METHODOLOGY

3.1 Introduction to research design

This preliminary study aims to assess the *4-ball* constraint implemented as a practical pre-competition warm-up. *4-ball* aims to assist coaches and players interested in conditioning perceptual-motor skills, with an emphasis on its use as a preparatory protocol to benefit competitive performance in football. The purpose of this initial study was to gather quantitative empirical data using a quasi-experimental design aiming for a degree of ecological validity (see also Future Research 5.7). The specific intention was to measure designated performance outcomes in football, following the implementation of the *4-ball* condition. For the purpose of comparison, performance data following two additional "game-specific" warm-up conditions were also gathered and assessed.

The three distinct conditions introduced in this study are as follows (see Appendix A for a detailed breakdown of conditions 1 and 2):

1) Light-physical (LP): ball passing in groups with no constraints applied
2) Keep-ball (KB): two-touch passing in box grids measuring 7.5 x 7.5m
3) *4-ball*: completing a 3 cone slalom circuit with cue-spotting

Each warm-up condition was implemented separately and timed to last fifteen minutes. All warm-ups were undertaken immediately prior to 4 vs 4 competitive games with the intensity level set at 80-90% by the researcher. All competitive games were timed to last 5 minutes and were performed in an indoor sprung-floor facility with a play area measuring 30m X 15m.

Performance was assessed over fifteen weeks with the three distinct conditions given five assessments. Video recording of all subsequent five minute, 4-a-side games was then systematically examined to quantify dependent variables. This data was then analysed using a variety of descriptive and quantitative statistical tools to assess the relative significance of the various conditions.

3.2 Amendments to research design following pilot study

A three-week pilot study helped clarify a principled research design. Key practical and procedural aspects were explored in the light of which considerable changes and refinements were made.

Chapter 2 reviewed research that indicates in the complex and fast moving environment of competitive football, the ability to pass the ball effectively requires advanced perceptual skills (see section 2.1.2). Hence, the initial focus of data gathering in the pilot study had been on pass completion rates with the assumption that the more passes executed, the more demonstrable the progress in terms of perceptual training effects. However, baseline assessments in the pilot study revealed no clear correlation between the number of passes executed and the degree of success achieved in terms of attempts on goal or goals scored. This resonated with findings from a study at elite International level on passing at the Soccer World Cup (Scoulding *et al.,* 2004). In other words, pass completion rates give little, if any, indication about the quality and effectiveness of the passing. For example, were the pass-executions lateral or defensive back- passes or were they more penetrating, attacking passes. More specifically, did these pass-executions lead to a positive outcome, for example a goal scored or an attempt on goal (so-called “end product”). Of equal importance, did the pass completion rates achieved consist of a series of isolated single passes or were they the summation of sustained and effective passing sequences (i.e. patterns of constructive play).

Gratton and Jones (2004) observe that to optimise the validity and practical relevance of any given research project, it is essential to ask the right questions. In the light of the limitations revealed in the pilot study, it was therefore decided to substantially extend the performance data gathered and focus on performance indicators associated with *effective* attacking possession football. Ali *et al.,* (2007), emphasise the “fundamental principle of soccer is to score more goals than the opposing team and so the most highly valued skills are those that lead to goals being scored” (see also Jinshen *et al*., 1991). According to research conducted at elite international level, teams adept at maintaining possession in attack tend to score more goals and be more successful (Hughes and Franks, 1997). Such teams are better able to co-ordinate and sustain “patterns of play” through which they can dictate the game (Daniel, 2003). As discussed in Chapter 2 (see 2.1.2), research on elite perception in football indicates such performance outcomes require advanced perceptual skills and decision-making under performance pressure. Hence, a main focus of this study was on collecting data on passages of play involving three or more passes that culminate with a measurable goal scored or an attempt on goal. In this way, the intention was to get a more defined picture of the quality (effectiveness), as well as the quantity, of passes executed by participants.

To further support this research emphasis, the study also focused on the related area of performance errors committed (pass errors, ball control errors and 3-touch errors). Again, as reviewed in Chapter 2, the more advanced a player's motor-perceptual skills, the less likely they are to concede possession of the ball, for example, through a misplaced pass or through a lack of ball control (see section 2.1.2). Hence measuring changes in these performance indicators were also identified as of key importance. Taken together, this extended range of dependent variables were selected in order to give a more comprehensive and exacting assessment of the impact on performance of the various independent warm-ups. See Appendix A for operational definitions.

3.3 Summary of dependent variables

The performance indicators (dependent variables) used to define data collection in the fifteen-week study, focus on two key performance areas in football:

a) Technical errors committed (see 2,3,4,5 below)
b) Attacking sequences of play achieved (see 6, 7, 8, 9, 10 and 11)

Assessments were made on the following dependent variables (for detailed definitions see Appendix B):

1) Successful pass completions (SPC)
2) Pass errors (PE)
3) Ball control errors (BCE)
4) Three touch errors (3T) - where a player takes three or more touches in contravention of the "2 touch" condition.
5) Total error rates: sum of PE + BCE + 3T.
6) Goal attempts culminating from three or more passes (GA+3)
7) Goals scored culminating from three or more passes (G+3)

8) Total unsuccessful goal attempts - including all strikes on and off target (UGA)
9) Total goals scored - including from moves involving three or more passes (TG+3)
10) Total goal attempts (TGA)
11) Total goals scored + goal attempts involving three or more passes (G+3 + GA+3).

3.4 Participants

Sixteen participants *(M* age: 13.6 years) took part in the study. According to guidelines set out by Williams and Grant (1999), players of this age should be amenable to perceptual training, recommended from age twelve (or potentially younger see Williams and Ward 2003). Participants were assigned at random to one of four teams. Each team comprised four participants.

All participants were “sub-elite” level (Ford *et al*., 2010) with between four and five years’ experience playing organised football and all drawn from the same FA chartered club. As an U-14’s team they perform in the Midlands Junior Premier League.

Prior to participation, all participants were informed of the demands of the study along with the minimal risks and the right to withdraw from the research project at any time. In addition, participants were informed that confidentiality would be maintained throughout the study. On the basis of the information and assurances provided, participants and their parents/guardians were asked to sign a consent form to acknowledge their willingness to participate (see Appendix B). The local university ethics committee gave approval for this process.

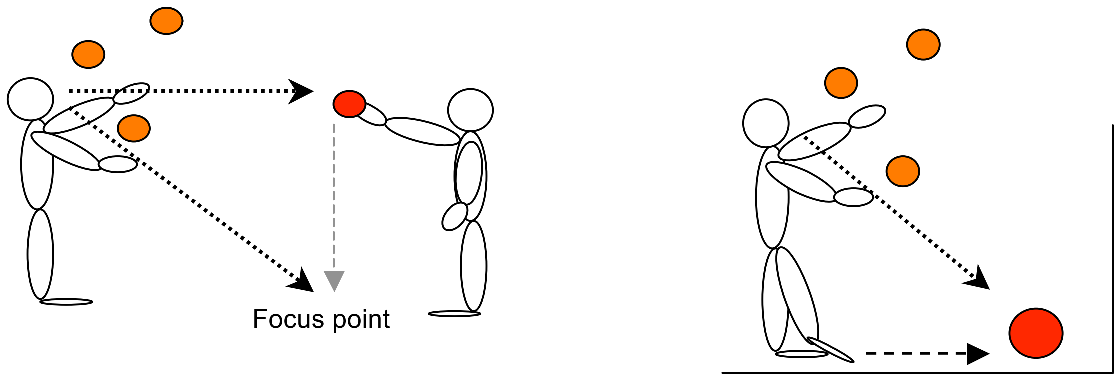
3.5 Training procedures

Participants were required to undertake a specific training procedure in order to enable them to successfully execute the *4-ball* constraint. Once participants achieved a certain level of competence (as detailed below), they were given the opportunity to apply themselves to the constraint as a preparatory warm-up prior to individual and group assessments of their performance levels in competitive football. Appendix C gives details of participant progress with the *4-ball* skills acquisition process.

As outlined in chapter 1, the *4-ball* training protocol developed for this study adopts a largely constraints-led approach that combines 3-ball cascade juggling using the upper limbs with concurrent ground-ball drills using both lower limbs to control and pass a regulation size (4 to 5) football. Subsequent drills also require the performer to verbally identify static and dynamic visual cues (different coloured cones etc. raised by a coach or strategically placed).

Figures 3.1 to 3.4 illustrate the *4-ball* skills acquisition process adopted in this study. Participants were required to have already achieved basic competence with football skills (the primary task). This is in accord with the cautionary observation that perceptual training is best introduced, "when sufficient mastery has been attained and the rules of the game are understood" (Ward and Williams, 2003, p.245). Based on this proviso, the *4-ball* training procedure was largely confined to teaching participants proficiency at three-ball hand-juggling (the secondary task). This involved a combination of explicit instruction plus facilitating observational learning (see Hayes *et al*., 2008 with recommendations for teaching juggling).

Prior to undertaking this study, no participants could juggle the three-ball cascade and hence, all were adjudged at novice level. Each participant was provided with a set of three juggling balls (125 gram, 4-panel) and received twenty minutes juggling instruction by the experimenter on a weekly basis training as a group (see also Hayes *et al*., 2008). The experimenter confined himself to giving verbal encouragement and suspending the target ball as illustrated in figure 3.1. In this way participants were left to experiment by themselves and apply the newly acquired upper-body coordinative skill (juggling), while simultaneously undertaking a more familiar range of drills using their lower limbs to control and pass a football.



1. Once able juggling 3 balls, players to focus at a point 'beyond the balls', looking 'through them' at a target ball (red ball).
2. players should practice side-footing a football against a practice bench or wall while sustaining the 3 ball 'visual handicap'.

Figure 3.1*:* example of the 4-ball skills acquisition process

Figure 3.2*:* players form into pairs and incorporate ground ball passing drills (juggling 3 balls with the hands while passing a football using his right/left feet).

As the diagrams illustrate, it is the concurrent combination of these upper and lower body skills that helps define this novel motor-visual conditioning method. Further progressions involved simultaneous cue-spotting as described above. Once the basic component skills were acquired, participants were encouraged to form into pairs and practice *4-ball* (passing the groundball using dominant and non-dominant feet as illustrated in figure 3.2).

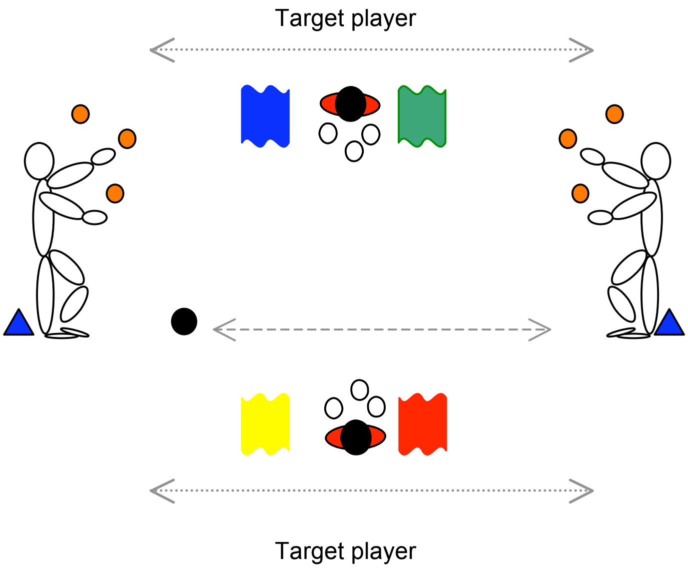


Figure 3.3*:* *4-ball* constraint with additional spotting challenges.

Figure 3.3 illustrates a further progression in the skills acquisition process. Once proficient with the basic *4-ball* routine, participants in the *control* and *skill* groups were encouraged to explore the constraint while verbally responding to coloured visual cues raised by the coach and teammates to left and right as well as from near and far (i.e. 5 to 25 metres distance).

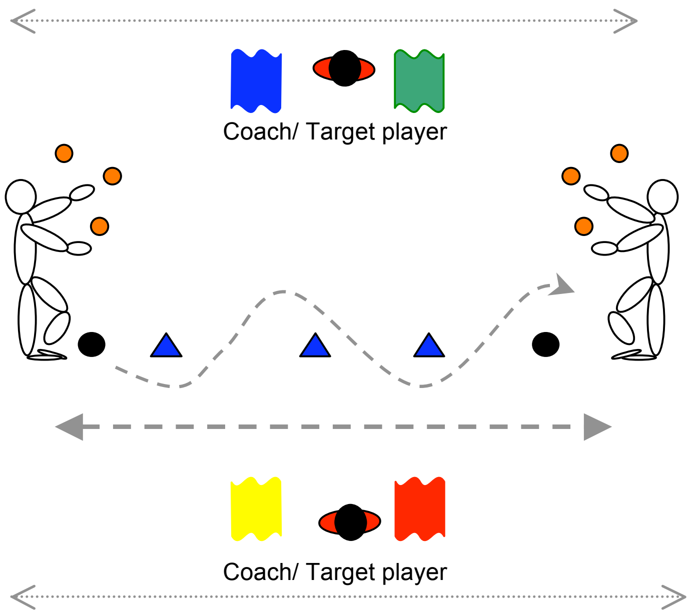


Figure 3.4: Participant to slalom between 3 cones set on the ground without dropping the 3-ball handicap or losing control of the ball at the feet. In addition, participant is required to verbally respond to visual cues (coloured cones etc raised by coach / target players in random order).

The motor-visual warm-up used in this study is illustrated in figure 3.4. With proficiency in the basic *4-ball* skill established, the "slalom" task constraint was introduced to participants in the control and skill groups. Participants in the skill group were set the following target: to sustain the *4-ball* dual-task while completing a short 'slalom' course (x fifty) between three cones each placed a metre apart. This process typically took 10 to 15 minutes to complete, depending on the ability level of the player (see 3.6).

3.6 Experimental procedures

Throughout all trials no explicit instruction was given to participants regarding football techniques or tactics or any other football related coaching. The one exception to this relates to the two-touch restriction imposed on all the competitive games following the three distinct warm-ups. Immediately prior to all trials (competitive games), the experimenter verbally reminded all participants of the two-touch condition. In order to maintain competitive momentum, all infringements of the three-touch condition were simply logged as a “three touch error” without penalties or stoppages being applied. Where prescriptive or explicit guidance was given, this was confined to simple individual and group physical demonstrations on a) how to juggle three balls with the hands and b) how to execute the basic *4-ball* skills (see 3.5).

Each of the three applied warm–ups lasted fifteen minutes with the competitive 4-a-side games commencing after a rest interval of five minutes. This interval was to allow players to be allocated to respective teams distinguished by coloured bibs. All games were video taped using a Sony Handycam Digital Video Camera Recorder (DCR-SR70 HDD). Video footage was then examined and every performance event (except deflections and incidental touches), were individually logged including the first name of participants involved in the specific action as set out in the ethical submission. An independent review of the data was conducted by a UEFA ‘A’ Licence holder (through three different football associations - English, Irish and Welsh FA). Levels of inter-observer agreement are set out in Table 3.1.

variable	SPC	PE	BCE	3T	GA3+	G3+	Shots on T	Shots off T	GA	Goals
% agreement	99	90	85	90	80	100	100	94	96	100

Table 3.1: Inter-observer agreement from the data calculated in percentage terms.

High levels of agreement are indicated of between 80% and 100% across the different variables.

Training procedure - the *4-ball* slalom: players were required to complete 50 X lengths of the three-cone circuit as a warm-up prior to being assessed in competitive 4 v 4 football games.

3.7 Data analysis and statistics

Each condition was assessed over 5 weekly trials with the study extended over fifteen weeks; group as well as individual data were gathered. The group data were calculated as the sum of performance outcomes of sixteen participants performing in four teams (A, B, C, D) with four players per team. To account for variation in team performance across the 5 weeks of each condition, the overall mean error for each warm-up and variable was calculated. As for Individual results, these were confined to three variables measuring performance errors committed by individual participants (pass errors PE, ball control errors BCE, and three touch errors 3T, in contravention of a 2-touch condition).

All data were tested for approximation to normal distribution using Shapiro-Wilk's tests and visual inspection of P-P plots. This showed that both the group and individual data were non-normally distributed. A number of types of transformations were attempted to normalize the data but acceptable results were not achievable. Due to this, non-parametric statistics were used to assess if there were any changes between the warm-up conditions. A Friedman test was used to assess any difference in individual errors (PE, BCE, 3T) between the three warm-up conditions. Where a significant effect of a warm-up condition was found, individual differences between warm-ups were assessed using a Wilcoxon signed ranks test adjusted by a Bonferroni correction for each variable (α=0.05/3 = 0.016). The same procedure was followed for group mean errors.

CHAPTER 4: RESULTS

4.1 Chapter introduction

The aim of this applied study was to evaluate performance levels in football following the introduction of three distinct warm-ups. The research trials indicate a number of substantial improvements in technical performance in football following the introduction of the *4-ball* condition. However, due to logistic circumstances, certain counterbalancing measures were not applied. Hence the following results should be interpreted with caution, as discussed in more detail in section 5.6.

4.2 Group results

Tables 4.1 and 4.2 provide a summary of the group scores gathered over fifteen weeks.

4.2.1 Group technical errors

	Light Physical	Keep-Ball	4-Ball
Pass Errors	8.6 (7.5-10.8)	8.1 (6.7-9.1)	5.6 (2.7-6.7)
Ball Control errors	2.4 (1.1-3.0)	2.4 (1.9-3.8)	1.4 (0.7-2.8)
3-Touch errors	6.8 (5.4-9.0)	6.5 (5.3-8.2)	4.0 (1.7-4.4)
Total Errors	17.4 (16.2-20.9)	17.1 (15.7-19.2)	10.5 (7.3-12.1)

Table 4.1: Group performance data: Median weekly warm-up condition/ technical errors committed by all teams during 5 minutes of play following respective warm-ups (Data are median / lower quartile-upper quartile).

Statistical analysis found no effect of condition on the weekly group pass errors committed ($\chi^2(2)=3.5$, $p=.27$, table 4.1), or on ball control errors ($\chi^2(2)=.9$, $p=.78$, table 4.1). However, a plot of weekly scores focused on *pass* *errors* suggests a trend for reduced errors when participants were distributing the ball following the *4-ball* condition (figure 4.1).

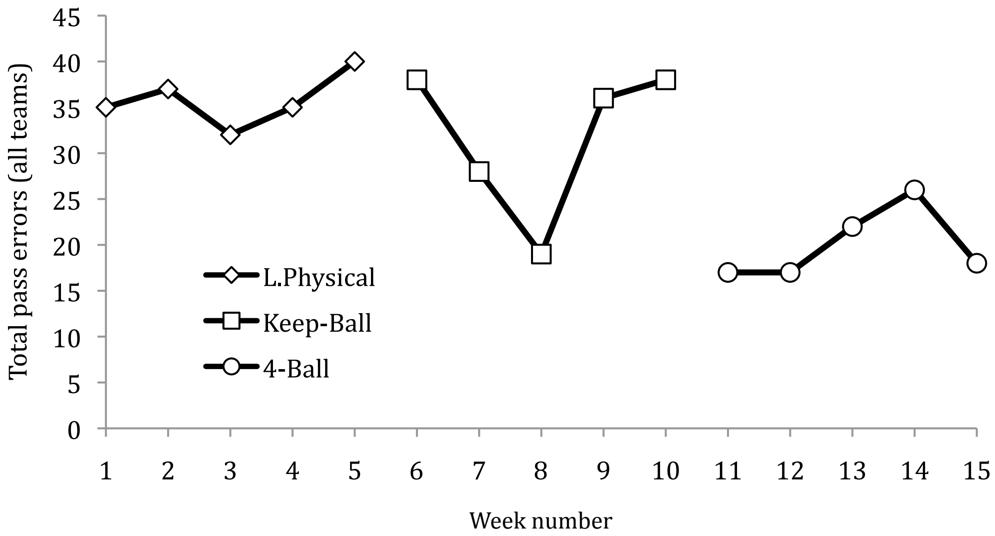


Figure 4.1. Total weekly group pass errors for each condition

Group results show a median *pass error* rate of 5.6 per five- minute game in the *4-ball* condition, compared with 8.1 *pass errors* following the KB condition, and 8.6 following the LP warm-up. In percentage terms this represents a 30.9% *decrease* in pass errors following the *4-ball* warm-up relative to the KB warm-up, with a greater *decrease* of 34.9 % in a comparison of *4-ball* with the LP warm-up. By comparison, the relative percentage decrease in pass errors between the LP and the KB condition was 5.8%. While order and practice effects are undoubtedly implicated in these results, viewed in terms of order of magnitude, the percentage changes in median pass error rates following the *4-ball* warm-up approximate to a step-change in terms of lowering the rate of misdirected or mistimed passes made.

There is a similar trend for a reduction in ball control errors made following the *4-ball* condition (see Table 4.1 and figure 4.2). The potential significance of this finding will be discussed in chapter 5.

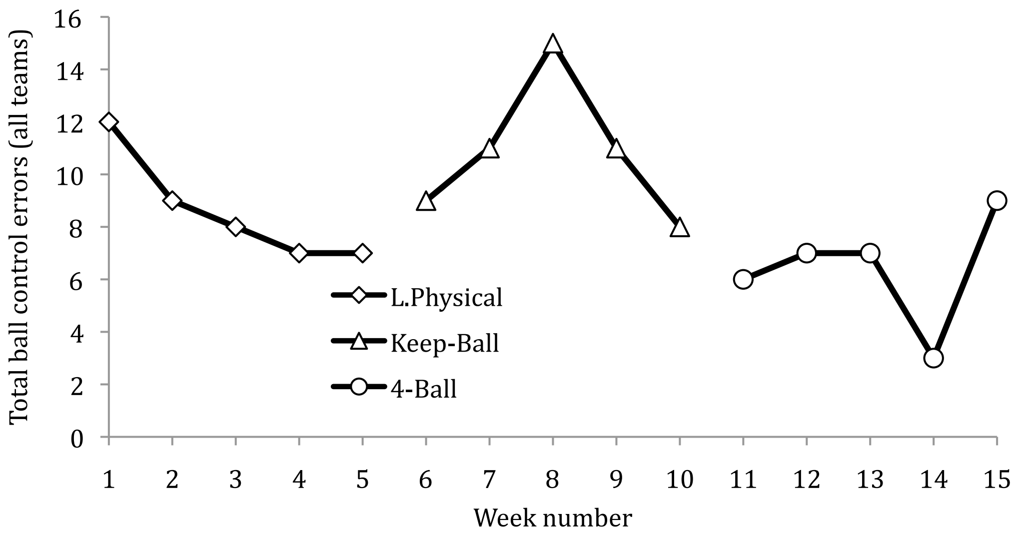


Figure 4.2. Total weekly group ball control errors for each condition

With regard to the group data on weekly 3-touch errors, the results indicate a significant effect of warm-up condition ($\chi^2(2)$=6.0, *p*=.49, table 4.1 & figure 4.3). Although Wilcoxon signed rank tests showed there to be no significant differences between individual conditions, again there was a clear trend for reduced 3-touch errors in the *4-ball* condition in the plot of weekly errors (Figure 4.3).

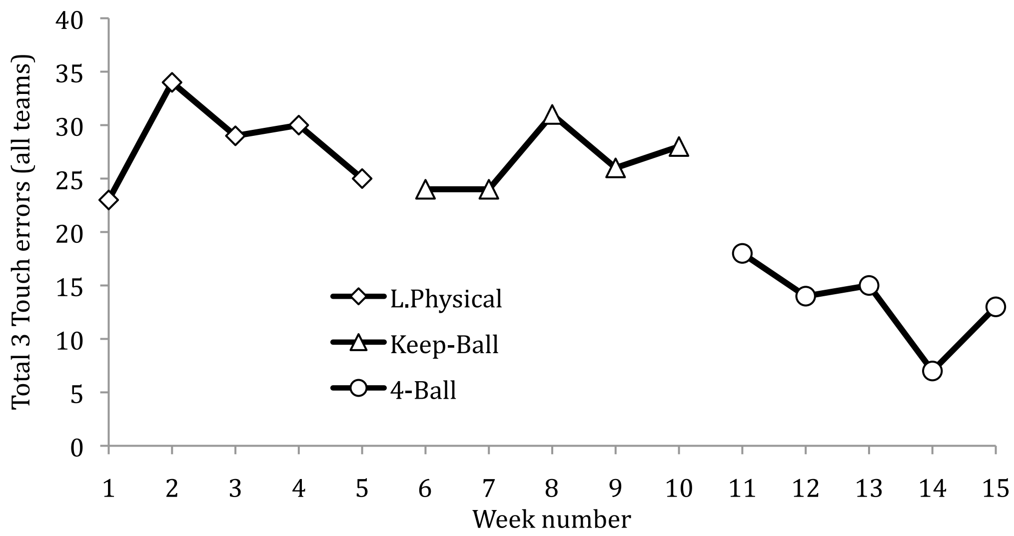


Figure 4.3: Total weekly group 3-touch errors for each condition

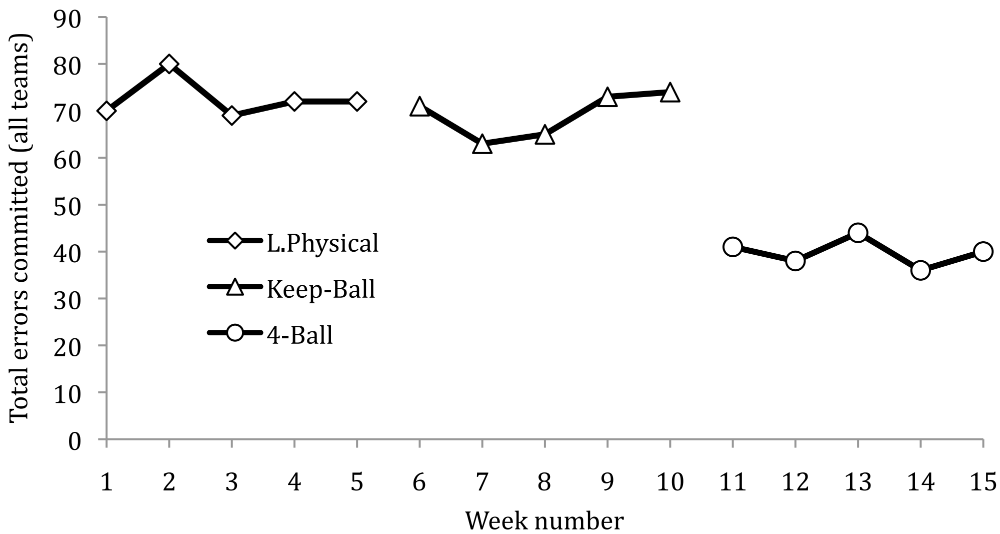


Figure 4.4: Total weekly group errors (total errors = pass errors + ball control errors + 3-touch errors) committed for each condition

Figure 4.4 gives an aggregate picture of the group results for technical errors committed (i.e. pass errors + ball control errors + 3-touch errors). Whilst an influence of order effects cannot be ruled out, the number of technical errors committed seems substantially lower following the *4-ball* condition relative to comparisons of the other two warm-ups. Whether assessed individually or as a whole, a review of the data on technical error rates suggest something of a step change in the proficiency with which participants controlled and passed the ball while under competitive pressure, following the *4-ball* condition.

There was no effect of condition on the total weekly number of passes completed ($\chi^2(2)=1.2$, *p<.58, table 4.2 & figure 4.5).* The modest upward trend is consistent with potential practice effects. However, as noted in 3.2, pass completion rates give little, if any, indication about the quality or effectiveness of passing.

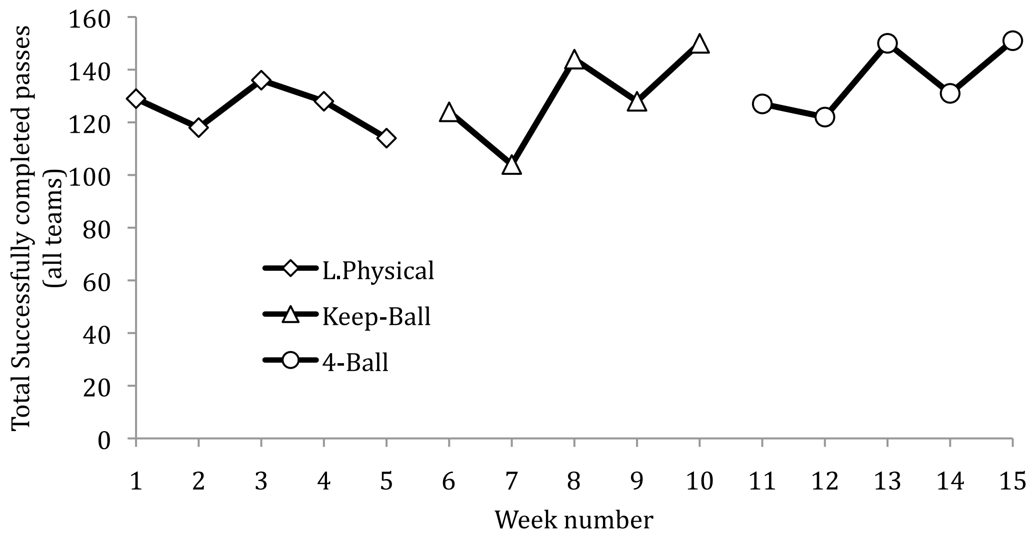


Figure 4.5: Total weekly group successfully completed passes for each condition

In light of the above, as well as gathering data on performance errors, the current study focused on attacking passages of play, assessing instances of combination passing leading to a goal scored or an attempt on goal.

4.2.2 Data on attacking passages of play

The data on attacking phases of play showed no effect of warm-up on the total number of goals scored ($\chi^2(2)=1.0$, $p<.70$, table 4.2) or on an aggregate measure of goal attempts plus goals scored ($\chi^2(2)=3.5$, $p<.27$, table 4.2; figure 4.6). There was a significant effect of warm-up on the weekly total unsuccessful goal attempts ($\chi^2(2)=7.6$, $p<.01$, table 4.2). However, subsequent Wilcoxon signed rank tests found no individual differences between conditions.

	Light Physical	Keep-Ball	4-Ball
Successful Pass Completions	32.7 (27.6-33.5)	32.3 (30.8-34.4)	33.7 (27.2-41.3)
Total unsuccessful goal attempts	2.8 (2.0-3.3)	2.5 (1.2-2.8)	3.9 (3.2-5.3)
Total goals scored	3.8 (2.4-4.0)	3.3 (3.0-5.1)	3.6 (2.1-5.0)
Total goal attempts	6.2 (4.9-7.2)	6.0 (4.3-7.6)	7.2 (5.6-10.2)
Unsuccessful goal attempts with 3+ passes	0.3 (0.1-0.6)	0.3 (0.1-0.4)	1.4 (1.1-1.9)
Goals scored with 3+ passes	0.5 (0.3-0.8)	0.5 (0.4-1.1)	1.3 (0.8-2.1)
Total goal attempts with 3+ passes	0.8 (0.5-1.2)	0.9 (0.5-1.3)	2.7 (1.9-4.0)

Table 4.2: Group performance data: Median weekly results per warm-up condition focused on attacking sequences of play achieved during 5 minutes of competitive play (Data are median / lower quartile-upper quartile).

In terms of assessing the magnitude of change between the various conditions, the median group data again provides a useful indication of effects on attacking performance (see Table 4.2). These median results are represented in the following plots, with the comparative data on attacking passages of play revealing similar trends to the data observed on performance errors (see table 4.2 and figures 4.6, 4.7 and 4.8).

There was a significant effect of warm-up condition on the number of total attempts on goal involving 3 or more passes ($\chi^2(2)=6.5$, $p=.03$, table 4.2). This was reflected in changes in the total number of goals scored with 3+ passes ($\chi^2(2)=7.4$, $p=.02$, table 4.2 and figure 4.8) as well as unsuccessful goal attempts with 3+ passes ($\chi^2(2)=6.5$, $p=.04$, table 4.2).

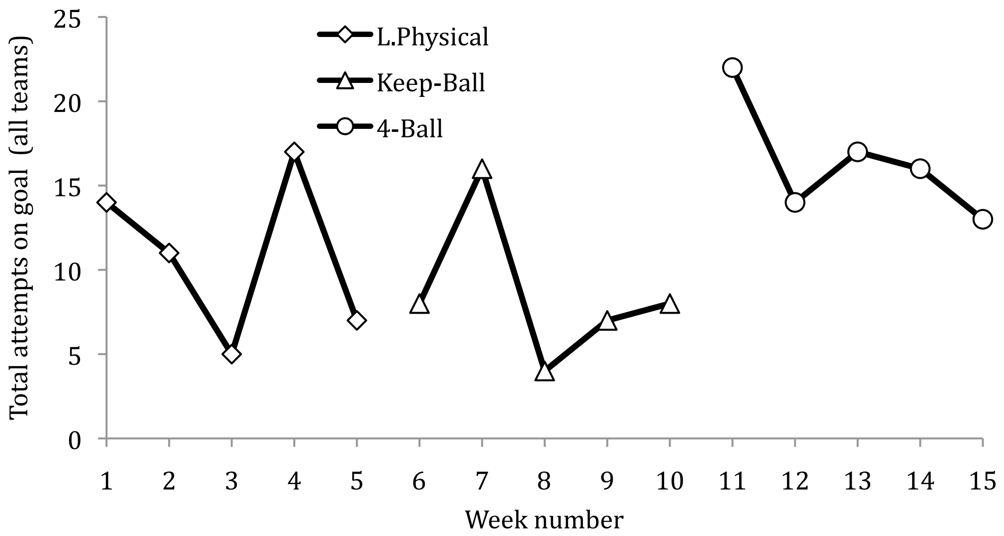


Figure 4.6. Total weekly group attempts on goal for each condition.

Whilst Wilcoxon signed rank tests again did not show significant differences between conditions, the plots of goal attempts with 3+ passes (figure 4.7), show a clear visual trend of increased numbers of goal attempts.

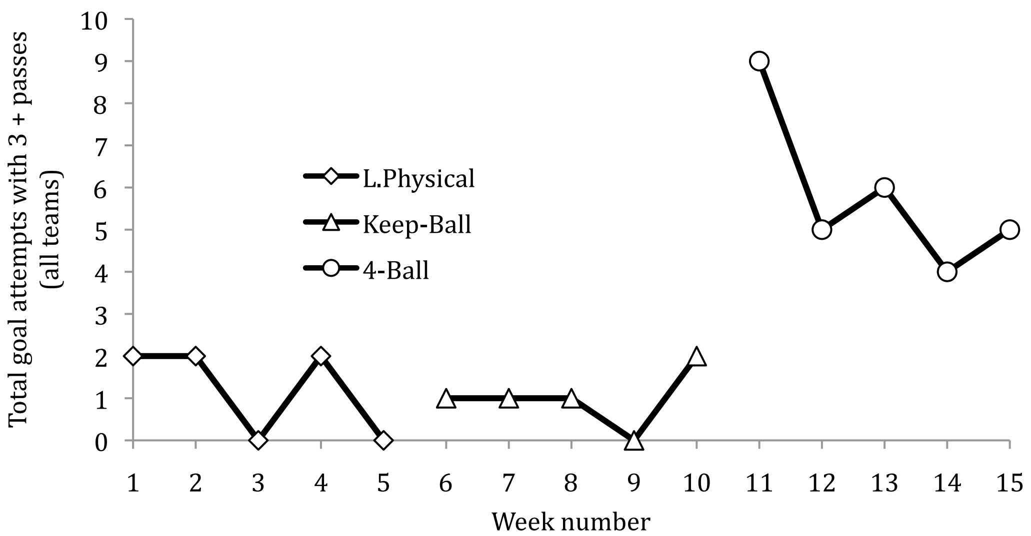


Figure 4.7. Total weekly group attempts on goal with 3 or more passes

Following the *4-ball* warm-up, the median weekly goals scored involving 3 or more passes amounted to 1.3 (by the four trial teams over 5 minutes of competitive play). This compared with 0.5 goals scored following the KB as well as the LP conditions (see Table 4.2). Measuring magnitude of change between conditions in percentage terms, this constitutes a 160% increase in goals scored involving three or more passes following the *4-ball* condition.

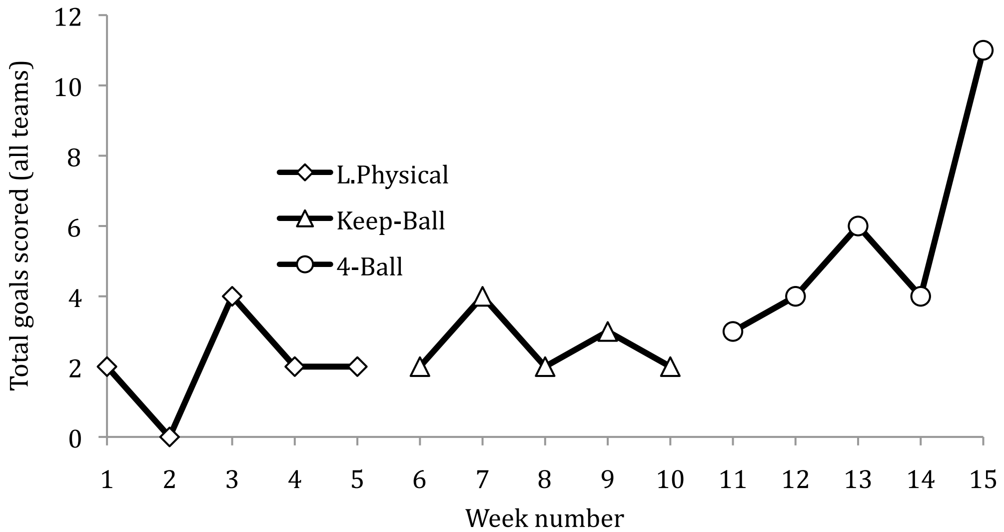


Figure 4.8: Total weekly group goals scored with 3 or more passes

For generating attempts involving three or more passes on goal, the magnitude of change is greater still in comparisons of the *4-ball* condition relative to the other two conditions. The median weekly score for *4-ball* of 1.4 compares with 0.3 for LP and 0.3 for KB. This constitutes a dramatic 366.7 % increase in opportunities created to score a goal involving a combination of three or more passes by all trial teams in any five minutes of competitive play following the *4-ball* condition. This was reflected in the aggregate variable total goal attempts involving 3 or more passes (i.e. goals scored with 3+ passes plus unsuccessful goal attempts with 3+ passes). A median rate of 2.7 was calculated for this variable following the *4-ball* condition compared to a rate of 0.8 following LP and 0.9 following KB condition. In percentage terms this represents a 200% increase in a comparison of *4-ball* and KB and a 237.5% increase comparing *4-ball* with performance following the LP condition. By contrast the percentage change between the LP and KB conditions showed a 12.5% increase following the KB condition.

As seen in the median data on performance errors, the results focused on attacking combination play (i.e. involving three or more passes between players to create opportunities to score), indicate dramatic increases in goals scored and attempts on goal following the *4-ball* condition. While order and practice effects are likely to be implicated, the comparative magnitude of change shown between conditions, suggests something of a step change in the quality of attacking combination play following the *4-ball* condition.

4.3 Individual results

As well as gathering and analysing group results, data on the performance of individual participants was also collected, with the focus restricted to the number of performance errors committed (i.e. individual pass errors, ball control errors and 3-touch errors). There was a significant effect of warm-up condition on weekly individual pass errors ($\chi^2(2)=7.9$, $p=.02$, table 4.3). Follow-up analysis with Wilcoxon signed rank test showed that the *4-ball* warm-up produced significantly less pass errors than the LP warm-up ($Z=2.9$, $p=.002$, $r=.52$). No differences were found between the KB and LP warm-up ($Z=.60$, $p=.57$, $r=.11$) or the KB and the *4-ball* conditions ($Z=2.1$, $p=.03$, $r=.38$).

	Light physical	Keep-Ball	4-Ball
Pass errors	2.3 (1.7-3.0)	2.0 (1.3-2.8)	1.1 (.9-1.7)
Ball control errors	.5 (.2-.7)	.7 (.3-1.0)	.4 (.1-.6)
3 touch errors	1.7 (1.2-2.2)	1.5 (1.0-2.1)	.7 (.3-1.3)

Table 4.3: The median of weekly individual trial errors per player in each warm-up condition: Data are median (lower quartile-upper quartile)

A significant effect of condition was also found on the weekly individual 3-touch errors ($\chi^2(2)$=14.9, p<.001, table 4.3). Wilcoxon signed rank tests found there to be significant difference between 3-touch errors in the LP and *4-ball* conditions (Z=3.0, p=.001, r=.53) as well as the KB and *4-ball* conditions (Z=3.1, p=.001, r=.55), with significantly less errors committed in the *4-ball* condition (figure 4.3). There was no difference in 3-touch errors between the KB and LP conditions (Z=.28, p=.79, r=.05). No effect of condition was found on individual *ball control errors* ($\chi^2(2)$=1.9, p=.41, table 4.3).

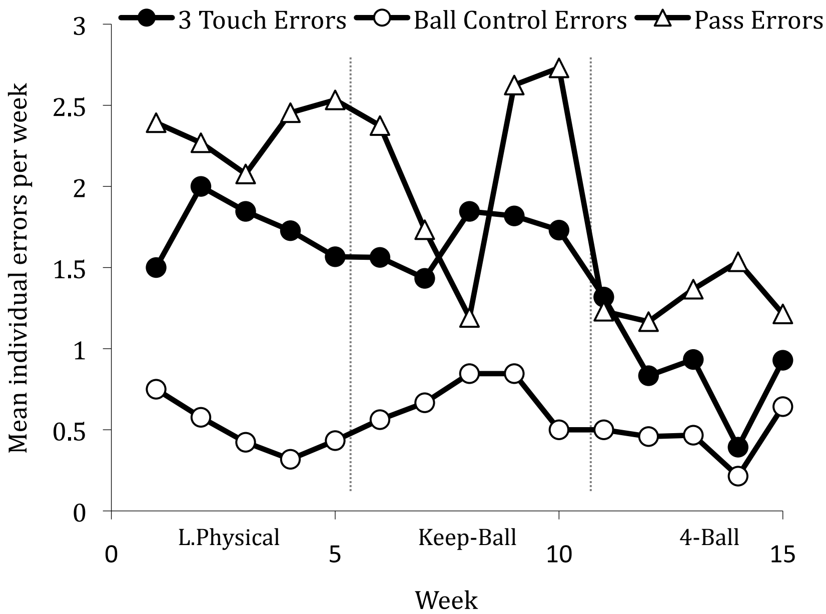


Figure 4.9: Mean individual errors per weekly 5-minute trial

The mean of weekly errors (per five-minute trial) committed by individual participants is shown in Figure 4.9. Again the plots illustrate a similar trend to the group results. In the *4-Ball* condition, there are notable reductions in all three variables measuring performance errors. This reduction in errors also remained largely consistent over the five weekly trials, especially with regard to ball control and pass errors.

CHAPTER 5: DISCUSSION

The purpose of this study was to provide data on changes in performance in football following the introduction of three distinct warm-ups: light physical, keep-ball in grids and a novel motor-visual warm-up (*4-ball*). Weekly group results (see table 4.2) indicate there was a significant main effect of warm-up condition on a number of variables. However, individual comparisons between conditions with Wilcoxon signed rank tests did not show significant differences. This may be due to a reduced statistical power resulting from the use of just 4 groups within the team data and adaptive design used in the applied field setting. In order to provide a visual representation of any trends in the data collected, median scores were plotted (see 4.2). However, it must be stressed the results presented here do not account for possible order effects and therefore need to be interpreted with caution.

For reasons outlined in 3.2, a focus on pass errors, ball control errors and 3-touch errors were seen as a more revealing indicator of effective performance than data on successful pass completions. Allowing for possible order effects, when performance following the *4-ball* warm-up was compared with performance following the other two conditions (LP and KB), the group data indicates:

1) Marked reductions in pass errors following the *4-ball* condition. A median error rate of 5.6 was recorded in the *4-ball* condition, compared with 8.1 (KB) and 8.6 (LP) per five-minute game. In percentage terms this represents a 30.9 % decrease in pass errors comparing *4-ball* with KB in grids and a 34.9% decrease *viz a viz* the LP condition. These results suggest participants following

the *4-ball* warm-up appear to have enhanced their ability to select and execute accurate passes to teammates while competing under situational pressure from opponents. As set out in 3.1, performance was confined to a playing area of 30 x 15 metres. The 4v4 games involved players repeatedly required to receive and pass the ball while challenged by opposition players within congested areas. In addition, a high intensity level was set by the experimenter, in an attempt to maximize competitive realism.

2) There were also reductions in ball control errors committed following the *4-ball* warm-up. A plot of weekly scores suggest a trend for reduced errors per 5 minute game of 2.4 (LP), 2.4 (KB) with 1.4 errors recorded in the *4-ball* condition. In percentage terms this represents a 41.7% decrease in ball control errors following the *4-ball* warm-up. Although practice and order effects are likely to be implicated, this performance indicator suggests the players may have showed improved composure in possession of the ball, that is, they were more successful in receiving incoming passes and controlling the ball under pressure following the *4-ball* warm-up.

3) Three touch errors measured all instances where a player dwelt on the ball taking three or more touches were lower in the *4-ball* condition (6.8 LP, 6.5 KB, 4.0 *4-ball*), representing a decrease of 41.2 % comparing *4-ball* with LP and 38.5 % comparing *4-ball* with KB). This would suggest that following the *4-ball* warm-up, the players displayed enhanced efficiency on the ball, both in terms of the quality of their first-touch and the tempo at which they dispatched their subsequent pass. An improved ability to control and pass the ball under competitive pressure from opponents (i.e. while restricted in terms of time and space on the ball), suggests the participants in the *4-ball* condition may have

been making informed decisions earlier; in other words, more effective anticipatory decisions, either on receipt of the ball or, arguably on occasions, in the time-to-contact prior to receiving the ball. On this basis, participants proved more effective at releasing the ball quicker to teammates, with the first touch to bring the ball under control and the second to pass it to a supporting player.

While order effects are undoubtedly a potential concern in these results, the data suggests that participants anticipated movements of supporting teammates more efficiently while "on the ball", allowing them improved ability to control and pass. However, this cannot be proven on the basis of this data alone (see 5.6).

Overall, the group data on error rates (PE, BCE, 3T) following the *4-ball* warm-up, suggest improved scores in technical performance, with participants retaining control of the ball more efficiently and dispatching it to teammates more effectively (see Table 4.1 for comparative median scores). To what extent such training effects are due to improved skills of players when *on the ball*, as opposed to improved support-play by teammates (or a combination of both these factors), is difficult, if not impossible, to determine. Early attempts at mapping more complex and configurative aspects of play are beginning to bear fruit (Davids *et al.,* 2005). However, such principled assessment is beyond the scope of the current study.

5.1 Perceptual skills conditioning–enhancing perception/action coupling

This study set out to answer the question can performance in football be enhanced through the use of a dedicated motor-visual skills conditioning warm-up. While mindful of the limitations to this study, the trends set out in the plots that represent group results show performance gains in the form of reductions in player pass errors, three touch errors and ball control errors following the *4-ball* warm-up. The individual results recording performance errors committed showed a similar pattern in terms of magnitude of change (see Figure 4.9).

In addition, group data was gathered on attacking passages of play, with a focus on quantifying goals scored as well as attempts on goal. For example, in percentage terms there was a 20% increase in goal attempts (following the *4-ball* condition compared to the KB condition (16% more compared to the LP condition). There were also substantial relative increases in attempts on goal recorded when comparing the *4-ball* condition with the other two warm-ups. However, this study placed a particular focus on goals scored and goal attempts created that involved three or more passes. The case was made that these two variables give a more effective indication of penetrating combination play between participants (see 3.2). Here the group data shows a markedly higher median rate for goal scored with 3+ passes (GS+3) following the *4-ball* warm-up, with 1.3 goals per 5-minute game compared with 0.5 goals for both the LP and KB conditions. This represents a 160% increase in goals scored involving three or more passes following the 4-ball condition. In terms of generating direct attempts on goal involving 3 or more passes (GA+3) the median group rate recorded for this variable in the *4-ball* condition was 1.4 per 5 minute game, compared to 0.3 chances created in both the LP and KB conditions (see Table 4.3). These two examples drawn from the data indicate improved combination passing following the *4-ball* condition, with players more successful at maintaining possession of the ball under situational pressure and distributing it more effectively between players to mount penetrating attacking passages of play. However, while acknowledging the likely influence of order effects, this study provides no principled data to help explain the substantial performance gains recorded. In order, therefore, to help assess these findings, the following discussion will advance a range of hypotheses building on the research reviewed in chapter two (see also 2.3.2 on task simplification).

Conclusions drawn from research on perceptual training programmes applied in sport, suggest the *4-ball* condition is unlikely to have helped improve the basic *visual functions* of participants in the optometric sense (see Helsen and Starkes, 1999). However, a number of studies previously cited confirm there is potential for perceptual training to encourage the acquisition of more effective *visual skills* or "search strategies" (for example, Farrow and Abernethy, 2002). This research consensus informs the premise of the following discussion.

5.2 Visuo-motor skills transfer from juggling to football

The rationale for incorporating the juggling component to help condition motor-visual skills in football was discussed in chapter 2. Key implications from this discussion now deserve closer attention to help elucidate the results gathered in this study and to point to possible underlying factors that would warrant further process-orientated research.

As noted in chapter 2, Huys and Beek (2002) have shown proficient jugglers will reduce the extent to which they visually track the balls they are juggling. Able jugglers tend to restrict focus on only certain segments of the ball-flight, principally those segments that provide more valuable optical information than others (see also Haibach *et al.,* 2004, p. 204). Bearing in mind that proficiency in juggling the 3-ball cascade forms a key component of the *4-ball* learning process, participants in this study were likely encouraged to develop similar (more selective and anticipative) visual search skills. Indeed, such visuo-motor skills may arguably have been further enhanced by the incorporation of the simultaneous ground ball passing drills, as used in the *4-ball* method (see 3.5).

Assuming this line of inference were correct, future research will need to asses to what extent perceptual skills acquired as part of learning to juggle 3 balls (with the hands) while controlling a groundball (with the feet), might be functionally relevant to motor-visual response in football? To address this issue Chapter 2 provided a summary of research on perceptual skills in juggling together with key findings on motor-visual expertise across a range of ball-sports, football in particular. These indicate elite/experienced athletes do not continually keep their eyes on the moving ball (Goulet *et al*., 1989; Abernethy, 1990; Amazeen *et al*., 2001). With increasing expertise, the tendency is for athletes to look at only a part of a ball's trajectory, the part most likely to provide information about its future position to aid interception etc. (see Huys and Beek, 2002). In other words, elite performers learn to rely on more predictive and peripheral visual search behaviour as a vital means to aid anticipation and instantaneous reaction in fast moving competitive ball-sports (Land and McLeod, 2000). As will be further elucidated below, this strategy is also seen as a means to free fovial vision to focus on other potentially more valuable sources of information (Williams and Hodges, 2004).

Based on a review of key research findings in this area, the supposition advanced here is that the *4-ball* constraint applied as a warm-up, may have encouraged participants to adopt a similar range of visual search strategies. This may in turn have facilitated a more expansive and flexible perceptual-motor response in the subsequent competitive football games (for relevant discussions see Davids *et al*., 2008; Araujo *et al*., 2004). See also the section on *4-ball* viewed as a form of task simplification (2.3.2).

Section 3.5 described how the *4-ball slalom* constraint encourages the participant to control a ground ball with two feet while keeping the head raised (in order to successfully juggle three balls as well as respond to additional visual cues). A key purpose of this multi-faceted constraint is to “prime” participants to rely less on central or foveal vision for monitoring and controlling the ball at the feet. Through the use of the *4-ball* technique applied as a warm-up, participants in this study may have been conditioned to increase their reliance on peripheral visual skills as well as more haptic and proprioceptive forms of ball control.

The research on the use of visual occlusion applied as a training aid provides some support for this rationale (see Williams *et al*., 1999; Davids *et al*., 2008). As outlined in 1.2, the emphasis on conditioning these acquired motor-visual skills in the immediate run- up to performance is what distinguishes this applied study. This emphasis was seen as a means to optimize the potential for transfer of this perceptual skills-set in the subsequent competitive football games. In other words, by means of this structured warm-up, the ability of participants to monitor the surrounding play and accurately assess “situational probabilities” in the subsequent football games may have been enhanced (see Davids *et al*., 2008).

One practical example may help illustrate this line of reasoning: by potentially inducing a more complex and diffuse visual search strategy, the *4-*

ball constraint may have helped participants overcome or minimise the disposition to "ball-watch". Ball watching is commonly defined as when a player repeatedly fixates for an extended period on the motion of the ball and/or the player "on the ball" (see Ward and Williams, 2003). Such a disposition is thought to come at the expense of awareness of other important sources of information in the surrounding play. Hence players who "ball watch" are likely to be less aware of off-ball runs of supporting team-mates; less aware of defensive movements from opposition players to "mark" or "screen" or intercept passing options; less able to "read" early cues indicating interceptive body movements by opposition players etc. (see Jordet 2005). According to Williams (2000), this tendency to restrict focus to "ball watching" commonly defines the visual search behaviour exhibited by novice, youth and more inexperienced players (see also Huys *et al*., 2004).

If it were possible to corroborate such suppositions through principled research, it would perhaps help account for the markedly improved scores shown in this study for passages of attacking inter-play that lead up to a goal scored or an attempt on goal involving three or more passes. Assessed together with the marked reductions in pass errors at both group and individual levels, these findings suggest that following the *4-ball* warm-up, participants may have spent less time "ball watching". This would have allowed for increased awareness of the surrounding play such as the positioning and movement of supporting teammates. Such increased awareness may be implicated in the substantial improvements noted in passing and attacking interplay. However, it will require future process-orientated research to determine possible underlying processes involved (see 5.7).

Assuming that certain anticipative and selective visual and proprioceptive skills are to some extent transferable across domains (i.e. from one ball-sport to another, from juggling to football, or between hands and feet), the participants in this study, by learning and exploring the *4-ball* constraint, may have been assisted in developing more advanced perceptual responses in the lead up to performance. This may have had a bearing on the results reported here.

The “overload” of combining aerial (three-ball juggling) and ground ball (football passing) constraints together with additional visual response cues, may have helped foster a form of accelerated perceptual learning correlating with the improved performance detected over the fifteen-week trial. The substantial improvements observed across a range of performance indicators in comparisons of KB and *4-ball*, suggest *4-ball* as applied in this study, may have potential as an effective and time-efficient method to inculcate advanced visuo-motor skills of functional relevance in football.

This is broadly in line with the findings of a study by Button *et al*., (1999), which suggested 11-year-olds who train with a smaller, heavier football may be guided towards improved reliance on haptic and proprioceptive sources of information in controlling a ball. The authors argue that through the use of this physical constraint, participants were encouraged to develop more effective coordination solutions, enabling skills transfer to other tasks (see also Williams and Hodges, 2004). Assuming such hypotheses were tested in future research, it would need to be viewed in the context of a) Proteau’s suppositions on the importance of maintaining strict specificity of practice (Proteau, 1992), and B) elements of the theory of deliberate practice as advanced by Ericsson *et al*., (1993). As far as the results from this preliminary study are concerned, the assumption that the best approach to improve or encourage expert-like performance is to confine players to a training regimen exclusively devoted to game-specific deliberate practice (e.g. KB exercises in grids), is at very least questionable (see Renshaw *et al*., 2009).

5.3 Flexibility in perceptual-motor response

Research on juggling has shown how flexibility in perceptual-motor response is vital to success in executing the cascade three-ball pattern (see Huys *et al*., 2003; for a review see section 2.2). Adding the ground ball passing constraint (as used in *4-ball*) arguably further intensifies the need for a highly malleable perceptual response. Section 2.2.3 outlined another form this flexibility in perceptual response might take. According to Santavoord and Beek, (1996), proficient jugglers develop a facility with the so-called "gaze through" technique in order to successfully suspend the motion of three or four balls simultaneously. Also described as "distant stare", this technique is defined as an acquired visual skill (see also Huys and Beek, 2002). The juggler learns to restrict the line of gaze to a small but economically selected region of the juggling pattern. In this way able jugglers learn to effectively shift their attention across the visual periphery to aid perception and co-ordination of the juggling pattern without changing their point of gaze.

Such observations suggest another potential perspective to this discussion. It has been argued that through the use of the *4-ball* warm-up, participants in this study attuned themselves to more expansive visual search skills that are functionally relevant to performance in football. By undergoing the *4-ball* constraint in the immediate run-up to competitive play, participants may have been encouraged to adopt a more complex range of visual search skills in their subsequent performance. In other words, the inference advanced in the light of results presented here, is that certain acquired visuo-motor skills, if conditioned through a warm-up, may prove transferable to other tasks (i.e. to benefit performance in competitive football).

Assuming the “gaze-through” technique were also implicated in some form in the execution of *4-ball*, participants in this study may have been conditioned to remain attentive to stimuli in their visual periphery while ensuring their point of gaze remained bounded within a small area. To what extent this visuo-motor strategy of “gaze through” (as observed in research on juggling) coincides with the so-called “visual pivot” as observed in research on visual skills applied in football is beyond the scope of this preliminary study. However, it may prove an area of possible further research. According to Williams and Davids (1998), elite level footballers were observed to rely on a so-called “visual pivot” (p.126) to extract more meaningful information per foveal fixation. A number of studies (Williams and Davids, 1998; Williams and Elliott, 1999) have explored this construct and the potential performance benefits it confers. According to findings from this research, in certain game situations, by fixating the gaze (i.e. the fovea) centrally, the skilled performer reduces the number of eye movements used, relying more on peripheral vision to extract task-relevant information from the surrounding play. Williams and David (1998) cite the example of expert defenders who, when marking an attacker, will at key moments (i.e. in 1V1’s) fixate their gaze on their opponent’s sternum. This area of the upper body is seen as providing the most effective early cue to help anticipate speed and direction of the player’s immanent movement (Williams and Davids, 1998). Restricting the point of gaze in this way allows the defender to keep a close mark on, or to intercept the run of, his opponent while also helping him maintain peripheral awareness of other important visual cues to action such as the movement of the ball and/or potential movements of other surrounding players.

Due to the diminished threshold for information processing when the eyes move from one fixation to the next (known as saccadic suppression), a visual pivot strategy is seen as a means to encourage more efficient dynamic visual processing. Furthermore, as peripheral vision is particularly sensitive to motion detection, information gathered in this way may be processed more quickly (see Milner and Goodale, 1995).

As set out in Chapter two, research has revealed how proficient jugglers develop a reliance on multiple sources of visuo-motor information. This allows them to "switch adaptively between functional organizations involving distinct perceptual systems" (Huys *et al*., 2004, p. 315; see also Haibach *et al., 2004*; Dessing *et al.,* 2007). Seen from this point of view, *4-ball* applied as a motor-visual warm-up with its incorporation of juggling skills, may arguably have helped prime a more extended and flexible perceptual response, incorporating foveal, parafoveal and peripheral aspects of the visual system as already noted, as well as more proprioceptive and haptic sources of information. To what extent *4-ball* also encouraged participants to explore more efficient search strategies similar to those used by expert performers, such as reliance on the use of visual pivots to aid anticipation, is beyond the scope of this study. This line of reasoning remains purely speculative. Detailed process-orientated research would be required to assess any such claims, assuming this were at all practical (see 5.7).

From the viewpoint of sports pedagogy, the potential benefits of encouraging so-called "discovery learning" provide another way to view the findings presented in this study (Williams *et al*., 2002 and section 2.5). The novelty of the *4-ball* constraint might be interpreted as a potential means to encourage more exploratory perceptual behaviour, with the goal of improving motor-visual performance in a ball-sport such as football. However, it must be stressed that without more principled research at a process-level such inferences remain strictly speculative.

5.4 *4-ball* as a means of implicit conditioning

For all its limitations, this study provides support for the view that preparatory warm-ups that adopt more implicit forms of conditioning (i.e. non-prescriptive methods such as *4-ball*), can have a significant impact on performance (for reviews with respect to the use of pre-performance routines see Lidor and Singer, 2000; Moran, 1996; for a counter argument see Jackson, 2003).

Results from this study indicate substantial improvements in performance on three-touch errors, suggesting participants were less prone to dwell on the ball, taking fewer touches and releasing it quicker. Similarly, the marked reductions in ball control errors, suggest participants were more effective with their first and second touch of the ball (receiving and passing skills). This is also evidenced in the data showing significantly fewer *pass errors*. However, to what extent these findings can be attributed to implicit learning or conditioning processes is impossible to determine based on this study.

Chapter two gave a brief review of the literature on forms of implicit instruction and learning. Examples of the experimental use of secondary tasks to facilitate implicit learning and performance "automaticity" were discussed and shown to yield some encouraging results (see Jackson *et al*., 2006). In this context, *4-ball* was described as a perceptual skills conditioning method that utilizes a secondary-task (3-ball juggling plus additional response cues), combining it with football passing and control drills (the primary task). This "dual-cue" condition was hypothesized as a means to encourage the athlete to rely on potentially more effective, unconscious or 'automatic' perceptual processing (see Cleeremans, 1997).

5.5 *4-ball* and mental concentration

As outlined in the description of training procedures (3.5), the *4-ball* constraint represents an intensive psycho-physiological task-load. Players are required to control four balls simultaneously (three with the hands, one with the feet), while also responding to additional visual cues. The intensity of this motor-visual constraint is alleged to help prime and enhance concentration, thereby potentially benefiting subsequent performance. Findings by Schmid *et al*., (2001), that concentration is an integral component of optimal performance can be cited in partial support of this case. Cox (1990) has similarly observed few areas are as vital as concentration in sport performance. However, until further research is conducted into the underlying processes informing the *4-ball* skills acquisition process, this remains purely conjectural.

In this sense it might be useful to conceive of the *4-ball* warm-up as a form of visual and coordinative "overload" or "handicap". Following the preparatory routine, the secondary constraint (three-ball juggling) is removed. Participants are then free to start the subsequent competitive football games focused simply on executing the primary task (to control and pass a size five football). With the removal of the three-ball juggling "overload", the player's capacity and willingness to be more flexible and adaptable in their perceptual behaviour in the course of playing football may arguably have been enhanced. For example, on receiving a pass while in space, participants might find they have more time and more propensity to visually scan defensive patterns of play and/or check positions of teammates while remaining in possession of the ball. Such changes in perceptual behaviour – suggestive of increased awareness of surrounding play - may help explain, amongst the other variables, the substantial improvements in the group results on attacking passages of play. As reviewed in 4.2.2, these results show clear improvements in performance levels correlating with the *4-ball* condition. For example, a 20 % relative increase in attempts on goal when median results from the *4-ball* condition were compared with those following the KB in grids warm-up. Perhaps more significantly, when the same comparison was made with regard to attempts on goal involving three or more passes in the build-up play, *4-ball* showed a relative increase of 200% on the KB warm-up (or a 237.% increase compared with the LP warm-up). However, to what extent this improvement is attributable to factors such as improved recognition of patterns of play or enhanced assessment of situational probability (see Williams and Hodges, 2004) is impossible to determine based on the current study.

5.6 Research limitations

A number of limitations to this preliminary study should be emphasized:

1) Counter-balancing measures to allow for possible "order effects" such as test familiarity and personnel dependency were not implemented as originally envisaged. Extending performance assessments with reconstituted teams composed of new combinations of players had been planned. The proposal was then to undertake a further two weeks of assessments on each of the three IV warm-ups (light physical / keep-ball / *4-ball*). Results from these additional assessments would then be analysed and compared with the first round of assessments in a bid to identify any possible order effects etc.

Due to circumstances relating to the extended nature of the initial trials, additional assessments using these counterbalancing measures were not undertaken. However, it should be noted that while 100 % attendance was the stated aim, with 16 participants involved, this proved impossible to sustain in practice over fifteen weeks (due to player injuries, ill health etc.). As a result, mean attendance rates of 13 participants per trial were recorded. This led to considerable rotation of players between the four respective teams over the fifteen-week study. In other words, a certain degree of reconstitution of team personnel was built-in more by default than design.

2) This study has focused on performance outcome and error scores, a research preoccupation usually associated with independent treatments of perception and action (Handford *et al.*, 1997). This research approach is of rudimentary value when assessing the impact of perceptual training on action-perception coupling. As is often observed, "assessment of movement in this way provides little direct information relating to the underlying mechanisms of

skill acquisition and, consequently, evidence of learning is often by inference" (Handford *et al.,* 1997, p.623).

3) While there are strengths to the extended time frame adopted in this research design, this also makes it difficult to discern whether improved performance is due to the introduction of the pre-performance warm-up or due to the extended physical practice (or a combination of these two).

4) In common with many previous studies on perceptual training, this investigation has not used a placebo group (see Williams and Grant, 1999). This raises the possibility that the performance benefits recorded were due to test familiarity or Hawthorne effects.

5) Another limitation is the lack of retention trials to assess longer term learning effects.

6) The findings of this research may only be applicable to players of similar age (U-14's) and competitive standard (sub-elite). Also all players were drawn from the same regional F.A chartered club.

7) As regards claims that *4-ball* encourages more implicit forms of learning: in common with the experimental set-up in most discovery learning experiments, participants in this study *intended* to learn. This has been shown to invoke significant explicit processing and hypothesis testing (Dienes and Berry, 1997).

Despite these limitations, it is hoped this study, with the encouraging results indicated in the data, will help encourage further research.

5.7 Future research

Three possible areas for extending research on *4-ball* might include

1) Further outcome-orientated research; 2) Incorporation of qualitative research methods; 3) Adoption a process-orientated approach.

1) In light of the limitations regarding research design set out in 5.6, future outcome-orientated research would need to implement a range of effective counter-balancing measures to ensure against order effects (test familiarity and Hawthorn effects). If a group design is adopted then Abernethy and Wood (2001) offer a strong experimental model with the use of placebo groups and the incorporation of sport-specific practice (see also Hagemann and Memmert, 2006; Williams *et al*., 2004; Lonsdale and Tam, 2008). With effective counter-balancing measures in place, further applied examination of the *4-ball* warm-up is recommended at elite level. Where possible, this research should aim to cover the academy youth and scholarship age groups (8 to 11, 12 to 16 and 17 to 21) up to senior squad level.

2) Future research could assess alternative strategies or “best practice” protocols for introducing the *4-ball* formula within the practical context of a football club, for example at youth academy or senior professional level. This research could combine further quantitative research focused on performance outcomes together with more qualitative assessments using, for example, semi-structured interviews (see Cote *et al*., 1995). Further intervention studies supported by a social validation questionnaire could prove an effective method to assess player reactions to the *4-ball* intervention.

3) Assessing the *4-ball* method from a more controlled, process-orientated perspective would no doubt involve many formidable challenges. Research

could focus on a detailed investigation of the skills acquisition process (see Keogh,1992). In this respect, some of the more stable and self-paced *4-ball* constraints may lend themselves to enhanced ecological experimentation in a laboratory setting. The use of 3-D imaging systems and various time-series analysis techniques for example, might prove a practical option in helping examine variations in coordinative dynamics between novices and experts.

5.8 Practical implications

This study has attempted to balance a quasi-experimental research format with the practical needs of football players and coaches. Despite the acknowledged research limitations, the results reported suggest there is potential for incorporating a specialized motor-visual warm-up such as *4-ball* as an integral part of training and pre-match preparation. However, more research is required to determine the full spectrum of age and ability levels potentially amenable to this novel motor-visual warm-up. In terms of the results presented in this study, any attempt to replicate the substantial performance benefits observed here, would require coaches to adopt similar methods and conditions as outlined in this research. This would involve combining the use of a specific *4-ball* motor-visual warm-up (i.e. the *4-ball* slalom) in conjunction with small-sided games with two- or three-touch conditions. Adopting this multi-faceted approach ensures the players have a structured and sustained opportunity to explore and incorporate any learning or “attunement” effects resulting from the *4-ball* warm-up into the more domain-specific perceptual “workspace” of competitive football (see Farrow and Abernethy, 2002). From a practical perspective, the most effective strategy would be to adopt the conditions as set out in this research design. This would entail combining the *4-ball* MVW with a short, football-specific, warm up (e.g. KB in grids), to complete an effective pre-performance warm-up prior to training or competitive play. Alternatively, where applied as a more general training tool, an effective approach may be to initiate sessions using a range of *4-ball* task constraints, followed by small-sided football games with "two touch" and "shoulder-height" conditions. Such a multi-faceted approach may prove effective by reinforcing groundball possession play as seen at the highest elite levels of the game (see Hughes *et al*., 1988).

5.9 CONCLUSION

This study has assessed a range of performance outcomes in football following the implementation of a novel motor-visual pre-performance warm-up described as *4-ball*. For comparative purposes, two additional game-specific warm-ups were also evaluated (Light physical and Keep-ball).

The group and individual results presented here, indicate that no improvements were shown when performance following the LP condition was compared with performance following the KB condition. This was the case on all the performance variables assessed even allowing for probable order effects.

When performance following the *4-ball* warm-up was compared to performance following the other two warm-ups, the data indicates reductions in the number of ball control and passing errors committed as well as in the number of three-touch infringements. These benefits were confirmed through an analysis of group as well as individual performance data.

The marked reductions in performance errors recorded following the *4-ball* warm-up, suggests improvements in technical performance, with participants maintaining control of the ball more efficiently and passing it to teammates more effectively. However, it is fully acknowledged that certain research limitations (i.e. practice and familiarity effects etc.) are likely to be implicated hence these results should be interpreted with appropriate caution.

The data gathered on attacking passages of play showed a similar pattern of improved performance in the *4-Ball* condition in terms of group comparisons of results following the three warm-ups. Once again, no significant changes were detected between the individual conditions. However, following the *4-ball* pre-performance condition, increases in goals scored and attempts on goal involving three or more passes were found.

No correlations were calculated between the significant reductions in performance errors and the improvements shown in attacking passages of play following the *4-ball* warm-up. However, because participants made less ball control and passing errors, it might be argued they were better able to mount sustained attacks on the opposition goal.

There are a number of avenues for future research on the back of this work and a number of practical implications for sports coaches and players with an interest in applying the *4-ball* warm-up routine. While the outcomes shown here are encouraging, this study provides no principled data to indicate what underlying processes may have been implicated in the performance improvements noted. Further process-orientated research will be required to assess possible training effects with regard to perceptual-motor skills (e.g. on visual search behaviour and proprioceptive reactions).

Appendix A:

Detail of conditions 1 (Light Physical) and 2 (Keep Ball in grids):

All three warm-up conditions were preceded by five minutes in which participants undertook a basic routine of dynamic stretching targeting hamstrings, quadriceps and calf muscles. All of these muscle groups are implicated in football.

All footballs used in the trials were size 4 as recommended by the English Football Association for age groups 9 to 14.

Each of the three warm-up conditions were undertaken for a period lasting fifteen minutes.

The light physical warm-up:

Participants were randomly divided into teams of three or four, each team provided with a football. No conditions or constraints were applied on movement. This allowed participants to utilize the full performance area measuring 30 x 15 metres. Participants were also free to take as many or as few touches of the ball as they wished before passing to a teammate. No intensity levels were set.

The Keep-Ball in grids warm-up:

Participants were randomly divided into four teams of three to four players. Four "grids" were marked out with coloured cones, each rectangular square measuring 7.5 metres x 7.5 metres (exactly half the width of the subsequent competitive performance area). Players of each team were required to keep the ball in constant movement, passing so each team-member made contact with the ball while in compliance with a two-touch condition (i.e. no more than two touches per player per contact with the ball). Participants were required to keep the ball at all times confined within the grid area in which they were performing. On completion of a set number of successful passes (x10), each team would move across to occupy the grid diagonally opposite with all teams rotating between grids subject to these same conditions. An intensity level of 80-90% was set by the researcher.

The *4-ball* warm-up is described in section 3.5.

Appendix B:

Definition of dependent variables:

The key dependent variables used in this study were operationalized as follows:

Successful Pass Completion (SPC) designates all instances where a pass from one player reaches a teammate without being intercepted by an opposition player (leading to loss of possession) or going out of play (i.e. over a by-line for an opposition kick-in).

Pass Error (PE) designates all instances where a player makes a pass that is intercepted by an opposition player or where a pass is misplaced (with the ball consequently going out of play).

Three-touch (3T) designates where a player clearly takes three or more distinct touches of the ball.

Ball Control Error (BCE) designates all instances where a player loses control of the ball on receiving a pass thereby yielding possession to the opposition or causing the ball to roll out of play.

Note: all instances where the ball ricochets, rebounds or accidentally strikes a player were not accounted for in the data gathered.

Total Errors (TE) equals total of PE + BCE + 3T.

Goal Attempt (GA) designates attempts on goal that required an opposition player to block or intercept the ball in order to stop it crossing the line into the goal.

Goal scored (GS) designates a goal scored where the ball crosses the line between the posts.

GA / GS +3 designates all passages of play involving three or more consecutive passes executed by one team that lead to a goal scored or an attempt on goal. On those few occasions where any one player involved in the link-up play took more than three touches of the ball on receiving a pass, the subsequent +3 outcome was not recorded.

Appendix C

4-ball skills acquisition process / participant progress.

Participants spent twenty-minutes per weekly training session practicing the 4-ball constraint. In addition, participants were encouraged to practice in their own time (i.e. home practice). During subsequent weekly training sessions, participants were streamlined into three ability groups using Newell's (1985) model of motor learning (co-ordinative, control and skill).

All participants began at the co-ordinative stage with the experimenter assisting participants as they attempted to assemble a suitable co-ordination pattern to achieve the juggling task goal. Once participants could execute at least twenty consecutive cascade catches, clearly exhibiting a degree of stability with the pattern, they were assigned to the control group. Participants in the control group were assisted as they explored a tighter fit between the assembled co-ordinated cascade pattern and the environment (see Davids et al., 2007). With this group, the experimenter extended the constraint by introducing the additional ground ball dual task (see figure 1). At this stage the experimenter also set the participants a target of fifty consecutive catches. Once this target was achieved participants were assigned to the skill group. According to Newell's model, in the skill phase of learning the performer is able to optimize performance by demonstrating instantaneous adaptability in their movements to satisfy changing task constraints (Davids, Button et al., 2007). In the process of skill acquisiton, with participants moving from the control to the skill phase of learning, the experimenter introduced the additional 4-ball constraints (see figures 2 and 3). Participants were then largely left to explore these progressions for themselves.

By the third week of training seven participants were assigned in the control group. By the fifth week the number of participants in the control group had increased to eleven, with three in the skill group and two remaining in the co-ordinative group. By the tenth week of training, fourteen of the sixteen participants in total were assigned in the skill group, with two remaining in the control group (having achieved between twenty and thirty-five circuits).

Appendix D:

Sample Consent form:

This information is being collected as part of a research project examining the effects on performance in football of using an innovative “4-ball” visual skills warm-up. The research project is being undertaken by Tag Lamche as part of his MPhil in Sports Coaching and conducted through the School of Education in the University of Birmingham in collaboration with FC youth development.

The information which you supply and that which may be collected as part of the research project will be entered into a filing system or database and will only be accessed by authorized personnel involved in the project. The information will be retained by the University of Birmingham and will only be used for the purpose of research, statistical and audit purposes.

By participating in this study and supplying this information, you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published. Please read the below statements, making sure that you are happy to go ahead with this research study.

- I confirm that I have read and understand the participant information leaflet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.

- I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. If I withdraw my data will be removed from the study and will be destroyed.

- I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.

- Based upon the above, I agree to take part in this study.

<u>Name, signature and date:</u>

Name of participant…………………………….. Date…………………..

Signature………………………………………

Name of parent………………………………….. Date………………..

Signature………………………………………

Name of researcher/individual obtaining consent ………………………………………………..

Date…………… Signature…………………………………………………..

Please complete this form and bring it to the next training session. Failure to complete and submit this form will result in you not being able to participate in the study.

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