ENHANCING REPRESENTATIVE PRACTICE DESIGN THROUGH CONSDERATION OF AFFECTIVE AND SITUATIONAL CONSTRAINTS IN COMBAT SPORTS

Michael Adrian Maloney

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College of Exercise and Sport Science

Institute of Sport and Health

Victoria University

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ABSTRACT

The overarching aim of this thesis was to examine the usefulness of a variety of existing combat sport practice tasks using representative learning design (RLD) as a framework. To date, RLD has largely focused on ensuring practice tasks sample the physical task and environmental informational constraints that support behaviour in competition. While useful, such empirical work has neglected to consider the role of emotions in training design. This thesis contains three experimental studies examining affect and representative practice design using taekwondo as a task vehicle.

The first study explored the impact of a competitive opponent on action selection and interpersonal behaviour in taekwondo by examining the behavioural correspondence between two common combat tasks: striking a representative dynamic target and a non-representative static target. Findings revealed that low behavioural correspondence between static and dynamic targets as emergent striking actions were uniquely constrained by each task. The second study compared the affective, cognitive and behavioural demands of combat practice relative to competition. The findings revealed that the affective and cognitive demands of practice do not represent competition and are associated with behaviour that does not represent how players act in competition. The final study tested the hypothesis that situational information could enhance the affective and cognitive demands of practice tasks by manipulating the presence of a live scoreboard. Results revealed that scoreboard presence lead to greater arousal and anxiety. These increased affective demands were associated with player behaviour that more closely represented the competition behaviour from the previous study.

In summary, this doctoral thesis contributes to an expanding body of work that advocates the use of principled theoretical and methodological frameworks to design sports practice tasks. The specific contributions include i) how affect and cognition influence action selection and

action fidelity, and ii) the conceptualisation and application of how the fundamental Brunswikian concept of situational information can add to the design of representative learning tasks. The findings of this thesis suggest that to design truly representative learning tasks, practitioners should sample information, action *and* affective constraints to create rich competition-like experiences in practice so that athletes think, feel and act like they would in competition.

STUDENT DECLARATION

"I, Michael Adrian Maloney, declare that the PhD thesis entitled enhancing representative practice design through consideration of affective and situational constraints is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

Signature: [redacted] Date: 03/07/2018

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List of Abbreviations

CI – Confidence Interval

CSAI-2 – Competitive State Anxiety Inventory-2

ES – Effect Size

IPD – Interpersonal distance

RLD – Representative Learning Design

SLEQ – Sports Learning Emotion Questionnaire

The headrest of the laboratory prevents the observer from turning his head and looking around

James J. Gibson

1 INTRODUCTION AND THESIS OUTLINE

1.1 INTRODUCTION

Theoretical advances in skill acquisition in sport have highlighted the need to design practice tasks that represent the constraints and demands of the performance environment (Pinder et al., 2011b). This need was captured in the concept of Representative Learning Design (RLD) which was developed to address a perceived need to formalize a principled approach to practice design in sports. By marrying concepts from Brunswik's representative design with Gibson's Ecological Psychology, the framework proposed by Pinder et. al. (2011b) emphasizes the need for the practice task constraints to represent the task constraints of the competition task – the information available, and the way performers (inter)act with that information.

A growing body of work has provided examples of how RLD can be applied in sporting contexts to enhance practice design. These studies have provided strong implications for the design of practice tasks in sport, and highlighted that practicing under non-representative conditions that omit key ecological constraints changes the way performers use information and how they coordinate their behaviour relative to the competition task (Barris et al., 2013a; Greenwood et al., 2016; Pinder, 2012; Shim et al., 2005). This work is important for practitioners and coaches who have grappled with ways of designing practice tasks that enhance transfer between training and competition.

Up to now, much of the work advocating for representative design has focused on physical informational environmental and task constraints (Barris et al., 2013a; Dicks et al., 2010; Gorman & Maloney, 2016; Greenwood et al., 2016; Pinder et al., 2011b). For example, comparing practice with a ball projection machine to a live bowler, springboard diving into a foam pit versus a swimming pool and basketball shooting with and without a defender. However, recent studies have highlighted that the design of learning tasks that adequately simulate aspects of competition is not simple and requires consideration of factors other than external physical information, such as emotions and cognition (Headrick et al., 2015).

In acknowledging that there is more to designing representative learning environments in sport than simply ensuring the presence of environmental information, Headrick et al. (2015) proposed that practitioners need to also consider the role of affect. For the purpose of this thesis, affect refers to a range of phenomena such as feelings, emotions and mood. This idea was underpinned by a body of work exploring the influence of anxiety on performance which has revealed that enhancing the representativeness of practice tasks through considering the affective demands will improve skill transfer to high pressure environments, like sports competition (Alder et al., 2016; Mace & Carroll, 1989; Oudejans & Pijpers, 2009, 2010). These findings have proved to be robust across different levels of expertise, anxiety intensity, and time scales. The implications of this work suggest that training sporting skills in environments that simulate the affective demands of the performance environment provides performers with the opportunity to develop functional solutions as they become accustomed to the relevant stressors. However, these studies have several limitations; they are limited in the type of task vehicles and the mechanisms adopted to induce affective demands like anxiety. Generally, these studies did not satisfy principles of representative design, with the generalizability of these results to performance environments being questionable (Araújo & Passos, 2007; Brunswik, 1956). For example, much of this work has explored behaviour in closed tasks, neglecting to understand how behaviour changes in complex open and/or interpersonal tasks. Additionally, there are very few in situ studies of typical sports practice tasks and how behaviour in these tasks might compare to data from competition.

Given that very few studies have examined the affective demands of typical sports practice tasks or collected data in-situ from training environments, there is a genuine lack of understanding as to whether typical practice environments adequately represent the constraints and demands of competition. Combat sports present an ideal task vehicle to extend this line of inquiry due to the inherent affective demands of the sport that contrasts to common training methods. For example, a common practice task is striking a static bag or pad which lacks the threat of getting struck; a constant in competition. Another common practice task is fighting an opponent (Hodges, 1995). While this activity samples informational constraints of competition, whether this activity represents the affective constraints and demands of the competition task is unlikely. For example, missing from this practice task are competition specific constraints such as a scoreboard, anxiety, aggressive opponents, crowds, unknown opponents, consequences and expectations (Wilson et al., 2007a). Consequently, there is a need to assess whether current practice environments adequately simulate the affective demands of competition and the effect this has on perception and action processes.

Finally, given it is unlikely practice environments simulate the affective demands of competition, it begs the question about how to better design practice tasks. One means proposed to enhance the affective demands of practice is to design vignettes or scenarios using situations sampled from competition (Headrick et al., 2015). This suggestion is congruent with Brunswik's fundamental ideas around the need to sample situational information reflective of the demands an individual will face in the performance environment (Brunswik, 1943, 1956). Previous work has explored how situational information impacts the affective demands of performers in competition. These findings have highlighted that performers report their highest levels of anxiety when competition scores are close and there is little time remaining in the match/game (Krane et al., 1994; Ritchie et al., 2017). Therefore, situational information, such as time and score, are strong candidate constraints to manipulate in training sessions in an attempt to improve the representativeness of practice by enhancing the affective demands.

1.2 Statement of the research problem

Much of the work advocating for representative design has focused on physical environmental and task constraints, neglecting to consider how affect influences the representativeness of performer-environment interactions in practice tasks (Barris et al., 2013a; Dicks et al., 2010; Gorman & Maloney, 2016; Greenwood et al., 2016; Pinder et al., 2011b). Recent theoretical advances have highlighted the need to consider the role of affect in practice design and how emotion, cognitions and actions interact to shape emergent behaviour (Headrick et al., 2015). Combat sports is an ideal task vehicle to study how affect influences the representativeness of practice tasks because of the dynamic and affective demands of the sport and how they train.

Therefore, the programme of work to follow will address the following questions:

1) How does the presence (and absence) of a threatening and dynamic opponent task constraint affect the decision making behaviour of taekwondo players (Chapter 3)?
2) Do practice environments adequately simulate the affective demands of practice, and if not, do these different demands impact action fidelity (Chapter 4)?
3) Can situational information constraints enhance the affective, and in turn, action demands of practice (Chapter 5)?

1.3 Thesis Structure

This thesis is presented in a traditional format and includes a combination of initial background literature and Chapters that are based on published journal articles or work being finalised for submission for peer-review. There is a proportion of repetition throughout the thesis which is necessary to allow the Chapters to be read as standalone articles and demonstrate the impact of each Chapter's contribution to the literature. While each Chapter has been written to stand alone, Chapters are also based upon the ideas, theory and findings that were generated in the Chapter(s) that came before. The programme of work has been constructed in 5 distinct Stages (see figure 1.0). Stage 11 represents the underpinning theoretical background and literature review (ChapterChapters 1 and 2). Stage 2 encompasses a two study empirical Chapter (Chapter 3) that explores a method of capturing collective behaviour in taekwondo while simultaneously examining the need to capture taekwondo behaviour in representative paradigms. Stage 3 (Chapter 4) examines differences between competition and practice, with particular interest in affective demands and whether changes in these are associated with changes in behaviour. Stage 4 (Chapter 5) is a natural evolution from the findings of Stage 3 and examines a way to enhance the demands of sports practice by testing the hypothesis that the presence of situational information can create emotion-laden learning tasks that make performers think, feel and act like they would in competition. Finally, Stage 5 (Chapter 6) brings together the findings and themes from the thesis to provide implications, limitations and future directions and highlights the theoretical and applied contributions of the thesis.

Stage 1 Development of research problem	Chapter 1: Introduction Chapter 2: Review of the literature
Stage 2 Exploring how the presence of a threatening opponent constrains emergent action selection	Chapter 3: Information for regulating action selection in taekwondo: behavioral correspondence between static and dynamic opponent constraints
Stage 3 Examining the affective and cognitive demands and action fidelity of expert practice relative to competition	Chapter 4: Taekwondo fighting in training does not simulate the affective and cognitive demands of competition: implications for behaviour and transfer
Stage 4 Can situational information constraints enhance the affective and behavioural demands of practice?	Chapter 5: The presence of situational information enhances the affective and action demands of practice: an intervention in elite combat sport
Stage 5 Review	Chapter 6: A review of the theoretical and practical implications from this PhD programme

Figure 1.1 Thesis overview and structure

2 LITERATURE REVIEW

The review of the literature is divided into four main sections and considers sports practice design and combat sport performance from an ecological dynamics perspective. The first section introduces ideas from dynamic systems and ecological psychology that underpin ecological dynamics. The second section addresses the need to design representative learning environments by drawing on past theoretical concepts and research in applied sport settings. The third section reviews the role of affect in designing representative practice, while the fourth section reviews existing research on skilled performance and behaviour in the striking combat sports.

2.1 ECOLOGICAL DYNAMICS

The ecological dynamics approach to studying human behaviour considers that the basis of skilled performance in sport is coordinating and adapting behaviour to the surrounding environment (Araújo et al., 2015a; Davids et al., 2012; Davids & Araújo, 2010). This approach is an appropriate scale of analysis for exploring such problems due to the emphasis placed on the relationship between performer and environment (Araújo et al., 2006). Ecological dynamics is a fusion of dynamical systems approaches to understanding human behaviour and Gibsonian ecological psychology (Davids & Araújo, 2010).

2.1.1 Ecological Psychology

The ecological approach emphasizes the role of a performers interaction with the environment to understand human behaviour (Barker, 1968; Brunswik, 1956; Gibson, 1986). Ecological psychology is driven through understanding behaviour in the context of the performer-environment relationship (Gibson, 1979). That is, a true understanding of performer behaviour can only be gained via consideration of his/her interactions with the natural environment. Gibson conveys this when he states: ‘Animal and environment make an inseparable pair. Each term implies the other. No animal could exist without an environment surrounding it' (Gibson, 1986, 8).

Gibson (1986) hypothesized that information that underpins the way performers interact with their environment is available in the form of invariant optic arrays - patterns of light containing visual information about the location of objects in space (Fajen, Riley, & Turvey, 2008). 'Particular perceptions and actions are informed by particular properties of ambient energy arrays' (Michaels & Jacobs, 2007, 4). The performer's perceptual interpretation of optic arrays becomes information for action, and movement decisions are a result of performers taking advantage of the informational richness of these arrays. For example, a long jumper's perception of light reflecting from the take-off board is important for guiding the regulation of gait throughout his or her approach (Maraj, 2002).

Within the ecological paradigm, functional movement solutions are viewed as products of a continuous prospective coupling between perception and action (Gibson, 1986). As performers move around the environment they pick up information which then informs their next movement. These perception-action couplings share an interdependent coupled relationship, relying on an organism's aptitude to perceive and act upon multiple sources of information within the environment (Pinder, Davids, Renshaw, & Araújo, 2011).

Performers interact with energy (e.g. light) in the environment around them to produce information. This information is available in the form of individual-specific action-relevant metrics termed affordances. (Fajen et al., 2009; Gibson, 1986). Affordances can be defined as 'relations between particular aspects of animals and particular aspects of situations' (Chemero, 2003, 184). They describe the relationship between the performer and the environment in terms of behaviours that are possible at a given time under a given set of contexts and conditions. In sport, athletic behaviour is supported by both physical and socioculture features nested within the surrounding environment (Rietveld & Kiverstein, 2014). For instance, in combat practice long limbed combat athletes will perceive their opponents as ‘strike-able’ at larger interpersonal distances (physical). However, the abilities, or effectivities of the athlete as Gibson describes them, will also determine if (and how) an affordance such as a specific interpersonal distance (IPD) can be realised. Performers are also constrained by affordances having a socio-cultural context. Hence, when practicing fighting there is a social expectation that they will lower their intensity, pacing themselves through fights due to a two hour session (socio-cultural) (Gernigon & Arripe-longueville, 2004). Consequently, the perception and realisation of affordances linked to individual perceptual and action capabilities, it is also multifaceted and complex (Bruineberg & Rietveld, 2014; Cañal-Bruland et al., 2010; Fajen, 2007; Gibson, 1986; Golonka, 2015; Stefanucci et al., 2008).

In a sporting sense, aAffordances emerge and decay as performers become attentionally educated and attune to more useful information (Michaels & Jacobs, 2007; Renshaw & van der Kamp, 2015). This concept of ‘education of attention’ highlights how affordances within the environment are also reliant on the capabilities of the performer. For instance, certain tennis shots may only be perceived as an action opportunity by the highly skilled player who can attune to advanced information available in the body actions of his opponent (Shim, Carlton, Chow, & Chae, 2005). Similarly, in the combat sports expert karate athletes are quicker at responding, likely due to a combination of greater physical capabilities and attunement to higher order information (Milazzo et al., 2016). The usefulness of different information sources for specific tasks are ascertained during learning, with individuals becoming attuned to the most usefulinformation sources (Michaels & Jacobs, 2007). Thereafter, any movement is tightly coupled to relevant information sources. Therefore, the landscape of affordances available in practice environments determine what abilities can emerge.

Within any given environment, performers have a metaphorical landscape of affordances from which to select from. However, only a handful are optimal for any given context. For example, boxers select punches that are the most efficient (optimal) for a given distance (Hristovski et al., 2006b). Selecting the most appropriate affordance for each context is a feature of expertise and indicative of the grip experts have on their environment (Bruineberg & Rietveld, 2014). Essentially, as skill increases, so too does the flexibility of human movement systems, allowing individuals to better adapt to interacting constraints of performance environments to achieve more consistent task outcomes (Davids et al., 2003; Fajen and Warren, 2003; Wu & Latash, 2014).. If performers are to develop an optimal grip over performance environments, then training tasks need to adequately simulate relevant constraints from those performance environments in practice. By sampling relevant constraints performers are provided with opportunities to practice attuning to and selecting these specifying affordances (Araujo & Davids, 2015).

The grip that skilled performers have on their environment highlights how experts can use higher cognition and their knowledge of and about their environment to enhance action selection (Bruineberg et al., 2018; Gibson, 1986; Golonka, 2015; Kiverstein et al., 2017). This knowledge performers possess can be described as ‘conventional’ knowledge and encompasses social customs or general knowledge of the environment (Bruineberg et al., 2018; Golonka, 2015). Conventional information is distinct from the lawful information which supports prospective control. Conventional information does not support action control because it does not physically exist and therefore light cannot reflect off it to create information that is directly perceivable (Gibson, 1986; Golonka, 2015). As an example, conventional knowledge that a particular taekwondo technique might be more likely to score can guide action selection. However, this knowledge does not help a performer prospectively organise this action. The prospective affordance based control of action – the organising of kinematic and kinetic dynamics in a manner which successfully strikes the opponent – is supported by the light reflecting from the body of the opponent. Therefore, the expert advantage is potentially twofold; not only are they attuned to more useful sources of information to support prospective control, but they also have greater cognition which allows them to better adapt to their environment via enhanced action selection (Araújo et al., 2015a; Araújo & Davids, 2009; Murphy et al., 2018).

2.2.2 Dynamical Systems Theory

Dynamic systems theorists consider humans as complex, self-organising neurobiological systems (Davids et al., 2015; Kelso, 1984a). Human behaviour, therefore, is understood as phenomena that is part of a complex system with many interacting component parts (Clarke & Crossland, 1985). Traits of a dynamic system include non-linear behaviour; that is, the capacity for stable and unstable behaviour and the ability for system sub-parts to influence or compensate for other system components (Chow et al., 2011; Davids et al., 2008; Rein et al., 2010; Seifert et al., 2016). Examples of dynamic systems are evident in daily self-organising phenomena such as weather, schools of fish, flocks of birds and human biological systems.

Functional (coordinated) behaviour, shaped by intentions, emerges and self-organises within boundaries provided by task, environmental and intrinsic constraints (Araújo et al., 2006; Chow et al., 2009; Newell, 1986). This behaviour is a product of human individuals mastering the many redundant degrees of freedom of the body; 10^2 joints, 10^3 muscles, 10^3 cell types and 10^{14} neurons to satisfy task goals (Bernstein, 1967; Kelso, 1995). Because of the complex and redundant nature of dynamic systems, humans demonstrate degeneracy meaning they can adopt many different states of organisation (Seifert et al., 2013a, 2016). Stable patterns of coordinated behaviour are referred to as attractors (Kugler et al., 1982).

The stability of an attractor (performance) is a trainable quality, with increased practice capable of increasing the consistency or stability of a particular behaviour (Chow et al., 2008; Wilson et al., 2008). The more stable a state is, the less susceptible it is to perturbation (Kelso, 1995).

A stated above, a key feature of dynamic systems is their non-linear characteristics. Practically, minute changes to any factors constraining the system can lead to rapid shifts (fluctuations) between coordinated states (Haken et al., 1985; Hristovski et al., 2006b). This non-linear nature of human movement systems is evident in the study of locomotion and the phase transitions between walking, jogging and running (Kelso, 1984a). The transition from walking to jogging does not occur progressively or linearly, rather it occurs spontaneously once a critical threshold of locomotor speed is reached (Kelso, 1984a).

The forces acting on systems often control the shifts between states of system order (Kelso, 1995). These forces are termed control parameters as they control the self-organisation of system order. Control parameters are variables that guide a system between different states of organisation. Minute changes in the value of a control parameter can bring about drastic changes in a movement systems dynamics (Kelso et al., 1994; Passos et al., 2008; Warren, 2006). A control parameter from the locomotion example discussed earlier is the speed of the treadmill. In the striking combat spots, an example would be the distance between a performer and their target. As interpersonal distance increases, different behavioural states emerge and decay in the form of different striking techniques as the motor systems degrees of freedom spontaneously re-organise (Hristovski et al., 2006b). These behavioural states of system order are called order parameters. Order parameters are variables that describe the macro organization of a movement system. In boxing, each coordinated striking technique is an example of an order parameter (Hristovski et al., 2006b). It is of great interest to movement scientists to empirically determine the key control parameters that act on movement systems and to identify order parameters that collectively reflect the organisational state of a system.

The strength of ecological dynamics is its integrative approach that considers how and why stable patterns of behaviour emerge from complex performer-environment interactions (Davids et al., 2013b; Seifert et al., 2013b; Warren, 2006). Dynamic systems theory provides a description and explanation of the patterns formed by multi-component systems such as individual neurobiological systems and/or more complex interpersonal systems (Bourbousson et al., 2010; Kelso, 1984b; Passos et al., 2008; Schmidt et al., 1990). Patterns of behaviour emerge from the interactions between these various (sub) system components as they self-organise within the boundaries provided by constraints (Fajen & Warren, 2003; Kelso, 2012). Ecological psychology reveals that the most relevant information for decision making and action regulation emerges from continuous performer-environment interactions (Araújo et al., 2005; Fajen et al., 2009; Michaels & Jacobs, 2007). Understanding how these unique performer-environment interactions lead to coordinated patterns of behaviour are insights unique to an ecological dynamics approach. A theoretically principled perspective such as ecological dynamics can help scientists interpret and predict how order emerges within extremely complex environments such as sport (Couceiro et al., 2016; Passos et al., 2009; Vilar et al., 2012a).

2.2 Constraints

Boundaries for action, termed constraints, shape the emergence of coordinated movements (Kugler et al., 1982; Newell, 1986). Constraints guide, invite, discourage and prevent movement opportunities and are divided into three classes – environmental, task and organismic (Kelso, 1995; Newell, 1986; Newell & Jordan, 2007; Newell & Valvano, 1998). Environmental constraints are time independent and external to the organism (Glazier, 2015). This may include gravity, ambient light, the temperature and the reaction forces exhibited by the ground. Socio-cultural factors have also been considered environmental constraints, including factors like expectations and social customs. Recently, the definition has been updated to encompass any physical constraint beyond the boundaries of the organism, such as implements or tools (Glazier, 2015; Newell & Jordan, 2007). Task constraints pertain to the goal of the activity and are therefore influenced by the rules and conditions that must be satisfied to achieve a particular activity goal (Newell, 1986). Examples include boxing rings and the situational or contextual, for instance, game specific situations such as an aggressive opponent or unfavourable referee decisions (Mellalieu et al., 2009). Task constraints can also include instructions issued by a coach or practitioner (Al-Abood et al., 2002; Newell & Ranganathan, 2010). Individual constraints are defined as personal characteristics of the individual, for instance: physically, physiologically, morphologically, or psychologically (Glazier, 2015). This may include factors such as handedness, the ability to perceive and act on information sources, the stability of certain behaviour, and anxiety (Krohne & Hindel, 1988; Mellalieu et al., 2009).

It is the environmental, individual and task constraints that act in concert on a movement system to shape self-organised emergent behaviour (Araújo et al., 2004; Davids et al., 2008). However, the relative contribution of each factor varies and is dependent upon the specific performance context (Oppici et al., 2017). The boundaries provided by constraints shape how humans organise their degrees of freedom into functional coordinative structures to produce patterns of coordination and control (Button et al., 2003; Chow et al., 2007). How these structures are affected by variations in task/environmental/individual constraints, and how they change during skill acquisition can be used to guide the design of practice tasks in sport (Newell, 1985). However, attempts to design principled practice that promote phase transitions (i.e. Newell & Valvano, 1998) is limited by the difficulty in identifying key control parameters in complex, dynamic performance environments such as combat fights.

Understanding how the manipulation of various constraints shape emergent movement behaviour can help practitioners design learning tasks. For example, a study by Chow et al. (2008) revealed that the presence of a barrier acting as a constraint for soccer players to kick over could facilitate the re-organisation of motor system degrees of freedom (Chow et al., 2008). In another study featuring the same task, Chow et al. (2007) revealed the organisation of movement behaviour was skill-level specific. Higher skilled players organised their degrees of freedom differently compared to more novice players (Chow et al., 2007). In the combat sports, the degree of threat posed by an opponent is a constraint that can be manipulated to shape either attacking or defensive behaviour states (Hristovski et al., 2011). The studies by Chow et al. (2007, 2008) highlight how manipulating certain aspects of the task or environment can facilitate immediate movement reorganisation. However, these studies were over the relatively short time frame of weeks.

One recent study explored the role of long term practice under domain specific task and environmental constraints (Oppici et al., 2017). Oppici and colleagues examined the gaze behaviour of players who had practiced extensively (i.e., more than 1000 hours) under either futsal or soccer constraints. Despite essentially performing the same skill (team invasion game using the feet to control the ball), the players gaze behaviour strategies were adapted from their many hours of practice under domain specific constraints. For instance, futsal players spent more time orientating their attention toward players in contrast to soccer players who spent more time looking at other information. The authors speculated this was likely an adaptation to extended exposure to futsal task constraints which have a greater density of players relative to playing area than soccer. These previous two paragraphs have highlighted how performers movement and perceptual behaviours adapt in a Darwinian sense to task constraints over moderate (Chow et al., 2008) to long term (Oppici et al., 2017) time scales (Dhami et al., 2004; Fajen & Warren, 2003).

Human perception-action systems are inherently adaptive, meaning we have multiple ways of interacting with the environment to achieve task goals (Bruineberg & Rietveld, 2014; Davids et al., 2003; Pinder et al., 2012; Seifert et al., 2013b, 2016). Because movement systems can be organised in a large number of ways due to the countless degrees of freedom possessed we are afforded variability in the way we move. Whilst previously movement variability had been considered ‘noise’, more recently this variability has been conceptualised as functional and adaptive (Davids et al., 2006a). For example, a comparison of triple jumpers across the hop-step transition phase revealed that the skill level of jumpers was related to increases in adaptive movement variability for more expert jumpers (Wilson et al., 2008). Similarly, an examination of the paddle trajectories of expert table tennis players revealed large amounts of variability at the beginning of the forehand drive which reduced to a relatively small amount as the movement progressed to ball contact (Bootsma & van Wieringen, 1990). This ‘funnel’ type of control allows players to adapt to the relative position and speed of the ball. The variability exhibited by the expert triple jumpers and table tennis players was functional and adaptive behaviour. This is a common feature of expert performance and similar control strategies are observed in other complex tasks such as basketball shooting and long jump run-ups (Button et al., 2003; Scott et al., 1997). Therefore, functional variability in dynamic systems affords experts the ability to exploit internal and external perturbations within the system in order to stabilize a desired outcome (Davids et al., 2003).

Along with being adaptive, skilled performers also have multiple solutions to the same problem, that is, they are able to use the same structures to form different movement patterns (i.e. degenerate traits). A specific trait of skilled performers is flexible behaviour (Araújo & Davids, 2011; Wu & Latash, 2014). In the same vein as adaptive movement variability, as skill improves, so too does an individual’s ability to satisfy the context-specific constraints of performance environments to achieve more optimal outcomes (Davids et al., 2003; Fajen &

Warren, 2003; Wu & Latash, 2014). For example, at certain interpersonal distances, boxers have multiple stable action modes that are possible (Hristovski et al., 2006b). The ability to transition between these stable states of movement organisation is ideal for performance in dynamic sports. Metastabilty describes the capacity to possess co-existent behavioural solutions (Hristovski et al., 2009). This trait is based on human movement system degeneracy and can be observed when multiple stable action modes exist for a given set of given constraints (Kelso, 2012).

Designing learning tasks that constrain learners into meta-stable regions can facilitate exploratory behaviours that lead to re-organisation of movement patterns and the emergence of new or novel action modes (Gibson, 1986; Hristovski et al., 2009; Orth et al., 2017; Pinder et al., 2012). Pinder et al. (2012) manipulated the ball pitching location in a cricket batting task. At certain pitching distances, stable action modes were observed. However, at a specific critical distance batters were afforded the opportunity to either move forward or backward to complete their shot. At this distance, batters were afforded the opportunity to utilise different action modes (front foot and back foot strokes) and displayed greater variations in movement timings. However, importantly, no changes in the quality of the outcome were observed. The authors concluded that by forcing batters into potential metastable regions invites the spontaneous emergence of variable coordination patterns, thereby providing opportunities for performers to develop flexible movement responses.

2.3 REPRESENTATIVE LEARNING DESIGN

On the first page of his seminal book the Ecological Approach to Visual Perception, James Gibson stated: ‘the headrest of the laboratory prevents the observer from turning his head and looking around’ (Gibson, 1986, 1). What Gibson meant, is that whilst laboratory testing offers control, it lacks the construct validity of the performers’ true environment. In this instance, the headrest prevents the performer from engaging with rich flows of information in a manner they usually would. A key principle of the ecological approach is its emphasis on performer-environment interactions to understand human behaviour (Barker, 1968; Brunswik, 1956; Gibson, 1986). Congruent with the Gibsonian approach, Brunswik believed in specificity of the relationship between the performer and the environment. He recognised that in any specific context, performers behaviour was supported by social and physical information (Fajen et al., 2009; Rietveld & Kiverstein, 2014). Therefore, the studies of human behaviour should reflect this and sample the environment (i.e. perceptual cues) from which the studies are intended to be generalized (Brunswik, 1956).

Brunswik's work is particularly pertinent for human movement scientists who have grappled with the problem of generating meaningful findings from laboratory settings that generalise to the real world. In the past, scientists have placed a premium on the control of experimental tasks often at the expense of ecological validity. Data collected from these laboratories and/or tasks is not the equivalent of data collected in-situ, and findings do not always generalise to the real world (Dicks et al., 2010; Serpiello et al., 2017). For example, the Loughborough passing test is a commonly used assessment of football passing skill. The test is popular due to its internal validity, which is achieved with the absence of opponents and a requirement to pass the ball to static targets (Ali et al., 2003). However, a concern is that the test lacks external validity as the static passing targets and the absence of defenders does not represent the constraints acting on the passing behaviour of performers in an opposed game (see Vilar et al., 2012b for a more extended critique). Recent work revealed that, while the test is highly reliable, the generalizability of results from this test to in-game passing performance is poor (Serpiello et al., 2017). The key limitation of this test is its organism-centric focus and failure to consider the interacting constraints of the performance environment. In a similar vein, a large number of studies investigating striking actions in the combat sports have used static targets such as bags or pads (Estevan et al., 2013, 2016; Pozo et al., 2011). These studies have removed important information that expert combat athletes may rely upon and therefore perhaps failed to capture how these performers interact with the environment.

Representative design is an experimental design philosophy advocated by Egon Brunswik (Brunswik, 1956). He positioned this approach in contrast to systematic design (an example of a systematically designed test is the Loughborough passing test described earlier). Similar to systematic design, representative design is underpinned by the principle of sampling. While systematic design is based on sampling subjects, representative design is based on sampling circumstances or objects. Brunswik recognised the ‘double standard’ where stringent approaches to sampling are applied to subjects, but not objects or circumstances (Brunswik, 1943; Hammond, 1998). For example, in systematically designed experiments, results can only generalize if an adequate number of subjects are sampled from the desired population to which results are meant to generalize. However, little consideration was given to whether generalizing results from a laboratory task to the real world was over-stating or over-reaching the findings.

The fallacy of this approach is highlighted by examining some systematic designs in experimental psychology. Psychology experiments might sometimes only sample one variable. In fact, positivistic psychology experiments are often predicted on changing one variable at a time. For example, a study investigating gaze behaviour in golfers asked them to putt from a single distance (Wilson & Vine, 2017). Similarly, an examination of gaze behaviour in tennis sampled serves from only a single person (Murray et al., 2017). The issue with these studies is that because they did not adequately sample from the vast array of possible variations within each of the tasks, it is difficult to make broad performance generalisations beyond the scope of the study. That is, how do the gaze behaviours found over the one distance sampled in the study of golfers generalize to other putting distances, and in the tennis study, to gaze behaviour beyond serve receptions from that one individual server. According to Brunswik, informational cues are only probable and never absolute in what they will or will not predict (Brunswik, 1943). Any change in task constraints will likely alter a cues level of functionality (Pinder et al., 2011a). Therefore, sampling only one set of cues under one given context will not provide results that are generalizable, given that in the real world it is likely a variety of cues are used complimentarily for a given context.

Brunswik captured these thoughts with a theoretical model he called the lens model (Brunswik, 1952). The model is based on the concept of probabilistic functionalism described in the previous paragraph: that such cues are only probable. The lens model is also based on the theory of vicarious functioning: that performers may use a variety of different information sources to provide more reliable predictions. These predictions are presented as ecological validities – a correlation between proximal information and a distal event the performer is trying to predict. In a sporting context, performers aim to predict what their opponent might do and how they should act based on the available proximal information (Araújo et al., 2006; Loffing & Hagemann, 2014; Savelsbergh et al., 2002). Proximal cues themselves are interrelated and a level of redundancy is observed – distal variables can be predicted with any number and combination of proximal cues, for instance, a combination of contextual or kinematic information (Milazzo et al., 2016; Murphy et al., 2018; Runswick et al., 2018). Some of these may have different ecological validities depending on the situation. Therefore, there is a degree of degeneracy in how performers predict distal events (Brunswik, 1952; Dhami et al., 2004). Under an ecological dynamics framework, designing sports practice tasks that do not contain the same ecological validities as the competition task will have negative implications for skill transfer (Araújo & Davids, 2015; Araújo & Passos, 2007). The implications for practice are, similar to Gibson's Ecological Psychology, that the coupling between performer and environment must be preserved.

A principled approach to practice design was developed by marrying concepts from Gibson's Ecological Psychology and Brunswik's representative design. These concepts were adapted by Pinder and colleagues as framework to guide the design of practice environments in sport (Pinder et al., 2011b). The framework proposed by Pinder et. al. (2011b) emphasized the need for the practice task constraints to represent the task constraints of the competition task. Specifically, to design representative learning tasks, there is a need to consider the information available to performers (functionality) and performers' action responses (fidelity). Because performers form functional relationships with the environment (or in Brunswik's language, informational cues), it is important to preserve and encourage the functional formation of these relationships in practice tasks. Therefore, sampling variables from performers' typical environments is crucial for the design of representative practice tasks (Brunswik, 1956; Pinder et al., 2011b). Practice tasks that violate these considerations may compromise the positive transfer of skills between training and competition.

Practicing under non-representative conditions that omit key ecological constraints impacts on the fidelity of athlete behaviour relative to the competition task (Barris et al., 2013a; Greenwood et al., 2016; Pinder, 2012; Shim et al., 2005). Action fidelity refers to the association of behaviour in a reference (e.g. competition) and a simulated (e.g. practice) situation (Stoffregen, 2007; Stoffregen et al., 2003). The concept of fidelity specifically deals with transfer and is achieved when behaviour in a simulated task adequately represents the behaviour observed in the actual performance task. For instance, practicing cricket batting with a ball projection machine leads to altered movement kinematics (low fidelity behaviour) as the machine lacks key pre-release kinematic information of a real person (Pinder et al., 2011a). These results suggest that training with a bowling machine will have a low transfer to the performance environment due to the low fidelity of the action response compared to the competition task where batters movements are coupled to a live bowlers advance kinematics.

In non-representative tasks, fidelity is impacted as performers adapt to form functional relationships that better suit their new environment. Because of the change in constraints, information that was utilised to underpin the emergence of functional perception-action couplings is either altered or no longer present, requiring performers to interact differently with the environment. For example, in the same cricket batting task described in the previous paragraph, the visual search behaviours of batters also changed (Pinder, 2012). Practicing under such conditions would lead performers to develop a less functional relationship as they are forced to attune to other information sources that may have a low ecological validity in the competition setting. In essence, performers would learn to couple their movements to artificial information sources (e.g. the angle of the machine or the sound of the ball as it is forced out of the machine) that have limited functionality under ecological task constraints. The implication for practice is that perception-action skills learned under such practice conditions would be less likely to transfer to performance environments where the task constraints are different.

The representativeness of practice and research tasks is also pertinent concern when attempting to capture expertise. Earlier in this section we demonstrated how the ecological dynamics approach considers that the basis of skilled performance in sport is coordinating and adapting behaviour to the surrounding environment (Davids & Araújo, 2010; Fajen & Warren, 2003). Essentially, experts become highly attuned to usefulness of the information in the environment around them and couple this with specific action responses (Mann et al., 2010). For instance, the direction that basketballers choose to attack when dribbling is coupled to the posture of a defender, and the run-up behaviour of cricket bowlers is shaped by specifying information provided by the umpire and the stumps (Esteves et al., 2011; Greenwood et al., 2016). Altering task constraints can have dramatic effects on capturing expertise. Experts are particularly sensitive to their surrounding environment due to their many hours of practice spent attuning to key information sources and adapting to the task and environmental constraints. An example of this sensitivity is found in a study by Mann et al (2010) where the way novice and expert cricket batters were asked to respond in a cricket batting scenario was manipulated. The responses ranged from verbal (non-representative) to ball interception using the bat (representative). When the action responses did not represent the way they batters respond in a match (by batting), there was no difference observed between the expert and novice groups (Mann et al., 2010). It was only when the task required batters to respond like they would in a real match that experts outperformed the novices (Mann et al., 2010). The results highlight that the expert advantage may only become apparent when the task constraints represent those they have spent many hours adapting to. Therefore, when studying expertise, designing representative experimental tasks is critically important.

Much of the research on representative design has focused on physical informational environmental and task constraints (Barris et al., 2013a; Dicks et al., 2010; Gorman & Maloney, 2016; Greenwood et al., 2016; Pinder et al., 2011b). For example, comparing practice with a ball projection machine to a live bowler, springboard diving into a foam pit versus a swimming pool and basketball shooting with and without a defender. However, performed in isolation of performance contexts, this area of research has overlooked some of Brunswik's fundamental ideas around the consideration of situational information in task design (Brunswik, 1943). This is an important consideration, as how performers interact with the environment is strongly influenced by the use of situational information like time and score (Araújo et al., 2006; Cordovil et al., 2009a). While these studies have advanced our understanding of practice design, their shortcoming is that they only "describe the environment in terms of physical stimuli does not adequately capture the properties of an environment" (Heft, 2001, 236).

Brunswik also acknowledged this limitation, highlighting that in addition to sampling representative information, the study of performer-environment interactions should sample a variety of situations reflective of the demands an individual will face in the performance environment (Brunswik, 1943, 1956). Brunswik termed this 'representative sampling of situations' and advocated for the sampling of likely scenarios where performers aimed to achieve the same goal: "A sampling of tests carefully drawn from the universe of the requirements a person happens to face in his commerce with the physical or social environment" (Brunswik, 1943, 263, 1955). In writing this, Brunswik acknowledged other variables, such as context, that dictate how performers interact with the environment.

Brunswik illustrated the importance of capturing situational variables in experimental designs with an example detailing a hypothetical study of distance perception (Brunswik, 1943). He argued that to gain a true understanding of distance perception, one could not just sample one single instance in which distance is assessed. Instead, perceptual distance estimates must be captured in a suite of situations representative of all the contexts and conditions in life which require judgement of distance. Therefore, for experimental design perspectives, sampling scenarios provides a basis for understanding whether results are generalizable or reflect abnormal behaviour (Brunswik, 1955, 204).

In a sporting context, performers have large amounts of information available to them within any given environment, and it is situational-variables that guide their search for the most useful cues and action responses. A 'landscape of affordances' describes the vast number of action possibilities a performer must select from (e.g. in football this might be team mates to pass to and/or opponents to dribble past) (Bruineberg & Rietveld, 2014). For instance, in tennis and association football the context provided by relative player positioning has revealed that some responses are more optimal than others (Headrick et al., 2012; Loffing &

Hagemann, 2014). Hitting a forehand down the line or passing to a team mate are only considered optimal for given contexts.

Researchers have explored the importance of situational information in sport tasks and how it can shape behaviour by sampling some competition-like scenarios in experimental tasks (Cordovil et al., 2009b; Maraj et al., 1998; McRobert et al., 2011). In a basketball task participants were asked to imagine they were in a scenario that required them to attack the basket with either high or low amounts of risk. When attacking in a situation that required a high degree of a risk, the basketballers displayed different movement behaviour compared to a low risk situation (Cordovil et al., 2009a). Despite the physical information sources being controlled for (i.e. court markings and opponents) the behaviour of individuals changed when they were provided with different situation-specific information. A similar study was performed with long jumpers where they were asked to jump under two different conditions: a situation that required jumping for distance, or jumping for accuracy. Jumpers displayed behavioural solutions that were unique and functional for each situation (Maraj et al., 1998). The results of both of these studies revealed that participants were solicited by affordances that were optimal for the imagined situation. The results also highlight how the addition of extra instructional information provided by situational information constrains performers search for action solutions and shapes the way they functionally interact with the environment (Araújo et al., 2006; Hristovski et al., 2011). However, in these studies performers were only asked to imagine they were in specific scenarios. Therefore, key informational cues such as the score and time left in the game were not represented in the experimental design. Further, experimenters did not collect affective and cognitive measures, which could provide useful insights.

These studies provide strong implications for the design of practice and research tasks in sport. They have revealed that performance is predicated upon performer-environment interactions and that sampling physical task constraints from the performance environment is required to design representative tasks. However, there are some limitations. Recent work has highlighted that designing simulations of competitive environments is not simple and requires considerations of factors other than information functionality and action fidelity (Headrick et al., 2015; Pijpers et al., 2006). Affective measures could provide insight about the usefulness of particular practice manipulations and why performers select one affordance over another. Additionally, there is a lack of investigation exploring affective constraints in typical sport practice environments and how situational information can be used to create more representative practice tasks.

2.4 AFFECT, SPORT AND BEHAVIOUR

Sport has been used as a common task vehicle to further our understanding of how affect influences behaviour (Gray & Cañal-Bruland, 2015; Hristovski et al., 2009; Nieuwenhuys et al., 2008a). The term affect will be used to refer to a range of phenomena such as feelings, emotions and mood. The terms affect and emotion will be used interchangeably to follow previous work in the area (Headrick et al., 2015; Lewis & Granic, 2000). Earlier, evidence was provided that complex biological systems are constrained by the perceptual and action capabilities of the performer. However, emergent behaviour is also shaped by additional parameters such as emotions interacting over various time scales (Lewis et al., 1999). Studies have revealed that the way performers feel can change the way they perceive and act within the world (Pijpers et al., 2006). For example, when fearful, individuals perceive geographical slants as greater than what they normally would (Bhalla & Proffitt, 1999; Stefanucci et al., 2008). Given the tight link between perception and action, these examples highlight how the way performers feel can shape their behaviour. Exploring this interaction between emotion and behaviour has been a focus for practitioners. In sport, this focus has largely been the anxiety-performance relationship due to the potentially detrimental effects of this emotion on performance (Nieuwenhuys et al., 2008b; Oudejans & Nieuwenhuys, 2009).

A variety of studies have revealed that under the influence of anxiety, the performance of complex sporting skills can decline due to a variety of mechanisms. For instance, when anxious, individuals have a reduced capacity to perceive and realize affordances, therefore limiting decision making and motor control (Causer et al., 2011; Nibbeling et al., 2012b; Nieuwenhuys et al., 2008b). With both the ability to act and pick up information perturbed, performance can decline. For instance, a study using a rock climbing task revealed how feelings of anxiety influenced the perception and realisation of affordances (Pijpers et al., 2006). This study had participants perform on two identical climbing routes that differed only in their height from the ground – a low route and a high route. The high route was designed to induce task related anxiety. On the high, anxiety inducing route, participants perceived changes in their action capabilities, evident in reduced perceived maximum reaching height. Additionally, the changes in action capability manifested as changes in action, and the actual maximum reaching heights of participants declined. Whilst the action capabilities of performers theoretically should have remained constant (their limb length and muscular strength did not change), performers' perceptions of what was and was not possible within the environment shifted. Further, in the high anxiety inducing route, performers were less likely to notice additional information in the form or red lights being projected on the wall. These results suggest that whilst individuals can still be attuned to important information sources, increases in arousal and different emotions can interfere with the perception and realisation of affordances.

2.4.1 Affective learning design

Training in conditions that simulate the affective-cognitive demands of the performance environment, like climbing at height, provides opportunities for adaptation and for performers to practice re-calibrating their action capabilities to the affordances on offer (Fajen, 2005; Oudejans & Nieuwenhuys, 2009). For example, a study by Gray et al. (2013) compared the movement patterns of two groups of golfers – those who thrived under pressure, and those who performed poorly under pressure. The findings revealed that the golfers who performed poorly exhibited relatively reduced amplitudes of arm and club movements of the backswing phase of golf putting (Gray et al., 2013). The authors suggested these results were a reflection of participants seeking to reduce movement variability as a strategy to decrease outcome variability. However, this movement solution proved non-functional as performance outcome declined. Instead, the results suggest that performers have not yet had the opportunity to develop a stable functional movement solution for when they are performing with anxiety.

Stable movement solutions (attractors) are known to emerge as interactions between these variables become increasingly coordinated, propagating over time (Lewis et al., 1999). For instance, practicing performing sporting skills under anxiety is known to enhance the stability of performances in high-anxiety competition-like scenarios (Nieuwenhuys & Oudejans, 2011; Oudejans & Pijpers, 2010). As the stability of attractors is a trainable quality, attributes such as technique and decision making would theoretically increase in stability if provided with the appropriate affordances for propagating this behaviour. Designing representative learning environments is rooted in the premise that these behaviour forming processes, adapt in a '*Darwinian sense*' to the environments in which they function (Dhami, Hertwig, & Hoffrage, 2004). Of specific interest, therefore, is understanding how athletes can train so they can better adapt to competition-induced anxiety (Mace et al., 1986; Oudejans & Pijpers, 2009, 2010).

An expanding body of work has revealed that enhancing the representativeness of practice tasks through considering the affective demands will improve skill transfer to high pressure environments, like sports competition (Alder et al., 2016; Mace & Carroll, 1989; Oudejans & Pijpers, 2009, 2010). For example, skilled dart players who practiced under anxiety were able to maintain performance in a high-anxiety transfer test, compared to those who practiced without anxiety (Oudejans & Pijpers, 2009). These findings have proved robust across different levels of expertise, anxiety intensity, and time scales. For example, Oudejans and Pijpers (2010) revealed that the protective effect of practicing with anxiety can still be maintained even if the anxiety experienced in practice is only small. Similarly, Nieuwenhuys and Oudejans (2011) revealed that the benefits of a short-term anxiety training intervention was still maintained months later. These findings suggest that training sporting skills in environments that simulate the affective demands of competition provides performers with the opportunity to develop functional solutions as they attune to these competition stressors. However, these studies have several limitations; they are limited in the type of task vehicles explore and the extent of the anxiety manipulations as detailed below.

These relevant studies have tended to fixate on the performance of closed skills such as golf putting, basketball shooting, rock climbing, and dart throwing (Gray & Cañal-Bruland, 2015; Oudejans & Pijpers, 2009; Wilson et al., 2009). Few studies have addressed the anxiety-performance interaction in open skilled sporting tasks such as invasion games or one-on-one opponent sports like the combat sports. Further, whilst some studies have succeeded in creating affectively demanding experimental tasks, they have done so via mechanisms that are not representative of performance environments. For example, affective demands have been created through the manipulation of non-ecological task constraints such as dual tasks, and height from the ground; for instance, performing arithmetic as a secondary task and throwing darts from a rock climbing wall (Noto et al., 2005; Oudejans & Pijpers, 2009). Other studies have placed pilots legs in buckets of iced water to elicit physiological stress, or used a joy-stick action-response in a video-based decision task which are known to have low fidelity (Dicks et al., 2010; Loon & Masters, 2001; McClernon et al., 2011; Navarro et al., 2013; Nibbeling et al., 2012b). Given these studies did not satisfy principles of representative design, the generalizability of these results to the actual performance environment is questionable (Araújo & Passos, 2007; Brunswik, 1956). The concern around behaviour correspondence is highlighted by Nibbeling et al (2012). In an attempt to replicate a field based running and throwing task, Nibbeling and colleagues asked participants to throw darts from a treadmill suspended in the air (Nibbeling et al., 2012b). Insight into the cognitions of participants in such experiments reveals their focus of attention shifts towards the non-representative stressor. Participants revealed that instead of focusing on the task at hand, they found it difficult to avoid thoughts about falling from the treadmill. While other studies have revealed that under pressure performers can shift their attention to task irrelevant information, the thoughts observed in this study would never be encountered if the task was representatively designed (Oudejans et al., 2011). Additionally, very few studies have examined the affective demands of typical sports practice tasks or collected data in-situ from training environments. Therefore, there is a genuine lack of understanding as to whether typical practice environments adequately simulate the constraints and demands of competition.

In open skilled tasks there are some examples of affectively demanding practice tasks that have been created using principles of representative design across a range of fields. In the military, Nibbeling and colleagues took the step from lab to real world when they investigated the effects of anxiety during training exercises of soldiers (Nibbeling et al., 2014). Their research considered the duel effects of fatigue and anxiety on performance and simulated a live invasion exercise with representative affective demands like uncertainty and the threat of being shot at (with non-lethal ammunition!). Similarly, the medical literature provides examples of successfully designed affectively demanding training environments. Experimenters have made valiant attempts to consider more representative forms of affective demands, for instance, in the emergency medical literature these have included difficult-to-diagnose ailments, emotional family members and complications leading to injuries where death was a realistic possibility (Harvey et al., 2011).

In acknowledging that there is more to designing representative learning environments in sport than simply ensuring the presence of environmental information, Headrick et al. (2015) recently proposed practitioners need to also consider the role of emotions (Headrick et al., 2015). Instead of viewing emotions as unwanted noise, similar to how movement variability was once considered (see section 2.1 for a recap), it was suggested that emotions were in fact a key part of learning and practice design. Recent work has explored theoretically the efficacy of sampling competition specific scenarios to create affectively demanding learning environments and the role this may play in the development of expertise (Headrick et al., 2015). Affective learning design considers the manipulation of the training environment to design “emotion-laden learning experiences that simulate the constraints and demands of performance environments in sport” (Headrick et al., 2015, 3). Such training tasks would afford performers the opportunity to develop more robust movement solutions to sporting task constraints, given that as attractors increases in stability, they become less susceptible to perturbations (Kelso, 1995; Lewis et al., 2004; Mesagno et al., 2008). Therefore, manipulating the environment to simulate the affective demands of performance environments may facilitate improved behaviour organisation under high stress situations, such as competition (Oudejans & Pijpers, 2010).

One proposed means to create emotion-laden learning experiences is to create vignettes or scenarios by sampling situations from competition (Headrick et al., 2015). This approach is congruent with Brunswik's musing on sampling situations and rooted in the premise that emotions emerge and decay according to performance contexts (Brunswik, 1943). For example, stressors and associated coping strategies varied over holes of golf, suggesting that by nature they are both dynamic processes (Nicholls & Polman, 2008). Similar results were found over the duration of football penalty shoot outs (Jordet & Elferink-gemser, 2012). The latter revealed intrinsic cognitions and affects were coupled with context specific stressors. At certain phases of the penalty shoot-out, individuals displayed a tendency to perceive certain stressors and feel certain emotions. For instance, at the mid circle subjects were stressed by waiting for their turn to shoot, leading to anxiety. Alternatively, the solitude of the walk toward the goal before their turn lead to stress via perceived solitude. Similarly, table tennis players experienced emotions according to the set results and game context, supporting the bi-directional nature of emotions in performance (Hanin, 2003; Sève et al., 2007). The implications for practice design is that scientists and practitioners must sample the task and environmental constraints that offer *"affective affordances"* (Szalma & Hancock, 2008, 328), so that athletes may train in environments affording competition-representative emotions.

2.4.2 Methodological considerations for capturing affect in sporting settings

These findings have implications for the design of studies investigating emotions in-situ, where discrete scales of analysis may not be appropriate. Some of the previous examples highlight the requirement for tools that can adequately measure the multi-directional nature and transition between emotions that is common during learning and performance (Hanin & Hanina, 2009; Headrick et al., 2015). The work of Hanin has identified many data collection techniques capable of gaining insight into the emotions during training and competition (Hanin, 2003). In-depth retrospective interviews are capable of providing rich insights into the subjective, such as thoughts and feelings that accompany competition specific situations. Due to ecological dynamics viewing the performer-environment relationship as interdependent, it is important that emotions are also understood in this context. Ideally, emotions would be assessed prospectively, however, this is not always practical, so the use of retrospective recall methods stimulated by video of natural athlete-environment interactions are growing in popularity (d'Arripe-Longueville et al., 2001; Hanin, 2003; Ria et al., 2011). Course of action theory provides an interview framework that satisfies these requirements, suggesting that *"affective and cognitive processes are inseparable from the situation in which they take place. These processes participate in the structural coupling of the actor with his or her environment and emerge from the effort to adapt to a context whose significant elements function as resources that the actor can use to act"* (Ria et al., 2011, 27).

Course of action theory is appropriate for investigating a performers' behaviour within a physical or social environment they share a cultural affiliation with, for instance, context specific interactions within a particular sport. The use of self-confrontational interview and video taken of the agent-environment interaction from a naturalistic setting, are used to complement quantitative measures of behaviour (Kiouak et al., 2016). These techniques reconstruct the meaning performers give to their in-competition activity through the recall and explanation of experiences during competition. These may be physical actions, communicative exchanges, interpretations, or emotions (Ria et al., 2011). Recall is able to provide scientists with insights regarding the intrinsic dynamics of a particular course of action, and how behaviour may have emerged under ecological constraints (Theureau, 2003). Essentially, a performers' emotions and cognitions are explained relative to micro and macro game specific actions and contexts. Such methodology affords scientists a multi-dimensional approach to understanding human behaviour.

This section has highlighted that even if players are perceptually attuned to the most useful sources of information, they still need to practice calibrating their actions under the affective and cognitive demands they experience in competition (Fajen, 2005; Oudejans & Nieuwenhuys, 2009). However, studies investigating anxiety and performance in sporting contexts are limited due to the lack of studies investigating open skilled sports (such as the combat sports) as well as non-representative task and anxiety manipulations. Finally, the affective and cognitive demands experienced in typical training tasks are not well understood, therefore it is a challenge for practitioners to know how much attention this factor warrants in their practice design.

2.5 Constraints and interpersonal coordination in taekwondo: implications for research and practice

Taekwondo is a striking Olympic combat sport that features two opponents. Fights occur on an eight x eight metre octagon shaped court and there are three rounds, each lasting two minutes. Players compete against their own gender and within specific weight classes. The aim of taekwondo is to outscore your opposite player. Scoring occurs through striking actions – either punching or kicking. To register a score, performers must strike their opponents front torso, flanks or head with appropriate force. Therefore, a key skill in taekwondo is adapting movements to the information provided by an opponent. However, much of the research in taekwondo has failed to consider the organism-environment system, instead overwhelmingly focusing on the performer. For example, there are many studies that either describe the physical qualities, physical responses or describe skills through notational analysis (Bridge et al., 2013, 2014; Falco et al., 2014). Therefore, a bias towards organismic asymmetry exists within the striking combat sport literature (Davids & Araújo, 2010).

As highlighted in section 2.1, a common methodology in the ecological dynamics approach to enhancing understanding of performance in sport has been to explore interpersonal coordination; how a performer adapts and coordinates their behaviour their environment (Araújo et al., 2015b; Duarte et al., 2012; Vilar et al., 2012a). Previous work in sport has revealed how opponents coordinate their behaviour to form dyads; an interpersonal system that self-organises within the boundaries created by task specific constraints such as the distance between players and the goals of the task (Cordovil et al., 2009b; Hristovski et al., 2009; Orth et al., 2014). Under these constraints, interpersonal dyads can transition between stable and unstable states of coordination depending upon individual performer behaviour (Passos et al., 2008). The implication is that interpersonal coordination is adaptive and must be studied under the unique constraints of each sport to understand how behaviour emerges for each given context.

In less complex sporting skills the parameters that constrain performance are much easier to identify. For example, in rowing, the coordination of a crew is constrained by the vertical oscillation of the boat (Millar et al., 2013). In this instance, the crews are fixed in a boat and success requires synchronisation of their movements with the boat. However, in more complex and open contexts like combat and team sports, the constraints acting on interpersonal coordination are much more transient (for example, the position of team mates and opponents and the location on the field) and therefore order parameters that represent coordination are more difficult to capture and interpret (Schmidt, 1999). A common vehicle for research in these sports has been one-on-one sub-phases of team invasion sports such as association football and basketball (Esteves et al., 2011; Headrick et al., 2012). While useful, the results from these studies are unlikely to generalize to other contexts with different constraints. In invasion sports, attackers have specific goals: to destabilize the attacker-defender dyad to move past the defender and towards the goal or basket (Passos et al., 2008). However, in in the combat sports, players aim to move within striking distance of their opponent, not past them toward a nested constraint. Further, players must satisfy dual goals of attack and defence. Therefore, the results observed in team sports or team sport sub-phases may only have limited generalization to a striking combat sport like taekwondo. How the unique constraints and goals of taekwondo shape emergent fighter-fighter coordination is not well understood. Therefore, there is little understanding of the control parameters that act on performers, or the order parameters that can be used to capture the global state of a fighter-fighter system.

2.5.1 Capturing and modelling behaviour in striking combat sports

Conceptual models of interpersonal behaviour in the combat sports suggested that combat athletes may form a temporarily stable interactive dynamic system (Dietrich et al., 2010). Dietrich et al (2010) hypothesized that collective behaviour during fighting activities could be measured directly from a global variable that is the relative distance between two subjects, or interpersonal distance (IPD). Using this measure, Dietrich and colleagues (2010) modelled fighters as non-linear coupled oscillators and identified two specific traits of a fighter-fighter system: the coordination phase and the decoupling phase. Coordination between the two fighters emerges as they form a coupled oscillator that represent action-reaction between fighters who are attempting to satisfy the competing goals of the task: escape or attack. In this phase the distance between fighters is more or less maintained and can be modelled by an equation that includes the length of the weapon or the attacking limb plus a variable distance that represents variability induced by the subject (such as limb length and/or speed).

The decoupling phase is a bifurcation whereby the previously stable coordination of the two fighters' is perturbed and new coordination state emerges. In this instance, a performer perturbs the system by attempting to attack. Therefore, the distance between fighters is dynamic in nature and emergent based on a variety of interacting constraints such as physical parameters like limb length, psychological and decision making factors. This suggests that IPD is a candidate order parameter to describe the fighter-fighter system in combat sports, and that a complex systems approach that considers an individual, task and environmental constraints that act on performers is an appropriate way to model behaviour. Therefore, the measure of IPD would allow scientists to investigate how constraints act on fighters' coordination tendencies.

However, not only does IPD act as an order parameter, it also acts as a control parameter and constrains the type of behaviour that is possible (Hristovski et al., 2006b, 2006a). Anecdotal evidence from observing taekwondo and boxing matches reveals that performers have a diverse range of striking actions, and some of these actions are more likely at certain interpersonal distances. Hirstovski et al (2006b) explored this by manipulating the distance between a boxer and their target. The aim of the study was to examine how IPD constrains striking behaviour by observing the type of striking actions that emerged and decayed as IPD was gradually manipulated (Hristovski et al., 2006b). Fighters revealed an affordance based control of behaviour as the individual constraints of the boxer (i.e. limb length and perceived striking efficiency) interacted with IPD to constrain the emergence of striking actions. The boxers showed sensitivity to small changes in distance, with the sudden emergence and decay of different striking affordances occurring as the distance was subtly changed (Hristovski et al., 2006b). Strong correlations between the occurrence of action patterns and the perceptual judgments of their efficiency suggest that a strikers' field of affordances is highly sensitive to the perception of punching efficiency. For example, the jab technique only emerged at larger IPD when the striker perceived it to be an efficient movement pattern. Alternatively, the uppercut technique was only observed at closer IPD. Results aligned with the theoretical modelling by Dietch et al (2006) that hypothesized IPD was a function of weapon (or limb) length and individual variability (i.e. decision making, psychological factors such as perceived efficiency). The results also highlight that body-scaled individual constraints (in this instance, limb length) are a strong predictor of movement behaviour in striking combat sports. We would hypothesize that similar results would be found in taekwondo. However, because performers mostly strike through kicking actions, as opposed to the punching actions investigated by Hristovski et al (2006b), it is unknown to what extent these results could be generalized to taekwondo.

However, the study by Hristovski et al (2006b) does come with some limitations as the target was a punching bag that did not move or strike back. Further, the degree of threat an opponent poses a key task constraint, a variable that was also missing from the Hristovski (2006b) study (Hristovski et al., 2009). Given that performance interpreted through the lens of ecological dynamics is based on adapting and utilizing critical sources of environmental information, such as advanced kinematic information from an opponent, the striking behaviour in this task might not represent that of a competitive fight (Araújo et al., 2006; Pinder et al., 2011b). The removal of key informational and affective constraints which might usually constrain decision making, such as a live fighter and/or the motivation to avoid being struck, casts further doubt as to whether behaviour captured in this task would correspond to a competitive fight (Nieuwenhuys & Oudejans, 2010). Insight can be gained from previous work investigating handgun shooting behaviour in police officers (Nieuwenhuys et al., 2012b; Nieuwenhuys & Oudejans, 2010; Renden et al., 2014). When police officers participated in a shooting exercise with a threatening opponent who occasionally shot back, their movement behaviour was different compared to when they completed the exercise against a non-threatening opponent (Nieuwenhuys & Oudejans, 2010).

2.5.2 Current practice tasks in striking combat sports

A common practice activity in striking combat sports is striking a bag and/or pad. Such an activity does not satisfy principles of representative design where learners need to become attuned to the relevant properties of the environment that produce unique patterns of informational flow (in this instance optic information from an opponent's body) (Michaels & Jacobs, 2007). Such flow sources act as invariant information that constrains decision making, such as whether to attack and punch type selection. Data from taekwondo competition reveals that taekwondo players are engaged in fighting only ~18% of total fight time, therefore, a large remainder of time is spent searching for moments that afford attacking (Heller et al., 1998; Okumura et al., 2017). Therefore, being attuned to the information that affords engagement could be a competitive advantage for fighters.

Previous work exploring attacks in one-on-one opponent tasks revealed performers are sensitive to the posture of their opponent and the attacking opportunities that posture provides (Esteves et al., 2011). Esteves and colleagues manipulated the posture of defenders in a one-on-one basketball task and found that postural kinematics constrained the decision making of attackers and the direction they chose to attack. Therefore, in the combat sports it is likely that combat athletes perceive some postures of their opponent as more favourable to attack than others (Carello et al., 1989). This aligns with other work that reveals individuals can be sensitive to the affordances of others (Fajen et al., 2009; Stoffregen et al., 1999). It is during practice that athletes should learn to couple their movements to these critical information sources and whether they afford attacking. Because of the time constraints on action in taekwondo, athletes must narrow down the minimal information required to regulate their movements from the enormous amount of available information in the performance environment. Practicing by striking punching bags or pads is unlikely to help develop such attributes.

The degree of threat an opponent poses is a key control parameter that shapes the probability of attacking behaviour and therefore requires consideration in the design of combat sport practice and research tasks. Manipulating the level of perceived threat leads to changes in players motivation to avoid being struck which in turn is associated with spontaneous shifts towards different attacking and defensive strategies (Hristovski et al., 2009). This was evident in a further study by Hristovski et al (2009) where the affective demands of a 'tag' game were manipulated. When performers perceived little threat, they were most attracted towards attacking modes. However, when they were asked to imagine their opponent with a sharp object, their behaviour predominantly switched towards defensive action modes. This study reveals that affect influences how combat athletes perceive and realise affordances from the surrounding landscape. Whilst fighting in training may satisfy principles of representative learning design (predicated on performance against a live opponent), it may not afford opportunities for athletes to practice under the same affective constraints as competition fights, where performers may be unfamiliar, more aggressive, and of higher skill. However, in the previously mentioned study performers were only asked to imagine the threat. At the beginning of this research programme no studies had yet examined interpersonal coordination in any striking combat sport under ecological constraints that include a live opponent and a the threat of getting struck. Therefore, the usefulness of common practice tasks such as striking a static bag and fighting under reduced affective demands, and how they might correspond to behaviour in completion is not well understood.

The first examination of combat athletes' behavioural dynamics in a competitive fight was conducted in a study of kendo athletes (Okumura et al., 2017). Kendo is a one on one combat sport where players aim to strike each other with sticks. In this study, the movement trajectories of kendo athletes were tracked across the duration of multiple fights. The results confirmed the earlier conceptual hypothesizing by Dietrich et al. (2010) and revealed two specific IPD attractors that players were drawn toward – near and far distances. Each of these distances represented stable behavioural states and were achieved only by a perturbation instigated by an attacker that would lead to a transition to the other state. The findings reflect the fighter-fighter system self-organising to satisfy the contrasting goals of the task: strike without getting struck. At near interpersonal distances, fighters are afforded striking opportunities (satisfying attacking task goals), whilst larger distances contain no striking affordances (satisfying defensive task goals) (Hristovski et al., 2006a, 2006b, 2011). However, the IPD players were attracted towards under kendo task constraints differed substantially from the boxing work of Hirstovski et al. (2006b) where boxers were generally much closer. The discrepancy between these results is perhaps due to kendo athletes using sticks, however, it mostly highlights the need to study coordination tendencies under the unique constraints of each task.

In summary, IPD is a collective variable capable of capturing the order of a fighter-fighter dyadic system in the combat sports. However, only a small number of studies have explored this measure. The generalization of this work has limitations due to the representativeness of the designs, and the variety of sports used (i.e. boxing, tag and kendo). Given behaviour is likely adapted to the specific constraints of a given sport, it is difficult to adapt these findings to other sports such as taekwondo. Further, many of these studies have neglected to capture cognitive and affective insights. Given the demanding affective nature of combat sports where performers can get punched and/or kicked in the face, it is likely affective measures could provide interesting insights. Presently, how IPD is influenced by individual dynamics such as emotions, cognitions and sociological factors is unknown. Further, understanding how coordination tendencies change in different practice tasks relative to competition could provide useful insights to coaches and practitioners.

One of the other common practice tasks, which on face value seems to satisfy principles of representative design, is fighting an opponent (Hodges, 1995). Fighting is perceived to be the most useful practice activity for expert combat athletes; therefore the way athletes spend their time in these sessions is critical (Hodges, 1995). While this activity samples informational constraints of competition, whether this activity represents the affective constraints and demands of the competition task, is unlikely. For example, a naturalistic study of judo athletes in their training environments revealed socio-cultural constraints acting upon players (Gernigon & Arripe-longueville, 2004). The qualitative findings of Gernigon & Arripe-longueville (2004) revealed that players reduced their intensity at certain times to reduce the difficulty for their opponent and so they could pace themselves through a long training session. An example of the potential discrepancies in combat training and competition was provided in a physiological comparison between training and competition environments in taekwondo. In this study training protocols alone were not able re-create the physiological stress of competition (Bridge et al., 2013). Researchers advocated for strategies designed to increase the representativeness of training environments, and highlight an important consideration for practitioners and scientists: how to re-create competition stressors in training environment. Despite this evidence and the increased advocacy for representative design, combat athletes regularly practice in environments that are ill representative of the competition environment. During competition, participants regularly contend with competition specific constraints such as a scoreboard, anxiety, aggressive opponents, crowds, unknown opponents, consequences and expectations (Wilson et al., 2007a).

Research exploring interpersonal coordination in live combat sport tasks featuring two active fighters is relatively scarce and understanding how these constraints interact to shape emergent attacking behaviour in taekwondo is non-existent. Research in taekwondo has tended to focus mainly on notational analysis of performance, such as the number of attacks and counter-attacks (Falco, Estevan, Alvarez, Morales-Sánchez, & Hernández-Mendo, 2014). This organism centric focus has limited our understanding of the role of the environment (and opponent) in shaping behaviour (Davids & Araújo, 2010). Therefore, we have highlighted several gaps in the combat sport literature. Namely, a lack of understanding around how taekwondo players coordinate their behaviour, and how this behaviour differs under different affective, cognitive and task constraints in practice relative to competition.

2.6 SUMMARY

The previous sections have discussed the role of representative learning design in sports practice and argued for the design of ecological practice environments. Emerging from principles that have their origins in dynamic systems and ecological psychology, an ecological dynamics approach has been advocated to represent the theoretical underpinnings of this PhD programme. The benefits of this approach is that is considers the performer and the environment as the key consideration and level of analysis for practice and research respectively.

Through investigation of the human-environment interaction within a practical setting like the taekwondo, ecological dynamics facilitates understanding of several key concepts underpinning expert performance: the individual's sensitivity to informational properties of their environment, the action responses afforded and the constraints on behaviour then shaping their emergence (Davids et al., 2013a). Therefore, this approach to understanding human behaviour is a sensitive means of identifying differences in performer-competition and performer-training environment interactions, and the success of the to-be proposed training intervention.

These discussions highlight research directions that are to be explored in this PhD thesis. Several gaps in the literature have been identified, revealing 1) the need to explore how the presence (of absence) of a live opponent who can move and strike back constrains emergent decision making of combat athletes, 2) the focus on sampling information to design representative learning environments has overlooked other constraints required to design truly representative learning tasks, such as the affective-cognitive demands of learning tasks, and 3) the need to explore means to enhance the affective demands of practice environments and test the hypothesis that situational information could be a useful way to do so . With these gaps identified, it is proposed that the design of representative learning tasks could be enhanced by considering affect and cognition.

BRIDGING STATEMENT A

A theoretical and empirical case was made that behaviour can only be captured in tasks that are representatively designed. Examples were provided that highlighted the importance of sampling information from performance environments to ensure behaviour corresponds between practice and/or experimental tasks and the performance environment. However, many combat sport practice tasks and studies adopt designs that consist of static targets that either lack the kinematic information and/or affective demands of an opponent who can strike back (e.g. Hristovski et al., 2006b, 2011; Milazzo et al., 2016; Pozo et al., 2011). Finally, it is important for the following Stages of this PhD programme that a variable capable of capturing individual fighter-fighter system behaviour in taekwondo is confirmed. A candidate order parameter is interpersonal distance, the distance between two fighters. This Chapter has two aims (1) explore how the presence (or absence) of a competitive opponent who can strike back affects the action selection of taekwondo player, and (2) to examine IPD is an order parameter that captures the state of a taekwondo fighter-fighter system. We do this by using measures of IPD to capture and compare the action selection of skilled taekwondo fighters in a common practice and research task – striking a static bag – to a competitive fight. The findings of this study form the theoretical and methodological foundations of the experimental Chapters that follow.

3 INFORMATION FOR REGULATING ACTION SELECTION IN TAEKWONDO: BEHAVIOURAL CORRESPONDENCE BETWEEN STATIC AND DYNAMIC OPPONENT CONSTRAINTS

3.1 ABSTRACT

There is growing interest in understanding the usefulness of practice tasks in sport and whether behaviour in these tasks corresponds to competition. In the combat sports, athletes commonly practice with bags or pads; activities that lack the threat and kinematic information of a competitive opponent who can move and strike back. This two part study explored the behavioural correspondence of taekwondo athletes kicking a static bag (study one) versus a live fight (study two). This was achieved by examining athlete's decision making behaviour relative to interpersonal distance (IPD) scaled to a percentage of limb length in both tasks.

The results revealed that when striking a bag taekwondo athletes organised their behaviour according to scaled distance to target. Study one identified several critical decision making regions: 1) IPD > 168 % of limb length where attacking behaviour decayed and no kicks were afforded, and 2) IPD 40 – 100 % of limb length where large amounts of action flexibility and unpredictability existed. The results of study two revealed that in a live fight taekwondo athletes form a dyadic fighter-fighter system that organises according the constraints of an opponent. Fighters were attracted to scaled IPD range 181 – 195 % of limb length, a region identified in study one as not affording attacking behaviour. In the live fight, however, it was from this region that fighters preferred to attack from. They did this by transitioning from far to near IPD, attracted to the scaled IPD region 76 – 90% of limb length identified in study one as affording great amounts of action flexibility.

The results of studies 1 and 2 reveal that the presence of a live opponent alters the attacking behaviour of taekwondo players. Together, these findings reveal that performers are sensitive to the threat and action capabilities of their opponent and use this information to guide behaviour. Therefore, practicing in the absence of the threat and kinematics provided by a live opponent has low behavioural correspondence to a live fight.

3.2 INTRODUCTION

An underpinning principle of the ecological dynamics approach to understanding human behaviour is ensuring the constraints of performance environments are adequately represented in practice tasks (Pinder et al., 2011b; Vilar et al., 2012a, 2012b). This approach calls for practitioners to consider the representativeness of the information and action responses in practice tasks, and whether behaviour corresponds to a given sport context (Araújo & Davids, 2015; Barris et al., 2014; Pinder et al., 2011a). This is a pertinent issue in the combat sports, as besides actual fighting, some of the most common practice tasks involve striking a static bag or pad. A major concern with using these targets is that they do not represent the task constraints of the performance setting where the target is moving and can strike back, consequently bringing into question the correspondence of behaviour from these tasks to a live fight (Araújo & Davids, 2015). This research aims to explore this issue with a two-study paper examining taekwondo players' behaviour in two different tasks: a static target kicking task and a competitive fight.

Research highlights that the basis of skilled performance in sport is coordinating and adapting behaviour to the surrounding environment (Davids & Araújo, 2010; Fajen & Warren, 2003). In one-on-one sporting tasks like combat sports, performers coordinate their behaviour forming a dyadic system that self-organises within the boundaries created by task specific constraints (Cordovil et al., 2009b; Hristovski et al., 2009; Orth et al., 2014). This premise has important implications for learning designers such as coaches. From an expertise development perspective, learning involves attunement to the usefulness of environmental information and coupling this with specific action responses (Mann et al., 2010; Michaels & Jacobs, 2007). The implications for practice are that practitioners must identify and sample the information from the performance environment to design representative learning tasks (Gorman & Maloney, 2016; Pinder et al., 2011b).

Despite this implication, it is not uncommon during skill learning for practitioners to reduce the demands of a given task by removing key aspects (Davids et al., 2001; Magill, 2007; Wilson et al., 2009a). Practicing part of a skill in isolation has been a means to reduce the difficulty to facilitate learning of more complex skills (Magill, 2007). While well intentioned, removing key aspects of tasks in practice, like a an opponent or teammate, can lead to behaviours that do not necessarily represent those observed under ecological constraints (Davids et al., 2001; Gorman & Maloney, 2016; Travassos et al., 2012). Some studies have explored how removing opponents influence the representativeness of action responses in certain sporting tasks (Gorman & Maloney, 2016). For example, when practicing basketball shooting in the absence of a defender, players displayed decreases in movement timing variability, which reflected the absence of any need to coordinate behaviour with an opponent (Gorman & Maloney, 2016).

The information provided by an opponent is a key constraint of combat sport. The kinematic information is used by performers when making decisions, whilst the interpersonal distance (IPD) between the performer and their target constrains the type of action responses afforded (Dietrich et al., 2010; Hristovski et al., 2006b; Milazzo et al., 2016). One study investigated the decision making performance of karate athletes and found that skilled karate athletes are more accurate and faster than lesser skilled counterparts at blocking, counterattacking and picking up attacking trends of an opponent (Milazzo et al.,, 2016). Another study explored how the distance between a striker and their target constrained action selection in a boxing context. The study provided important insight as to how the IPD between performers and their target provides key perceptual information critical for regulating action selection (Dietrich et al., 2010; Hristovski et al., 2006b). Different striking techniques emerged and decayed based on the interaction of how far (or close) strikers stood from their target (Hristovski et al., 2006b). The results of both of these studies highlight how combat opponents provide specifying information useful for regulating the control of action, and have important implications for combat practice: task must sample opponent constraints from competition.

The study by Hirstovski et al (2006) also highlighted the potential advantage attacking combat athletes could attain by standing at a certain IPD. Of particular interest is the result revealing that at a critical IPD (60% of limb length) the boxers in this study were able to flexibly switch between many different techniques (jabs, uppercuts and hooks) to deliver functional outcomes. Standing at this IPD in a fight would provide the most uncertainty for opponents as they are *punchable* in degenerate ways. Given the dynamic nature of sporting tasks, this flexibility is an important component of expertise (Komar et al., 2015). Being tightly attuned to the affordances of a performance environment and hence having access to a variety of action responses for a given context is a feature of expertise and indicative of the grip experts have on their environment (Bruineberg & Rietveld, 2014; Seifert et al., 2016). Theorists have hypothesized that skilled performers are drawn to these regions where flexible behaviour is possible due to the rich number of action modes they afford (Bruineberg & Rietveld, 2014). However, this has yet to be empirically tested in more dynamic environments like a competitive fight.

However, the combat studies detailed in the previous paragraphs have some limitations which may limit the generalizability of their findings. In the work by Hirstovski et al (2006) and Milazzo, 2016), performers either did not have any threat of being hit, or were only able to be lightly tapped (as per karate constraints). Additionally, the generalizability of Hirstovski et al. (2006) is further limited through the use of non-representative static targets that could not move or strike back. A key finding was how boxers' emergent behaviour is shaped by the interaction of action capabilities and the physical environment. By neglecting to sample an important feature of the environment – a live opponent – it is likely that the striking actions observed in this study do not represent those in a live fight. The threat of being struck by an opponent may be a key constraint on IPD (Hristovski et al., 2009). This constraint is likely to change cognitions and emotions, which have been shown to influence perceptions and actions (Headrick et al., 2015; Hristovski et al., 2009).

Very few studies have adopted more representative experimental designs to explore the coordination tendencies of fighter-fighter systems (Okumura et al., 2012, 2017). Okumura et al. (2017) used a kendo task to provide some insight about interpersonal coordination tendencies when opponents can strike back. In line with Hristovski et al (2006), the kendo fighter-fighter system organised according to IPD. However, the findings also revealed that a kendo fighter-fighter system is strongly attracted to IPD where they could not be struck, and spent much of their fight time in this region. Fighters transitioned to 'strikeable' IPD only when an attacking opportunity was afforded. The findings may reflect the fighter-fighter organising to satisfy the contrasting goals of the task: strike without getting struck. They also highlight a key decision fighters must make that previous studies have not yet revealed: deciding when to transition from far to near distances for an attack.

However, comparing these results in kendo and boxing reveals divergent results. The reported IPD that kendo athletes strike at in a competitive fight does not align with the IPD that boxers strike a static target (Hristovski et al., 2006; Okumura et al., 2017). The kendo athletes made the decision to attack from a much greater IPD than observed with the novice boxers. Whether this discrepancy is a result of unique striking constraints (striking with hands in boxing verses striking with sticks in kendo) or the differences in the target they were striking (a static bag in boxing versus a competitive opponent in kendo) is unknown.

Whether action selection when striking a static non-threatening target is representative of the action selection observed when striking an opponent in a real fight is an important question for combat practice designers. This research explored this question using taekwondo as a task vehicle with two inter-connected studies. The first study replicated Hristovski et al's. (2006) work where skilled taekwondo athletes' decision making relative to IPD was explored by recording the emergence and decay of kicking techniques as athletes struck a static target at progressive IPD using kicking instead of punching actions. The second study assessed the decision making relative to IPD of skilled taekwondo athletes during competitive fights. Finally, we discuss behavioural correspondence between the two studies and implications for research and practice.

3.3 Study One

The aim of this study was to examine the decision making of taekwondo players by observing their action selection at various interpersonal distances while striking a static target. We explored this aim by manipulating the distance between taekwondo athletes and a static target as they performed kicking actions. We hypothesized that, consistent with the work of Hristovski et al. (2006) in boxing, that the emergence of kicking techniques would be constrained by IPD scaled to each individuals limb length and each kicking techniques perceived efficiency.

3.3.1 Materials and methods

The protocol was approved by the institutional Human Research Ethics Committee of the first author. All participants provided written informed consent prior to the commencement of the study in accordance with the Declaration of Helsinki.

Participants

Ten skilled taekwondo players (5 female, 5 male) participated in this study. The average age of participants was 17 years (SD = 1 year). The participants were members of a national squad that included athletes who had placed in the top three at national championships within their weight category and age group.

Task and apparatus

Participants were asked to kick a human-shaped soft mannequin placed at pre-determined interpersonal distances (Figure 3.1). The mannequin was 1.68 m in height and was positioned with its chest facing participants. Interpersonal distance markers were placed on the ground at progressive 0.15 m increments away from the mannequin. The first distance marker was set at 0.00 m and corresponded to the mannequin's feet; the final distance marker was placed at 1.90 m.

Before each kicking action, participants were asked to stand in a parallel stance with their preferred leg forward facing the mannequin from a side-on position. Participants were allowed to gaze at the target for a short amount of time before commencing their kicking action. When kicking, the non-kicking support leg had to remain planted in-line with the distance marker. Balance was to be maintained and after completing each kick participants were asked to return to their parallel stance with two feet on the ground. If any of these instructional constraints were violated participants were asked to repeat the attempt. After completing 30 kicks at each interpersonal distance participants were asked to rate the efficiency of each kicking action using a Likert scale (Hristovski et al., 2006b). A digital video camera (Sony HXR-NX30P) was used to capture kicking actions for the purpose of retrospective coding. The camera recorded at 25 Hz and was placed in line with the corresponding distance marker.

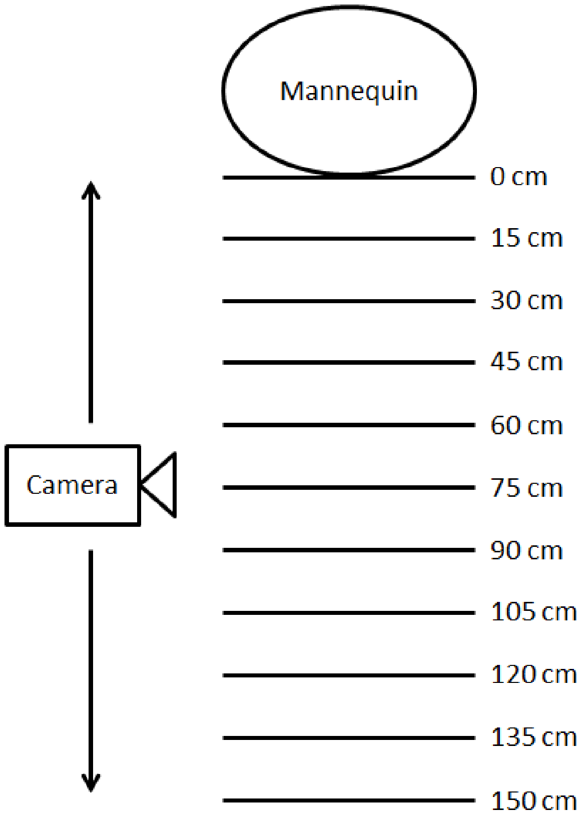

Figure 3.1 View from above the experimental set up. .

Procedure

Upon arrival at the testing hall participants were briefed on the task by the researcher had their leg length measured and were then asked to warm up. Participants then went through a familiarisation protocol that required them to perform 10 kicks under experimental conditions at a near (0.15 m), middle (0.60 m) and far (1.20 m) distance before beginning data collection. To prevent order effects, five participants began the experiment from the maximum 1.90 m distance marker with each successive kick progressively nearer to the target. The remaining five began at the first 0.00 m distance marker and progressively moved away from the target. Maximum kicking distance was determined by the point at which participants reached a critical IPD where they were not able to kick whilst satisfying the instructional constraints. Participants were tested individually and each testing session lasted approximately 20 minutes. Participants were given no instructions about how to kick the mannequin and they were allowed to make contact with the mannequin at any location (Hristovski et al., 2006).

Measures

Kicking techniques

The type of kicks were operationally defined with the help of two national level coaches and a coaching textbook (Park & Seabourne, 1997).

Vertical striking action (included front, axe and crescent kicks): strikes with a predominantly vertical kicking action. The kicking leg is raised in a vertical fashion and contact is made with the sole of the foot.

Side/cut striking action- The leg is raised with the knee flexed so the medial aspect of the knee is parallel to the floor and the kicker then uses a horizontal pushing action during knee extension so contact is made with the sole of the foot.

Turning striking action – The leg is raised with the knee flexed so the medial aspect of the knee is parallel to the floor and the kicker uses the support leg to pivot and extend their knee to perform a horizontal striking action in a 'whipping' motion so contact is made with the top of the foot.

Back striking action – where the body pivots 180 degrees on the front leg as the rear leg is raised with the knee flexed. The striking action is performed by extending the hip and the knee and using a pushing motion to make contact sole of the foot.

Hook striking action - The leg is raised with the knee flexed so that the medial aspect of the knee is parallel to the floor, the knee is then extended before a hooking action occurs through knee flexion and contact is made with the sole of the foot.

Unconventional striking action – A kicking action unable to be operationally defined: usually in close where no proper technique is possible.

The striking actions were categorised retrospectively using the video data.

Perceived kicking technique efficiency

A continuous Likert scale was used to measure perception of technique efficiency (Hristovski et al., 2006). The scale consists of six points (0-5) and two anchors; zero reflected no kick, and five reflected a maximally efficient kicking action.

Leg length

Leg length was measured according to International Society of Advanced Kinanthropometry (ISAK) standards to allow IPD to be scaled relative to each individual's limb length.

Quantitative analysis

Kicking technique interpersonal distance

Kicking technique emergence was assessed as the smallest IPD at which kicking technique was observed. Kicking technique decay was assessed as the largest IPD at which the kicking technique was observed. A two (IPD: kicking technique emergence and kicking technique decay) * five (technique: unconventional, hook, vertical back, turning and side) repeated measures ANOVA was conducted to assess for differences in the scaled IPD that each kicking technique emerged and decayed at. Alpha was set at .05 and any violations of the assumption of sphericity were corrected using the Greenhouse-Geisser method. Any significant main effects or interactions were followed up using post hoc pairwise comparisons with a Bonferonni corrected alpha. Effect sizes were calculated using partial eta squared (η^2p) for omnibus comparisons, and Cohens d for post hoc comparisons.

Relationship between the probably of kicking technique and perceived kicking technique efficiency

A Pearson's correlation was used to analyse the association between the average probability of kicking techniques and their averaged perceived efficiency at each scaled IPD.

The probability of techniques was calculated by dividing the number of times a technique was performed at a given distance by the number of striking actions (30) at that distance (Hristovski et al., 2006). This was a means to assess the degree of attraction to the different kicking techniques at each scaled IPD.

The average efficiencies across participants for each kicking technique were calculated for each scaled IPD using the likert scale scores.

Kicking technique predictability

The (un)predictability of kicking techniques at each IPD was assessed through Shannon's information entropy. This measure was consistent with the study by the study by Hirstovski et al. (2006).

3.3.2 Results

Kicking technique interpersonal distance

Results of IPD x technique repeated measures ANOVA revealed a significant main effect for IPD, $F(1, 9) = 963.114$, $p = .000$, $\eta^2p = .991$; a significant main effect for technique, $F(2.574, 23.163) = 41.717$, $p = .000$, $\eta^2p = .823$; and a significant interaction between technique and IPD, $F(5, 45) = 13.069$, $p = .003$, $\eta^2p = .592$.

Post hoc pairwise comparisons of IPD indicated the mean IPD that kicking actions emerged (M = 19.03 %, 95 % CI: [14.27, 23.33]) was significantly less than the IPD that kicking actions decayed (M = 111.51 %, 95% CI: [104.57, 118.45], d = 3.31).

Post hoc comparisons of technique indicated that the IPD of techniques was equivocal. Results can be found in Table 3.1. Hook, vertical and back techniques all had similar IPD lifespans which was indicated by the lack of statistical differences between them. However, the unconventional and side techniques had unique lifespans. Significant differences were observed in comparisons between unconventional technique and all other techniques; while significant differences were observed between side technique and unconventional, hook and vertical techniques. Further, there was no technique possible at scaled distances greater than 168% of limb length.

Technique comparison		Mean difference	SE	t	p_{bonf}	95% CI Lower	95% CI Upper
Unconventional	Hook	-36.38	7.97	-4.562	0.003*	-51.39	-21.36
	Vertical	-39.98	8.53	-4.683	0.002*	-54.99	-24.97
	Back	-42.50	7.55	-5.623	< .001*	-57.51	-27.48
	Turning	-51.76	7.48	-6.92	< .001*	-66.77	-36.7
	Side	-69.85	6.13	-11.38	< .001*	-84.86	-54.83
Hook	Vertical	-3.60	4.62	-0.779	1	-18.61	11.40
	Back	-6.12	5.16	-1.186	1	-21.13	8.89
	Turning	-15.38	3.74	-4.109	0.009*	-30.39	-0.36
	Side	-33.46	4.57	-7.31	< .001*	-48.48	-18.45
Vertical	Back	-2.51	4.01	-0.627	1	-17.52	12.49
	Turning	-11.77	3.00	-3.92	0.014*	-26.78	3.23
	Side	-29.86	5.75	-5.194	< .001*	-44.87	-14.85
Back	Turning	-9.26	3.78	-2.448	0.363	-24.27	5.75
	Side	-27.34	6.28	-4.351	0.005*	-42.36	-12.33
Turning	Side	-18.08	5.37	-3.367	0.049*	-33.10	-3.07

*Table 3.1 Post hoc comparisons of average IPD for each technique. All data is presented as a percentage of limb length. * denotes a statistically significant difference.*

Relationship between the probably of kicking technique and perceived kicking technique efficiency

Pearson's correlation revealed significant associations between the probability of kicking technique (Figure 3.2) and average perceived kicking efficiency (Figure 3.3) for the following kicks: unconventional, r = .824, p = .003; turning, r = .978, p = .000; hook, r = .751, p = .012; vertical, r = .946, p = .000; and back, r = .918, p = .000. The only kick that did not have a significant association was side, r = .365, p = .300.

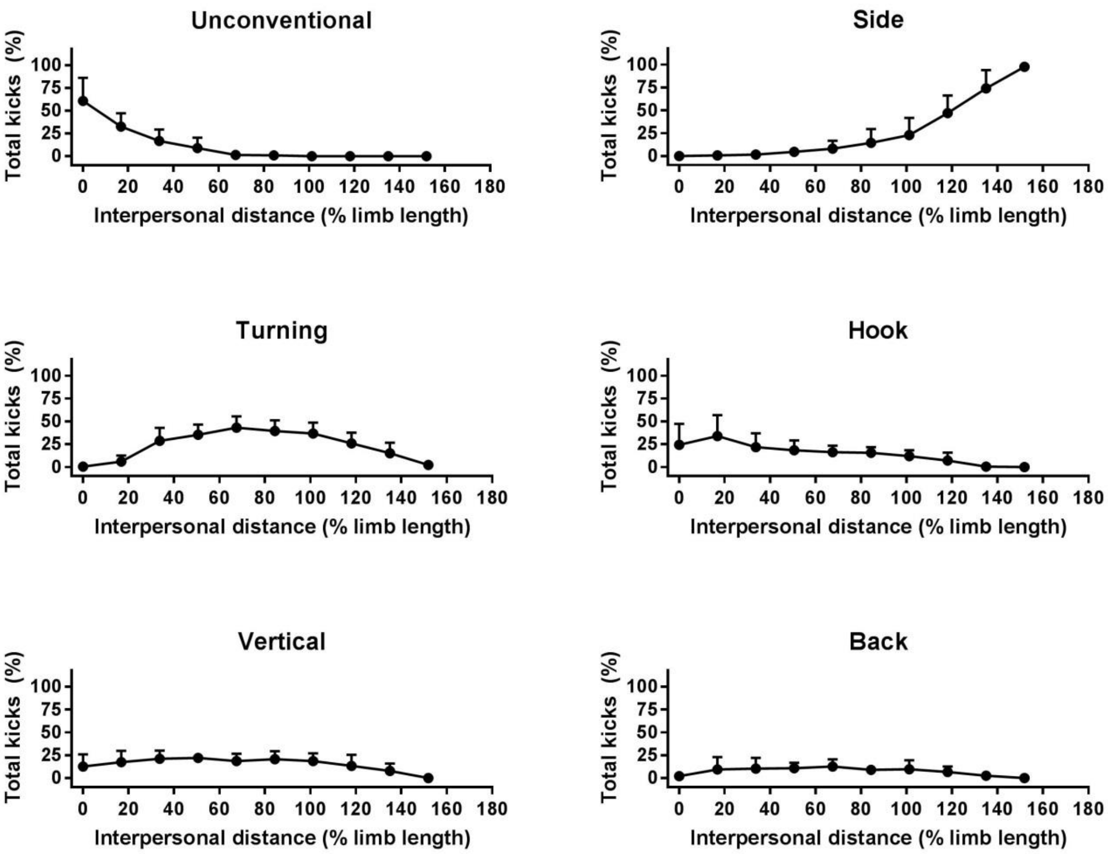

Figure 3.2 Probability of occurrence of each kicking technique as a function of the scaled IPD

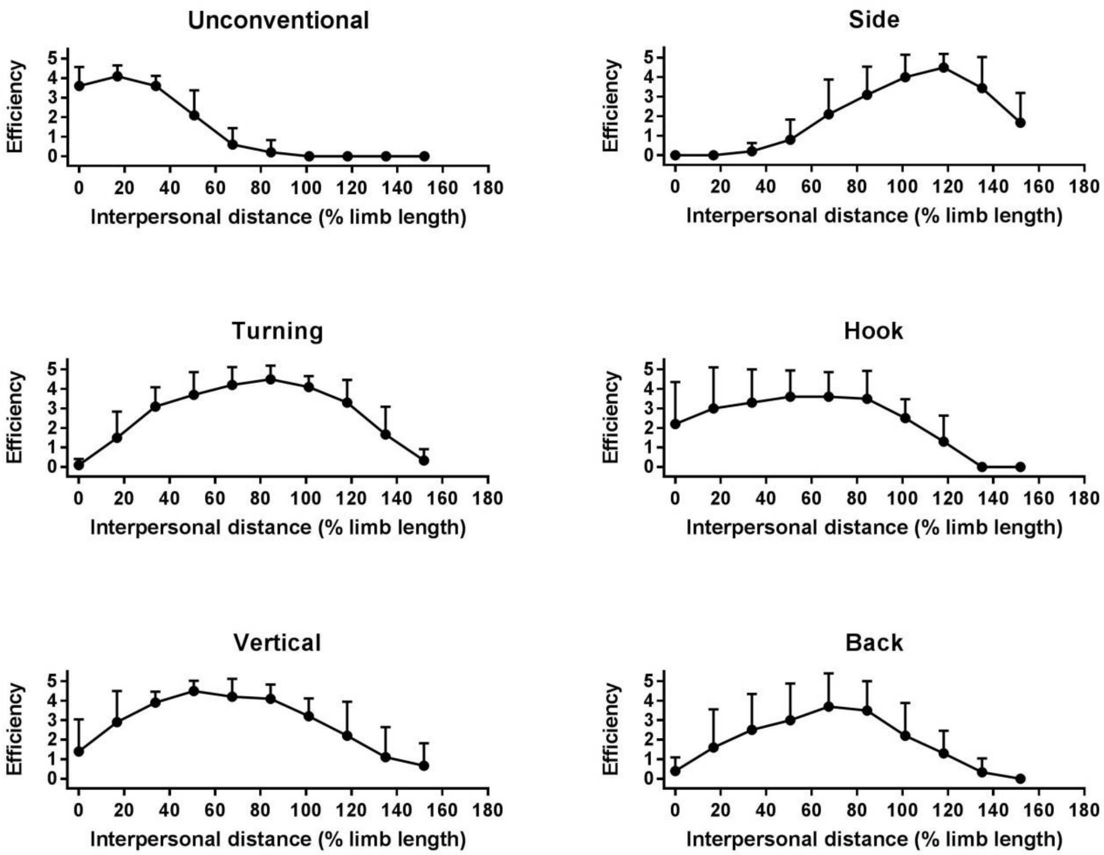

Figure 3.3 Average perceived efficiency of kicking technique as a function of the scaled interpersonal distance.

Kicking technique predictability

Analysis using Shannon's information entropy revealed that kicking technique predictability varied across scaled IPD (Figure 3.4). At near and far scaled IPD technique emergence was the most predictable. No clear peak scaled IPD zone of unpredictability was observed. Instead, the emergence of techniques were the most unpredictable across a large scaled IPD region (40 – 100 % limb length) contained at middle scaled IPD.

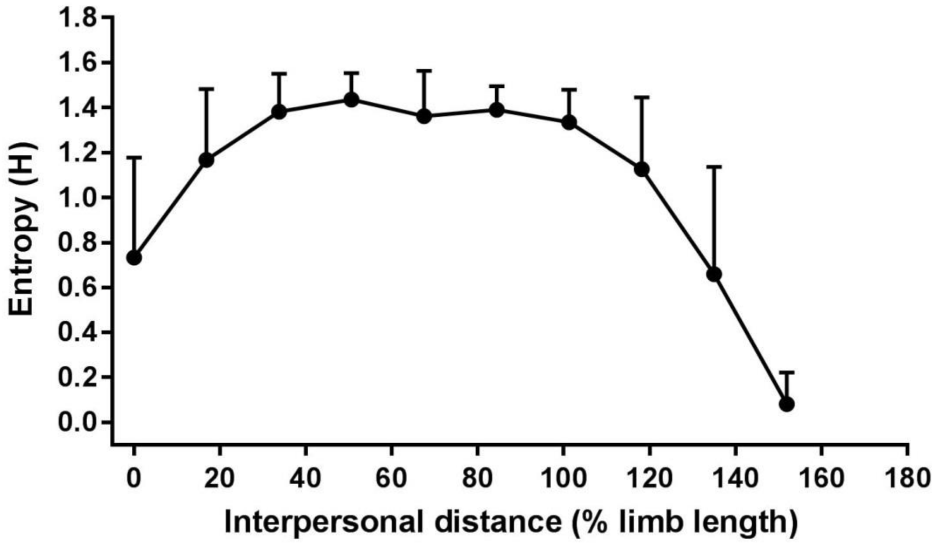

Figure 3.4 Kicking (un)predictability as measured by Shannon's information entropy. Data is presented as a function of the scaled kicker – target distance.

3.3.3 Discussion

In this initial study, we replicated the Hristovski et al. (2006) study of boxers to investigate how decision making in taekwondo is affected by the distance between a taekwondo athlete and their target. To explore this issue we manipulated the distance between taekwondo athletes and a static target as they performed kicking actions. The results revealed that technique selection in taekwondo is a result of an interactional relationship between the performer and the environment. More specifically, our findings aligned with those of Hristovski et al. (2006) and showed that the distance a taekwondo athlete stands from their target and their perceptions of kick efficiency shape the emergence and decay of taekwondo kicking techniques. Compared to Hristovski et al's (2006) findings, our results also reveal that expert taekwondo athletes exhibit unpredictable striking behaviours over a larger scaled IPD region than observed in the study of boxers.

The kicking technique that participants selected emerged from the interaction between performer intrinsic dynamics and the environment. This included the individual constraints of kicker (limb length and perceived technique efficiency) and the IPD between the kicker and their target (environment). As IPD changed, so too did the affordances on offer which was evident in the lifespan of individual kicking techniques. The decision to perform a technique emerged and decayed as kickers selected the most appropriate techniques in order to achieve the task goal (kicking the target with adequate force). For instance, unconventional kicks were observed at small IPD, before decaying at an IPD of 70 % of limb length as the perceived kicking efficiency data revealed the technique was no longer perceived as efficient. The decay of the unconventional kick and the emergence of other striking modes are examples of the performer self-organising to adapt to the available affordances of the environment. By adapting their action modes, performers are able to continue to satisfy the task demands of striking a target with adequate force. Overall, our findings suggests that while a large scaled IPD range affords striking, skilled performers are solicited by the affordances that are most efficient for striking the target. This is further evident in the strong correlations between kicking efficiency and action mode selection.

The results also highlight the greater flexibility of the skilled taekwondo athletes relative to novice boxers. Despite performing the same number of action modes as the novice boxers (six), the skilled taekwondo athletes exhibited metastable behaviour over a greater scaled IPD region. That is, they were not 'locked in' to a specific kicking technique solution at any given IPD, and were instead able to flexibly switch between different kicking techniques. These findings were evident in the four predominant kicking techniques, i.e., the hook, vertical, back, and turning techniques having some probability of occurrence over a wide IPD. The emergence of all four of these action modes corresponded to an increase in kicking unpredictability, as measured by Shannon's entropy. Hirstovski et al. (2006) revealed that at a single scaled IPD of 60 % of limb length, novice boxers exhibited a greater degree of unpredictability than any other IPD region. However, no such clear single peak region was present for the taekwondo athletes in this study. Instead, the taekwondo athletes exhibited a similar amount of unpredictability over a large IPD range (40 – 100% of limb length). Compared to the findings of Hirstovski et al. (2006), these results revealed that skilled taekwondo athletes had greater flexibility in the range of techniques they were able to call upon over a larger IPD. In line with previous work on flexibility and expertise, these results possibly highlight the high degree of flexibility possessed by skilled performers, though this cannot be conclusively stated due to the different task constraints of punching versus kicking (Davids et al., 2003; Fajen & Warren, 2003; Wu & Latash, 2014).

Given the different task constraints between striking a non-threatening static target and striking a competitive opponent, it is unknown whether the decision-making observed in this study is generalizable to a live fight. Previous theorising has suggested that in a competitive fight, fighters would be drawn to the regions of high flexibility due to the large number of action modes available (Bruineberg & Rietveld, 2014; Hristovski et al., 2006b). An interesting question, therefore, is whether the decision making observed when striking a non-threatening static target is representative of the decision making observed in a competitive fight with skilled taekwondo athletes. This question is explored in Study two.

3.4 STUDY TWO

Study two aimed to compare the findings of Study 1 to the decision making behaviours of taekwondo players in a competitive fight. We did this by tracking the movement coordinates of skilled taekwondo players as they competed in competitive training fights in order to understand the IPD between players when, a) the decision was made to attack, and 2) they performed a kicking technique. In line with earlier work in kendo, we predicted that fighters would form a dyadic fighter-fighter system (Okumura et al., 2017). We also predicted that the unique constraints of a live opponent that could strike back would draw the fighter-fighter system to large IPD, outside striking distance. Accordingly, fighters would initiate most of their attacks from outside the reach of their opponent and transition to IPD regions of high flexibility where a large number of action modes are afforded (Hristovski et al., 2006; Okumura et al., 2017).

3.4.1 Materials and methods

Participants

Eleven skilled taekwondo athletes (8 male, 3 female) participated in this study. The average age of participants was 23 years (SD = 4 years). Participants were part of a national squad who had placed in the top 3 in their weight category at the national championships. All participants provided written informed consent prior to the commencement of data collection.

Task and procedure

Participants all competed in one taekwondo fight organised for the purpose of this study. Fights were held in a taekwondo training facility on a competition standard 8.00 m x 8.00 m octagon shaped court. Each fight consisted of three two minute rounds that were officiated by a qualified referee and used the electronic scoring system consisting of instrumented protective shields, helmets and foot socks linked to a digital screen displaying the real time score (Daedo, Gen 2). Participants were allocated into matched pairs of the same gender, skill level and weight category by the national coach. They were not provided with any instructions other than their goal was to win the fight. The interpersonal fighting behaviour of participants was recorded using a digital video camera sampling at 25 Hz (Sony HXR-NX30P). The camera was fixed 4.0 m above ground and orientated at approximately 45 ° to the central point of the court (Bartlett, 2007).

Data processing

After filming, data cleaning took place and all irrelevant footage was deleted (i.e., such as when the referee stopped the match due to injury, or the field of view was interrupted by either the referee or a player that would not allow for a fighter to be accurately digitised). The video data was used for notational analysis of fighters attacking actions and to digitise the location coordinates of players across the duration of their fight.

Notational analysis

Notational analysis was performed using the video recordings of the fight to identify the time point that each attack was initiated and the time point that each kicking action made contact with an opponent. As the camera sampled at 25 Hz, the identified time points were accurate to the nearest 1/25th of a second. Attack initiation was defined as either the time of the first forward movement of an attack, or if the athlete did not move forward, the time at which the foot first left the ground. Kick contact was defined as the time of first point of foot contact with the opponent.

It should be noted that the original intention was to code each type of type of kicking technique that occurred to afford analysis of the distribution of each technique across the range of IPD as in study one. However, only a small sample of kicks were observed, and a large majority of them were the one technique. Many of the techniques did not occur often enough, posing a problem for analysis. For example, vertical kicking techniques averaged less than 5 instances per fight. Therefore, individual technique analysis was not possible. Instead of grouping kicks by techniques, we instead grouped all kicks together under the broad category of attacks..

Player location

Location coordinates were determined through manually tracking players' movement trajectories using digitising software (Kinovea, version 0.8.25). This process provided x and y coordinates for each participant across the duration of their fight. The court was calibrated using the known distances provided by the 1.0 x 1.0 m jigsaw mats that made up the 8.0 x 8.0 m octagon fighting space. Digitising consisted of tracking the centre of mass, i.e., the mid-point between fighters' feet. This point was chosen as past research used a similar technique in tracking individual movement trajectories (Headrick et al., 2012). Accuracy and inter-reliability assessment was performed on the digitising procedure. Measurement accuracy was assessed by digitising 8 known distances within the calibrated space. The error of the measurement was found to be in-line with previous research at 0.02 m. The reliability of the digitising methods was determined by re-digitising one round (two minutes, or 33 %) of a fight. This provided 3000 x and y coordinates for reliability analysis. The reliability between the two sets of x and y coordinates was assessed using an absolute agreement 2-way mixed effects intra class correlation coefficient (ICC) (Headrick et al., 2012). An acceptable degree of reliability was found: the average ICC for x coordinates was 0.994, 95% CI [.994, .995], and the average ICC for y coordinates was 0.997, 95% CI [.994, .998] (Maloney et al., 2018).

Digitised x and y location coordinates were used to calculate the IPD between the two fighters. Interpersonal distance was determined using the x and y coordinates of each fighter and Pythagorean Theorem with the following calculation:

$$IPD = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

Following digitising, IPD was available for each 0.04 second epoch.

Data analysis

Attack initiation interpersonal distance

Attack initiation IPD was analysed by time synching the notational analysis and location coordinate data (Okumura et al., 2017). Descriptive analysis was performed by calculating the relative percentage of total observations that occurred in 15 % scaled IPD regions between 0.00 m and 4.00 m in each condition (Okumura et al., 2017). Data is presented in 15 % limb length ranges to allow comparison to Study one. The first zone was 0.00 – 0.15 % limb length, the next zone 0.16 – 0.30 % limb length, and so forth.

Based on the results of study one which revealed that at 168 % of limb length, no striking actions for any strikers were possible, the data was then split into either in range or out of range for statistical analysis. Therefore, we used the threshold of IPD 168 % of limb length to explore the number of attacks that were initiated either within or outside of this range. The intention of this was to examine the correspondence of results from kicking a static target to kicking a moving target that can strike back.

Kick contact interpersonal distance

Kick contact IPD was analysed by time synching the notational analysis and location coordinate data (Okumura et al., 2017). Kick contact IPD was defined as the IPD at the time of kick contact. As described with the attack initiation IPD, kick contact IPD is presented as the percentage of total kick contacts made in each 15 % scaled limb length IPD region.

Attack behaviour

To understand the interpersonal coordination of the live fighter-fighter system during an attack, we selected all attacks for descriptive analysis. Attack behaviour was presented as changes in IPD across the duration of an attack.

Statistical analysis

Differences between percentages of attacks initiated in range and out of range

A dependent t test was conducted to assess any differences in the percentage of attacks initiated ‘in range’ and ‘out of range’. Effect sizes were calculated using Cohen’s d, with 0.20, 0.50 and 0.80 representing small, moderate, and large effects (Cohen, 1988).

Relationship between IPD frequency and attack initiation IPD

A Pearson's correlation was used to assess the association between IPD frequency - the percentage of fight time participants spent in each IPD region - and attack initiation IPD.

3.4.2 Results

Attack initiation interpersonal distance

The limb scaled IPD region that players initiated most of their attacks from was in the scaled IPD range between 181 - 195 % of limb length (Figure 3.5). More attacks were initiated from 'out of range' (M = 52.73 %, SD = 12.59) compared to 'in range' (M = 47.27 %, SD = 12.59); t(10) = -7.19, p > 0.05, d = 0.43, though there was no statistical difference.

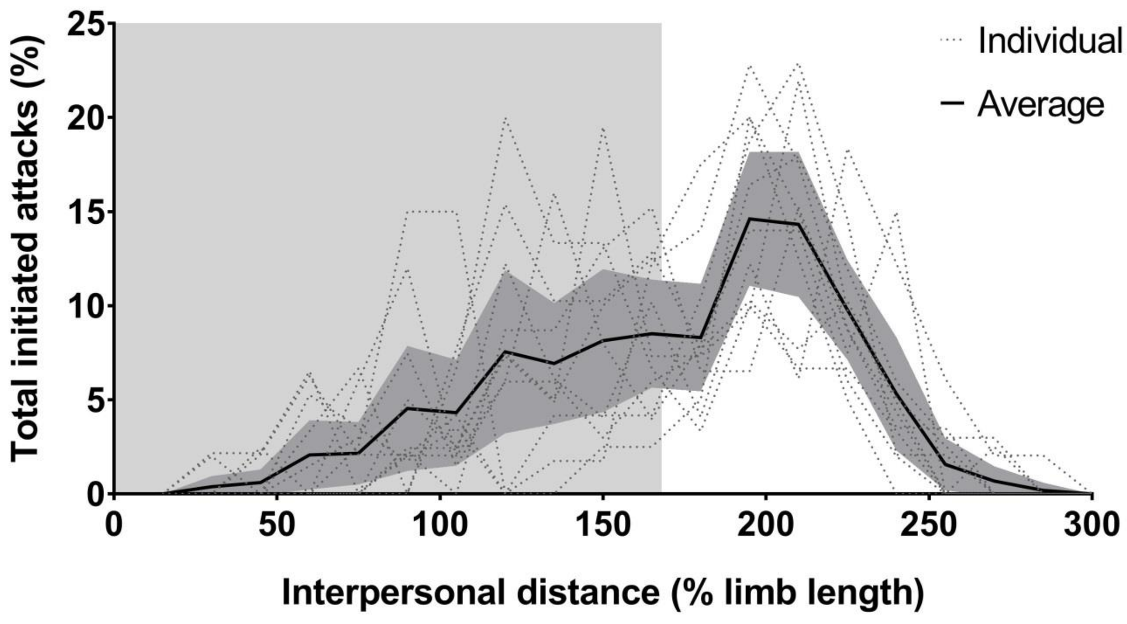

Figure 3.5 Percentage of attacks initiated at each scaled IPD. IPD are presented in 15 % bins. The figure contains the group average with 95 % confidence intervals and the individual results. The grey zone indicates attacks that were initiated 'in range' (≤ 168 % of limb length, as per study one).

Kick contact interpersonal distance

The limb scaled IPD region that players kicks made contact with an opponent was in the scaled IPD bin between 76 - 90 % of limb length (Figure 3.6).

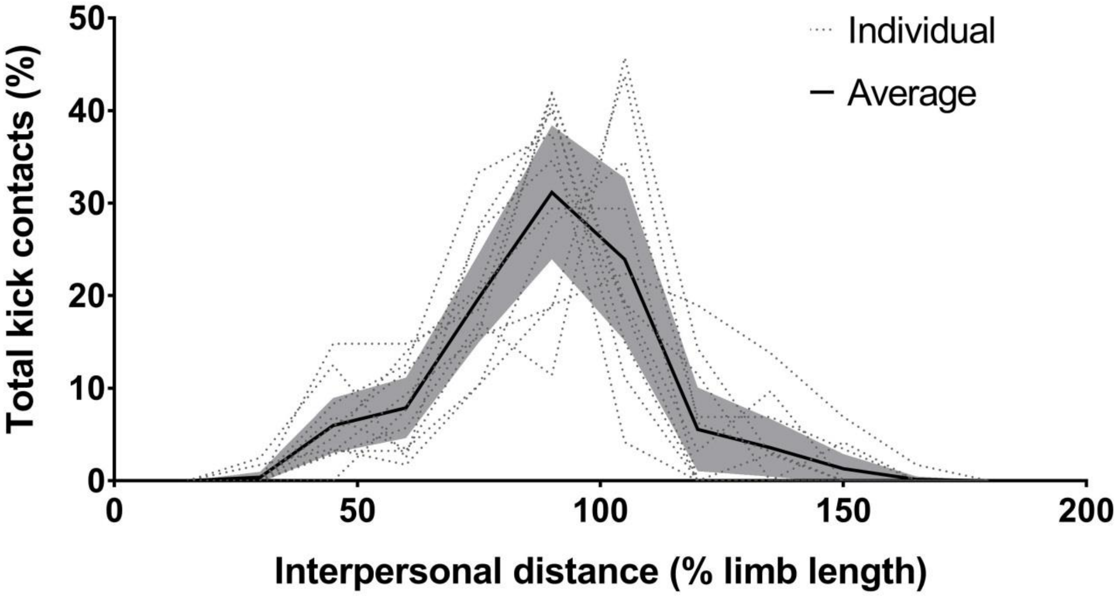

Figure 3.6 Percentage of kicks that made contact at each scaled IPD. Interpersonal distances at presented in 15 % bins. The figure contains the group average with 95 % confidence intervals and the individual results.

Attack behaviour

Descriptive analysis revealed that the fighters form a fighter-fighter dyad that oscillates over time with transitions between far and near distances (Figure 3.7). Descriptive analysis of attacking interpersonal behaviour revealed successful attacks feature a swift transition from far to near distance system states (Figure 3.8).

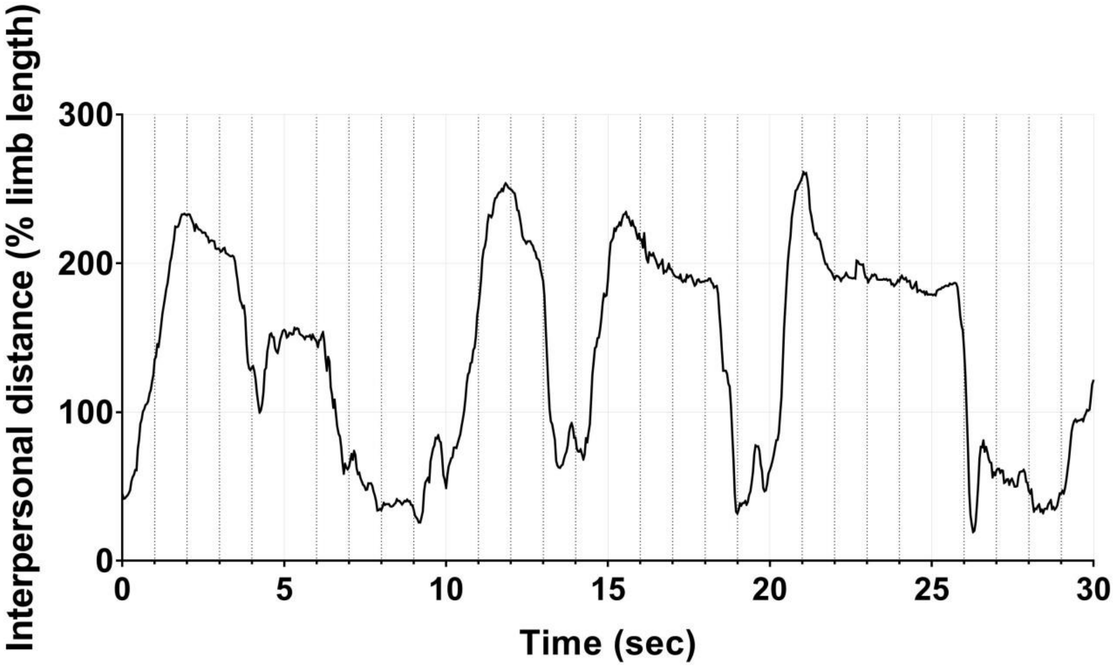

Figure 3.7 Exemplar data of a fighter-fighter dyad. The x axis represents the time in seconds, whilst the y axis represents the IPD between the two fighters.

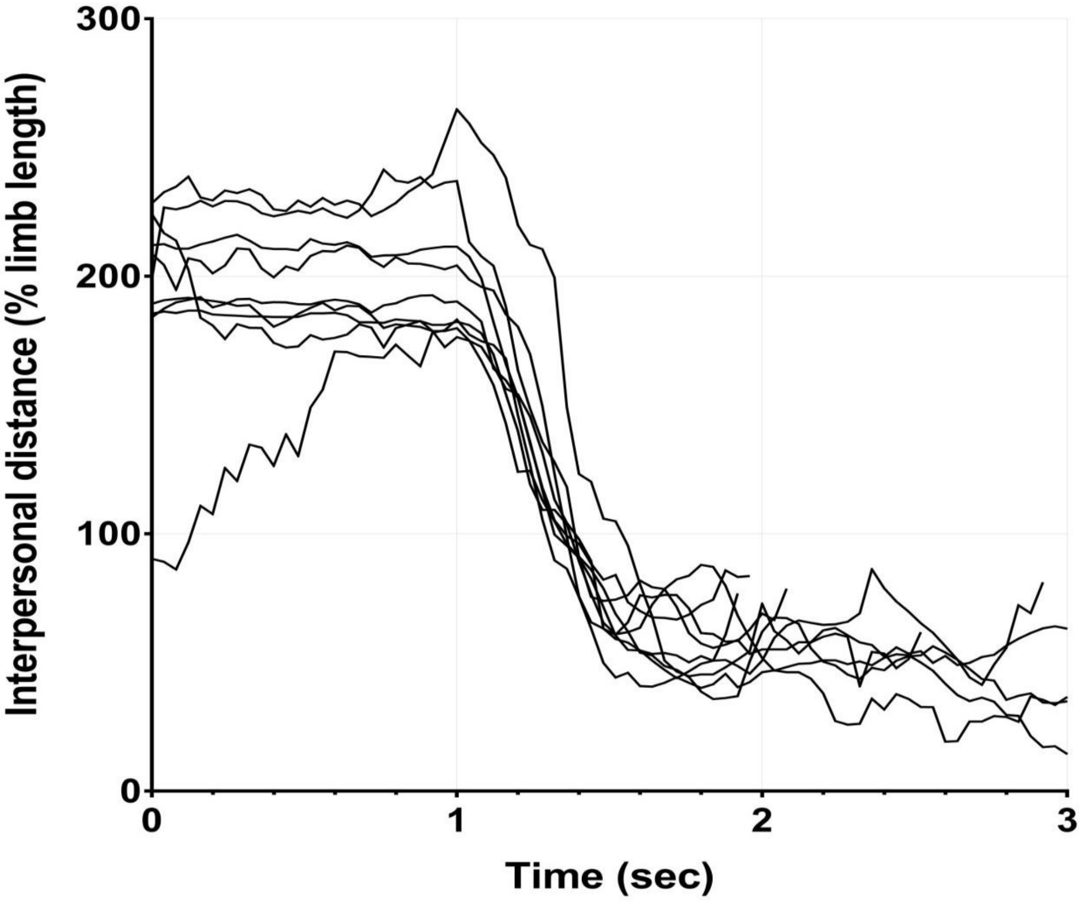

Figure 3.8 Exemplar data of IPD data during an attack. The x axis represents the time in seconds, whilst the y axis represents the IPD between the two fighters.

Relationship between time spent at IPD regions and attack initiation IPD regions

A paired sample correlational analysis between the percentage of time spent at each 0.15m IPD bin (Figure 3.9) and preferred attack initiation IPD revealed a significant association; $r = 0.96$, $p = < 0.05$ (Table 3.2). Within participant results reveal the majority of participants have significant moderate – large associations between preferred IPD and preferred attack initiation IPD.

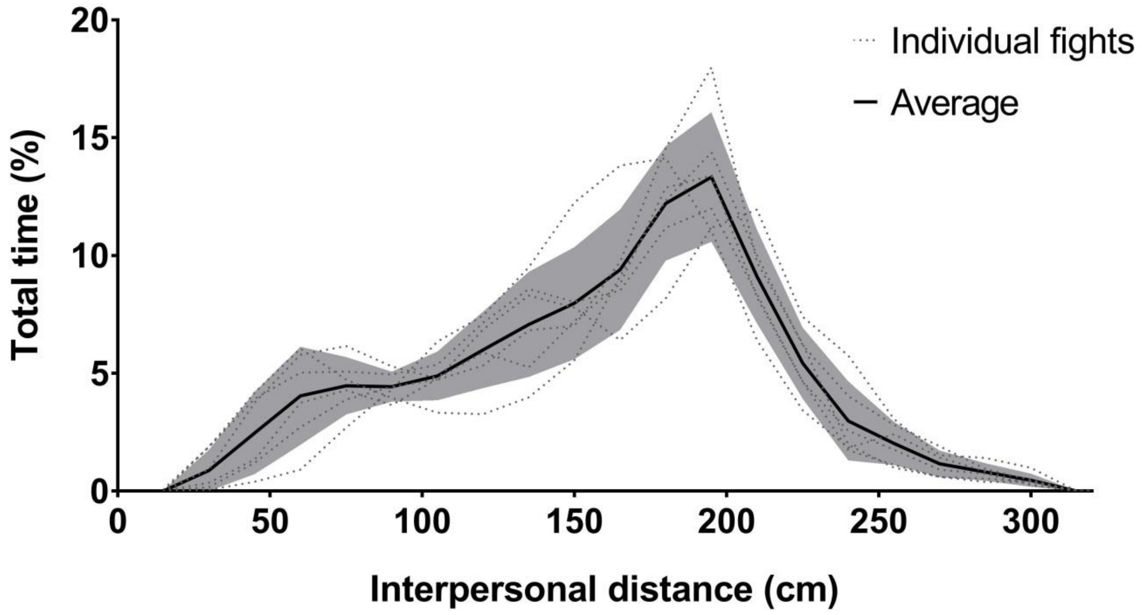

Figure 3.9 Percentage of total fight time spent at IPD. Interpersonal distances are presented in 0.15 m bins. The figure contains the group average with 95 % confidence intervals and the individual fight results.

Participant	Correlation	P value
1	0.78	0.00
2	0.50	0.06
3	0.82	0.00
4	0.24	0.39
5	0.70	0.00
6	0.49	0.07
7	0.77	0.00
8	0.80	0.00
9	0.90	0.00
10	0.83	0.00
11	0.82	0.00
Group	0.96	0.00

Table 3.2 Paired sample correlations between preferred IPD and attack initiation IPD for each participant and the group. Statistically significant correlations ($p = < 0.05$) are shaded grey.

3.4.3 Discussion

The aim of Study two was to assess decision making behaviour in a competitive taekwondo fight. To explore this aim we collected data as taekwondo players fought in practice to assess the IPD that players initiated their attacks from, and the IPD that players performed kicking techniques. The results suggest that performers were sensitive to the threat and body-scaled action capabilities of their opponents and used this information to moderate the distance between themselves and their opponent accordingly. In study one we showed that players could not kick a target beyond 168 % of their limb length. The results of Study two reveal that in a competitive fight players preferred to initiate their attacks from outside this IPD (i.e., out of range). They did this through explosive movements that perturbed the fighter-fighter system to cause a rapid transition between states (from far to near IPD, see exemplar data in Figure 3.8), with a striking action nested at the end of the transition. In line with other work on interpersonal coordination in sport, transitions in taekwondo occur when an attacker destabilized a previously stable dyadic system through a chaotic event such as a rapid change in velocity (Kelso, 1995; Passos et al., 2008).

Once players have initiated an attack and transitioned from far to near IPD, they prefer to make contact with their kicks from a specific scaled IPD. This IPD region is between 76 and 90 % of limb length and is consistent across most performers in this study. In study one, this region was identified as rich in action opportunities. These results provide evidence supporting the hypothesis that players are drawn to affordance rich regions due to the large number of action modes possible. This will be expanded upon further in the general discussion.

3.5 GENERAL DISCUSSION

There is growing interest in understanding the usefulness of practice tasks in sport and whether behaviour in training corresponds to the performance environment (Araújo & Passos, 2007). In the combat sports, athletes commonly spend time in practice with bags and pads; activities that are different to competitive fights as the target lacks the kinematic information of a real fighter and does not strike back. We explored this issue with two studies. The first replicated and extended the work of Hirstovski et al. (2006) in a study examining how IPD constrains the decision making of skilled taekwondo athletes when kicking a non-threatening static target. The second examined whether the findings from the first study would correspond to the decision making behaviour of skilled taekwondo players observed in a competitive fight. We hypothesized that due to the different task constraints of a live opponent who can strike back, the behaviour exhibited by taekwondo players when striking a static target would not represent how they attacked in a competitive fight. The findings supported our hypothesis; in Study two players exhibited different attacking behaviour that was adapted to the presence of a competitive opponent. In this general discussion we compare the differences and similarities between the results of Studies One and Two. We will also discuss the importance of ensuring the constraints and demands of competition are adequately represented in combat sports practice.

3.5.1 How does striking a static target differ to striking in a competitive fight?

The results of these studies reveal that kicking a static target does not represent the constraints and demands of a kicking in a competitive fight. Our findings reveal that in a competitive fight, performers form a dyadic system with their opponent that self-organises within the boundaries created by individual and task specific constraints, such as the requirement to score without being scored on (Cordovil et al., 2009b; Hristovski et al., 2009; Orth et al., 2014). When in a competitive fight, the dyad players form has specific coordination tendencies: the fighter-fighter system is attracted to near and far IPD distance regions and players regularly transition between the two. At near IPD, fighters are afforded striking opportunities (satisfying attacking task goals), whilst larger distances contain no striking affordances (satisfying defensive task goals and motivation to avoid being struck) (Hristovski et al., 2009).

The attacking behaviour of players in Study two is driven by their continuous interaction with their opponent. In a fight, in line with other research on interpersonal dynamics, players couple their decision to attack with the movements of an opponent (Esteves et al., 2011; Gorman & Maloney, 2016). In the competitive fights kicks are nested on the end of transitions from far (out of range) to near IPD. Previous work has revealed that taekwondo players spend only ~17 % of their fight time engaged in combat (Falco et al., 2014). Therefore, the decision as to when to transition could be a key skill of taekwondo performance. Prior to attacks in the competitive fight, exploratory periods were observed (Figure 3.7) where players actively manipulated their IPD. A previous study of taekwondo competition at the Olympic Games revealed athletes who moved around more were more likely to win a medal (Santos et al., 2011). Given these findings and those of Study one where small changes in IPD lead to the abrupt emergence or decay of action modes, continually manipulating IPD might be a highly functional exploratory process whereby subtle shifts in IPD lead to the spontaneous emergence of attacking affordances.

3.5.2 Correspondence between static, non-threatening target and live fight constraints

There was some correspondence between the results of Studies One and Two. In a competitive fight, players were attracted to the IPD regions that were shown by Study one to contain the richest source of action modes. That is, the distances where flexibility exists and players are afforded easy transitions between different types of kicks. At this IPD region players were highly unpredictable due to the large variety of movement solutions they were able to select from and switch between. Our results support theoretical claims regarding expertise that skilled athletes would be drawn to affordance rich regions (Bruineberg & Rietveld, 2014; Komar et al., 2015; Seifert et al., 2016).

Alternatively, while attracted to this zone for offensive reasons, players also avoided spending time in this affordance rich region as it also affords their expert opponents a variety of different action possibilities. This was evident in the results of Study two, where the fighter-fighter system spent the majority of the fight time attracted to far IPD regions well out of reach of any attacks. These results were further supported by consistent findings across both Studies One and Two regarding the IPD at which striking is no longer possible. In the competitive fight the far IPD region players were drawn to was beyond this critical scaled IPD.

3.5.3 What information do performers use when deciding whether or not to strike a target?

Previous research has shown that IPD acts as a control parameter over the decision to strike a target in boxing and kendo (Hristovski et al., 2006a; Okumura et al., 2017). Our results support IPD as a control parameter in taekwondo and demonstrate that expert taekwondo players are attuned to the IPD between them and their target. However, the findings in Study two also provide new insights to suggest that a variety of other factors in a competitive fight act to constrain whether a target affords striking.

The large amount of inter-individual variation in the attack initiation IPD data suggests that the decision to initiate an attack in taekwondo is affordance driven and unique to the action capabilities of the performer (Araújo et al., 2006; Passos et al., 2009; Seifert et al., 2014). This is further evident in the strong correlations observed between attack initiation IPD and the percentage of total fight time spent at each IPD in Study two. These strong correlations suggest that performers are attracted to spending time at IPD that affords the initiation of attacks. Therefore, rather than attacking behaviour in the combat sports being constrained entirely by IPD, the decision to attack is likely driven by complex performer-environment interactions that are heavily influenced by IPD and a variety of other factors (Araújo et al., 2006). Factors that may be nested within the IPD data may include but not be limited to individual constraints like physical capability, perceptual-cognitive skill, tactical preferences, emotions, and task constraints like opponent skill, match context and the continued in-match adaptation to an opponent. At this point in time, these ideas are pure conjecture and more research is needed to explore the interacting constraints that solicit attacks in taekwondo. Further studies should also explore a similar design to study one without constraining athletes to kicking from pre-determined distances. While this design and replication of Hristovski's (2006) work provided useful insights for the purpose of this study, it is perhaps not entirely representative of usual bag or pad practice where athletes will usually self-select their own IPD.

3.5.4 Conclusion

In summary, our findings highlight why decomposing training and research tasks to remove key parts such as an opponent can comprise the correspondence and generalizability of behaviour to performance environments (Araújo, Davids, & Passos, 2007; Davids et al., 2001; Gorman & Maloney, 2016; Pinder, Davids, Renshaw, & Araújo, 2011). We revealed that the reduced demands that come with attacking a non-threatening static target changes an individual's decision making. While training with static targets is a common practice task of striking combat sports, these findings suggest that this task may have some limitations. While the use of static targets in training may have some use, the findings suggest coaches and practitioners should be aware of their limitations. In addition, future research in the combat sports should strive to capture behaviour in representative experimental tasks predicated on the constraints of the competition environment.

BRIDGING STATEMENT B

The findings of Stage 2 revealed that there was low behavioural correspondence between striking a static bag and striking a dynamic and competitive opponent. The results highlighted that the task constraints of taekwondo, such as the threat of getting struck and a competitive opponent, continuously interact to shape emergent behaviour. Further, it was confirmed that the behaviour of a taekwondo fighter-fighter system can be expressed through measures of interpersonal distance (IPD), the relative distance between two fighters. The implications for the following Stages of the PhD programme are that taekwondo behaviour must be captured in representatively designed experimental tasks that include active opponents.

Highlighted earlier was the recent extension of representative learning design to consider affective and cognitive demands. However, little is known about the affective and cognitive demands of typical high performance practice environments. Gaps in the literature were identified related to 1) what the affective demands of practice are relative to competition, and 2) whether these reduced demands impact the action fidelity of training behaviour. The next Stage of the PhD programme (Stage 3) examines the affective, cognitive and action demands of taekwondo practice in two representative settings. We do this by comparing the taekwondo fighting behaviour of skilled performers in practice relative to competition. The findings from this study will help inform the next Stage of the research programme.

4 TAEKWONDO FIGHTING IN TRAINING DOES NOT SIMULATE THE AFFECTIVE AND COGNITIVE DEMANDS OF COMPETITION: IMPLICATIONS FOR BEHAVIOUR AND TRANSFER

This Chapter is based on the following peer-reviewed journal article:

Maloney, M., Renshaw, I., Headrick, J., Martin, D. T., & Farrow, D. (2018). Taekwondo fighting in training does not simulate the affective and cognitive demands of competition: Implications for behaviour and transfer. *Frontiers in psychology*, 9, 25.

4.1 ABSTRACT

Enhancing practice design is critical to facilitate transfer of learning. Considerable research has focused on the role of perceptual information in practice simulation, yet has neglected how affect and cognition are shaped by practice environments and whether this influences the fidelity of behaviour (Headrick et al., 2015). This study filled this gap by examining the fidelity of individual (cognition, affect, and actions) and interpersonal behaviour of 10 highly skilled Australian Taekwondo athletes fighting in training compared to competition. Interpersonal behaviour was assessed by tracking location coordinates to analyze distance-time coordination tendencies of the fighter–fighter system. Individual actions were assessed through notational analysis and approximate entropy calculations of coordinate data to quantify the (un)predictability of movement displacement. Affect and cognition were assessed with mixed-methods that included perceptual scales measuring anxiety, arousal, and mental effort, and post-fight video-facilitated confrontational interviews to explore how affect and cognitions might differ. Quantitative differences were assessed with mixed models and dependent t-tests. Results reveal that individual and interpersonal behaviour differed between training and competition. In training, individuals attacked less ($d = 0.81$, $p < 0.05$), initiated attacks from further away ($d = -0.20$, $p < 0.05$) and displayed more predictable movement trajectories ($d = 0.84$, $p < 0.05$). In training, fighters had lower anxiety ($d = -1.26$, $p < 0.05$), arousal ($d = -1.07$, $p < 0.05$), and mental effort ($d = -0.77$, $p < 0.05$). These results were accompanied by changes in interpersonal behavior, with larger interpersonal distances generated by the fighter–fighter system in training ($d = 0.80$, $p < 0.05$). Qualitative data revealed the emergence of cognitions and affect specific to the training environment, such as reductions in pressure, arousal, and mental challenge. Findings highlight the specificity of performer–environment interactions. Fighting in training affords reduced affective and cognitive demands and a decrease in action fidelity compared to competition. In addition to

sampling information, representative practice needs to consider modelling the cognitions and affect of competition to enhance transfer.

4.2 INTRODUCTION

A key issue for practitioners working in competitive sport is enhancing the design of practice to facilitate the transfer of skills from training to competition. One way to enhance practice is through simulating key aspects of competition through the design of representative learning tasks (Araújo & Passos, 2007; Barris et al., 2014; Pinder et al., 2011b). However, recent theorising has highlighted that designing adequate simulations of competitive performance environments in practice is not simple and requires consideration of factors other than information and action (Headrick et al., 2015; Oudejans & Pijpers, 2010). For example , in competition performers must adapt to unique constraints such as consequences, prizes, referees, crowds and unfamiliar opponents, Given the complexity of performance environments and an acknowledgement of the impact that affect[1] and cognitions may have on perceptions and actions in high stakes competition, representative practice tasks need to also model the cognitive, affective, and behavioural demands of competition (Headrick et al., 2015; Pijpers et al., 2006). However, currently there is little understanding of the extent to which typical training environments adequately simulate the affective and/or cognitive demands of competition and whether this impacts on the fidelity of training behaviour and subsequent transfer. Therefore, the paper aims to explore this issue in a combat sport setting and assess whether taekwondo fighting in training adequately simulates the affective and cognitive demands of competition, and subsequently, whether the affective-cognitive demands observed in training impact on the representativeness of individual and

[1] The term ‘affect’ will be used to refer to a range of phenomena such as feelings, emotions and mood. The terms affect and emotion will be used interchangeably to follow previous work in the area (Headrick et al., 2015; Lewis & Granic, 2000).

interpersonal behaviour relative to competition. A growing body of work has explored how improving training task design can potentially enhance the learning and transfer of skills to competition environments (Araújo & Davids, 2015). One way to describe the usefulness of different training tasks in sport is through the lens of ecological dynamics (Davids & Araújo, 2010). Ecological dynamics integrates concepts from dynamical systems theory and ecological psychology to understand how athletes coordinate their actions with the surrounding environment (Brunswik, 1956; Gibson, 1986; Kelso, 1995). An underpinning principle of this approach is the need for learners to form functional relationships with their environment (Fajen et al., 2009; Fajen & Warren, 2003).

In sport specific environments, social and physical information supports athletic behaviour and provide opportunities for action (Fajen et al., 2009; Rietveld & Kiverstein, 2014). As behaviour is regulated prospectively by a continuous process of perceiving and moving, invitations for action emerge in the form of affordances as an athlete moves around the environment picking up information (Gibson, 1986). For instance, in the combat sports, picking up certain postural or kinematic information from an opponent might invite an opportunity to attack. As an athlete learns, they attune to environmental features and the different actions they afford (Bruineberg & Rietveld, 2014; Gibson, 1986). Attunement 'educates' the attention of performers toward the most useful information, improving their 'fit' within the environment (Bruineberg & Rietveld, 2014; Michaels & Jacobs, 2007). The implications for training design in sport are that the coupling between the performer and environment present in competition needs to be preserved so that athlete learnings can transfer between environments.

These implications were captured by marrying concepts from Gibson's ecological psychology and Brunswik's representative design to develop a framework to guide the design of practice environments in sport (Brunswik, 1956; Gibson, 1986; Pinder et al., 2011b).

Representative learning design emphasizes the need for the practice task constraints to represent the task constraints of the competition task (Pinder et al., 2011a). Therefore, any practice needs to satisfy this principle if transfer from practice to competition is to be optimised. A way to evaluate the potential for practice to transfer is through the specificity of relationship between performer and environment. The specific nature of this relationship – our actions are tightly coupled to specific information - provides a principled approach for scientists to evaluate the representativeness of different training tasks through comparing the fidelity of action responses (Araújo & Davids, 2015; Davids et al., 2012; Pinder et al., 2011b; Stoffregen et al., 2003).

Action fidelity refers to the correlation between a performance in a reference situation (real world environment) and a performance in a simulated situation (e.g. training) (Pinder et al., 2011b; Stoffregen, 2007; Stoffregen et al., 2003). The concept of fidelity specifically deals with transfer and is assessed in terms of task performance. Fidelity is achieved when behaviour in a simulated (e.g. training) task represents the behaviour observed in the performance task (Stoffregen, 2007). The fidelity of athlete behaviour in learning tasks is known to be impacted when practitioners omit key ecological constraints to create *non-representative* practice conditions (Barris et al., 2013b; Dicks et al., 2010; Greenwood et al., 2016; Pinder et al., 2009; Shim et al., 2005). For example, when cricket batters practiced with a ball projection machine as opposed to a human bowler it resulted in re-organised low fidelity action responses (Pinder et al., 2011a). In contrast, fidelity is maintained when practitioners sample key informational constraints from performance environments to design *representative* practice tasks (Barris et al., 2013b; Dicks et al., 2010; Greenwood et al., 2016; Pinder et al., 2011a). Designing representative practice tasks that maintain fidelity will theoretically have positive implications for transfer (Araújo & Davids, 2015; Araújo & Passos, 2007; Brunswik, 1956; Pinder et al., 2011b). However, much of this research has focused on the utility of different external information sources on action fidelity, neglecting to consider how other factors such as affect and cognitions constrain perception and action behaviour in sports practice (Pinder et al., 2015).

Researchers in psychology have demonstrated how task and environmental constraints shape the emergence of affective and cognitive responses (Oudejans & Nieuwenhuys, 2009; Pijpers et al., 2006). For example, Nieuwenhuys and Oudejans (2010) compared the behaviour of police officers between two different practice tasks: a non-representative task where officers were required to shoot a ‘dummy’ target that could not move or shoot back versus a more representative task where the target could ‘shoot back’(Nieuwenhuys & Oudejans, 2010). Practicing in the more representative task resulted in higher levels of anxiety and mental effort which were accompanied by poorer performance, quicker movement responses, increased blinking and changes in postural orientation. Perception and action behaviours declined in the high anxiety task, raising questions about how to best train for tasks and environments that induce high amounts of affect.

An expanding body of work has demonstrated that enhancing the representativeness of practice tasks through the consideration of affective and cognitive demands will improve skill transfer to demanding environments (Alder et al., 2016; Nieuwenhuys & Oudejans, 2011; Oudejans & Pijpers, 2009, 2010). For instance, expert dart players who practiced under anxiety and high amounts of mental effort were able to maintain performance outcomes despite still experiencing high anxiety, arousal and mental demands in a high anxiety transfer test (Oudejans & Pijpers, 2009). These findings suggest that training in conditions that simulate the affective and cognitive demands of performance environments may provide performers with opportunities to adapt to these performance constraints (Fajen, 2005; Oudejans & Nieuwenhuys, 2009; Rietveld & Kiverstein, 2014).

The importance of ensuring training environments simulate the affective-cognitive demands of performance environments has been captured in recent theoretical work. Affective learning design (ALD) builds on representative learning designs' framework to consider affective and cognitive constraints in conjunction with environmental information (Headrick et al., 2015). Headrick and colleagues advocate for practice tasks that afford "emotion-laden learning experiences that effectively simulate the constraints and demands of performance environments in sport" (Headrick et al., 2015, 85). The practical application of ALD promotes the design of practice tasks that afford rich competition-like experiences so that athletes are cognitively and affectively engaged so that they *think* and *feel* like they would in competition (Headrick et al., 2015; Pinder et al., 2015). Whilst work has examined affect and cognition in competition settings no studies have looked at whether typical sport training tasks simulate the affective and cognitive demands of competition and what the implications for skill transfer may be (Bridge et al., 2013; Hauw & Durand, 2007a; Ria et al., 2011; Sève & Poizat, 2006).

At the elite level, fighting fellow squad members is a key training activity to prepare for combat competitions (Hodges, 1995). Using the principle of fidelity, assessment of taekwondo performance provides an opportunity to gain insight as to whether changes in affective and cognitive demands impact on performance behaviours in competition and training. One candidate performance variable that might be impacted is the interpersonal distance of fighters (Dietrich et al., 2010). Interpersonal distance (IPD) is a global variable representative of the fighter-fighter system (Okumura et al., 2017). The distance between fighters' provides different affordances for action and different striking techniques emerge and decay depending on this IPD (Hristovski et al., 2006b; Okumura et al., 2017). Practically, IPD constrains the respective *attackability* of each fighter (i.e., specific critical IPDs invite an attack or being attacked). Given the influence of cognitive-affective subsystems on perception and action, any changes in affect should manifest in measures of IPD.

The aims of this study were twofold. First, we aimed to assess whether taekwondo fighting in training adequately simulated the affective and cognitive demands of competition. Second, we wished to use the concept of fidelity to assess whether changes in these demands impacted the representativeness of fighting actions compared to competition. For our first aim it was hypothesized that the training environment would not adequately simulate the affective and cognitive demands of competition due to factors such as familiar opponents and lack of consequences. This would be evident in a reduction in affect (arousal, anxiety and frequency of reported emotions) and less demanding cognition (mental effort and reported thoughts). In line with ALD, it was reasoned that this would lead to athletes being less emotionally and cognitively engaged in the task, creating intra and interpersonal fighting actions of lower fidelity. These reductions in engagement would manifest through a greater amount of time spent at larger IPD, larger attack initiation IPD, more predictable movement behaviour, and fewer attacks.

4.3 MATERIALS AND METHODS

The university Human Research Ethics Committee of the first author approved the protocol for this study. All participants provided written informed consent prior to the commencement of the study in accordance with the Declaration of Helsinki.

Participants

Ten international level senior taekwondo athletes (7 male, 3 female) participated in the study. The average age of participants was 23 years (*SD* = 5 years). Participants were members of a national team and their demographics can be found in Table 4.1.

Participant	Highest level of competition	World ranking at testing
1	Olympics*	5-10
2	Olympics*	5-10
3	Olympics	11-20
4	World Championships*	5-10
5	World Championships*	11-20
6	World Championships*	20-50
7	World Championships	100-150
8	G4 International competition*	20-50
9	G2 International competition*	100-150
10	G2 International competition*	50-100

*Table 4.1 Highest level of competition and world ranking range for each participant. * denotes multiple times competing at the highest level of competition.*

Experimental task

Data were collected during a national training camp. Participants were filmed and participated in mixed methods data collection as they fought in two distinct conditions – a typical training fight and a simulated competition fight. Training condition data was collected first during one of the national teams' training sessions. The training condition consisted of the typical training activity of sparring against a fellow national team member. From practice observations, this is one of the teams most common practice tasks and would generally be prescribed multiple times per week. As per usual training custom, the coach acted as the referee and allocated fighters into pairs of similar ability. The composition of these pairs was determined according to the judgement of the national coach, who based the match ups on skill level, sex and weight category. Much like the competition task, the coach would usually provide instructional feedback to the athletes during the fight; however he did so at his own discretion.

Competition condition data was subsequently collected during a 'friendly' competition against a visiting international team. This condition included competition-specific task constraints of an international opponent, crowd, professional referees, professional judges, and competition for an individual prize for highest score, and a team prize for most collective wins. In order to control for athletes intentions, in both conditions they were given the aim of winning the fight. Players received feedback from their coach at the coaches' discretion just as they usually would in competition.

Quantitative measures

Perceived anxiety and arousal

Perceptions of cognitive and somatic anxiety were assessed using the Competitive State Anxiety Inventory-2 (Martens, Vealy, Burton, Bump, & Smith, 1990). Autonomic arousal was assessed by collecting the pre-fight average heart rate of participants in the one minute epoch before the fight started. This approach has been used successfully before in similar studies to infer anxiety and arousal (Nieuwenhuys et al., 2012a).

Perceived mental effort

Participants perception of mental effort has proved an insightful measure of task demands (eg. Oudejans & Pijpers, 2009). Consequently, perceived mental effort was determined using the Rating Scale of Mental Effort (Zijlstra, 1993). This scale consists of a vertical axis scale with a range of 0-150 and descriptive anchors from not effortful to awfully effortful and has shown to be reliable across a range of real life settings (Zijlstra, 1993).

Movement trajectories

To understand the emergent time-distance coordination strategies of fighters the evolution of system behaviour was plotted over time for the entire fight. The movement trajectories of the players were manually tracked at 25 frames per second using digitising software (Kinovea, version 0.8.25). This processes provided x and y coordinates for each participant across the duration of their fight. The court was calibrated using the known distances provided by the 1.00 x 1.00 m mats that made up the 8.00 x 8.00 m octagon fighting space. Digitising consisted of tracking the centre of mass, the mid-point between fighters' feet. This was chosen due to past research that had used a similar technique in tracking individual movement trajectories (Headrick et al., 2012). Measurement accuracy and reliability was assessed in the previous Chapter.

Interpersonal distance

Interpersonal distance (IPD) was determined using Pythagorean Theorem and the x and y coordinates for two fighters with the following calculation:

$$IPD = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

Attack initiation interpersonal distance

Attack initiation IPD was analysed using both the video and IPD data following previously published methods (Okumura et al., 2017). Attack initiation was determined using the video and defined as either the first forward movement of an attack, or if the athlete did not move forward, the time at which the foot first left the ground. Attack initiation IPD was defined as the IPD at the onset of attack initiation.

Number of kicks

The number of attacks was assessed from the video data by counting the number of times participants performed a kicking action.

Qualitative measures

Self-confrontational interview

Verbalisation data was collected from individual self-confrontational interviews with each participant using a course-of-action methodology (Theureau, 2003). Self-confrontational interviews are a tool used to ‘confront’ actors about their context specific behaviour soon after that behaviour took place and capture their in-performance cognitions and feelings (von Cranach & Harre, 1982). While watching a video replay of the fight, participants were asked to relive their experience and comment and/or answer questions based on what they did, thought, and felt during the fight (Theureau, 2003). These techniques reconstruct meaning actors give to their in-situ activity through the recall and explanation of experiences (Ria et al., 2011). A number of previous studies have demonstrated how this approach is useful in understanding task demands and complementing quantitative approaches to increase understanding (Hauw & Durand, 2007a; Seifert et al., 2017; Sève et al., 2005).

The interviews averaged 46 minutes in length (SD = 9 min) and were completed by the lead author who was familiar to the participants. To ensure trustworthiness of the data, leading questions that might have influenced the responses were avoided (Patton, 2002). During the interview both viewers could stop and rewind the video at any point. Generally, the video was stopped by either player or interviewer after an interaction between the two fighters. At this point the player would make a comment or the interviewer would ask a prompting question.

In-fight emotions

Previous work has used the course-of-action methodology to determine in-competition emotions experienced by participants (Ria et al., 2011). During the confrontation interview participants were asked how they felt throughout the fight (Ria et al., 2011). Previous studies have shown that athletes are able to reliably recall their emotions in retrospect within 7 days (Martinent et al., 2012). To facilitate accurate recall of emotions, participants were provided with a list of emotions based on those reported in the Sports Emotion Questionnaire (SEQ), a 22 item tool developed to measure Emotions in sport (Jones et al., 2005). The list of emotions in the SEQ was developed from two sources: a list of emotions gathered from the literature, and completion of an open-ended questionnaire to identify emotions experienced by athletes in sport. The 22 items of the SEQ collapse into five basic emotions: happiness, anger, dejection, excitement and anxiety. For the purposes of this study, collected emotions were collapsed into one of those five basic emotions.

Procedure

Measure	Pre fight	Fight	Post fight	24 hours post fight
Competitive State Anxiety Inventory-2	X			
Heart rate	X			
Video		X		
Rating Scale of Mental Effort			X	
Interview and in-fight emotions				X

Table 4.2 Measures and their timing of collection.

A repeated measures design was adopted and the procedure for both conditions was identical. Table 4.2 details the measures and their timing of collection. Upon arrival participants were fitted with heart-rate monitors (Firstbeat Technologies, Finland). Participants were then instructed to go about their usual warm-up routine before presenting to marshalling 10 minutes before the fight. At this point participants completed the Competitive State Anxiety Inventory-2. Participants then sat for one minute before entering the ring to begin their fight. During this period pre-fight heart rate was collected. Fights consisted of three two-minute rounds, separated by a one minute break. Official World Taekwondo Federation rules were adhered to and scoring was undertaken via the standard electronic protector and scoring system (Daedo TK-Strike, South Korea). Video data was collected using a digital video camera (Sony HXR-NX30P) positioned approximately 4.00 m above ground level, orientated at approximately 45 degrees to the central point of the court (Bartlett, 2007). This data was to be used to digitise player movement trajectories and as a stimulus for the confrontational interview. Following the fight, participants returned to the marshalling area to fill out the Rating Scale of Mental Effort. Within 24 hours of the fight finishing participants completed the confrontational interview. None of the participants participated in another fight between data collection and their confrontational interview and were asked to avoid analysing their fight.

Quantitative analysis

The predictability of participants' movement trajectories was assessed by running the x and y coordinates of each participant in each condition through a sample entropy equation. The analysis for sample entropy was carried out using the R package RACMA (Borchers, 2017; R Core Team, 2017).

Interpersonal distance frequency and attack initiation IPD were analysed descriptively by calculating the relative percentage of total observations that occurred in each 0.20 m IPD region between 0.00 m and 4.00 m in each condition (Okumura et al., 2017). The first zone was 0.00 m – 0.20 m, the next zone 0.21 – 0.40 m, and so forth. For both variables (IPD frequency and attack initiation IPD) the 0.20 m IPD regions with the largest relative percentage of observations were selected for statistical comparison between conditions. These were called peak IPD frequency and peak attack initiation IPD.

Differences between competition and training conditions in perceived cognitive and somatic anxiety, mental effort, pre-fight heart rate, peak IPD frequency, peak attack initiation IPD and the number of kicks were analysed using paired t tests and Cohen's d effect size calculations (Cohen, 1988). These were analysed using SPSS computer software (version 19.0)

Differences between conditions for the entropy scores, attack initiation IPD, and in-fight emotion frequency were analysed using linear mixed models, also performed in SPSS. The entropy mixed model had two fixed factors and one random factor; fixed factors: condition (training or competition) and coordinates (x or y), random factor: participant. The attack initiation IPD model had one fixed factor and one random factor; fixed factor: condition (training or competition), random factor: participant. The in-fight emotion frequency mixed model had two fixed factors and one random factor; fixed factors: condition (training or competition) and emotion (anger, anxiety, dejection, excitement or happiness); random factor: participant. Significant effects were further investigated with pairwise comparisons using Bonferroni corrected alphas. Assumption testing of the residual values was carried out for all models and no violations were observed.

Qualitative analysis

The verbal data were analysed using a four step methodology (Gernigon & Arripe-longueville, 2004; Theureau, 2003): 1) Producing a summary table of time-matched actions and verbal data, 2) Establishing the elementary units of meaning (EUM) for an individual, 3) Reconstructing the course of action for each EUM and labelling the EUM with a name representative of its content, 4) Grouping EUMs into like categories exclusive to either training or competition conditions (d'Arripe-Longueville et al., 2001; Theureau, 2003).

For the first step, two types of data were collated and paired chronologically: the verbatim transcripts from the confrontational interviews and match logs of the participants' observed behaviour during their fights. The second step consisted of identifying the smallest courses of action that were meaningful for each individual. For taekwondo fighters this was generally confined to an interaction (attack or defence) with their opponent. The third step required identifying the underlying components of each elementary unit of meaning: the object, representmen and interpretant (Hauw & Durand, 2007b). This was achieved by asking a set of specific questions about the data: what is the participants' intention (object)? What part of the situation is the athlete perceiving or making judgement of (representmen)? And what prior knowledge is the athlete using to interpret the situation (interpretant)? An object is linked to a representamen through an interpretant. When these components are linked together, an EUM emerges. The third step also included naming the EUM with a label representative of the contents (d'Arripe-Longueville et al., 2001; Gernigon & Arripe-longueville, 2004). EUMs were grouped into categories corresponding to higher order themes, which were then grouped into broader categories termed dimensions (d'Arripe-Longueville et al., 2001; Gernigon & Arripe-longueville, 2004). Summary labels were used for each grouping variable (d'Arripe-Longueville et al., 2001; Gernigon & Arripe-longueville, 2004). Finally we characterized the experience of the participants in competition and in training, specifically we were interested in the dimensions that lead to divergent experiences related to the affective and cognitive demands of each environments (Kiouak et al., 2016).

4.4 RESULTS

A summary of quantitative results can be found in Table 4.3.

Perceived anxiety and arousal

Perceived anxiety and arousal graphed results can be found in

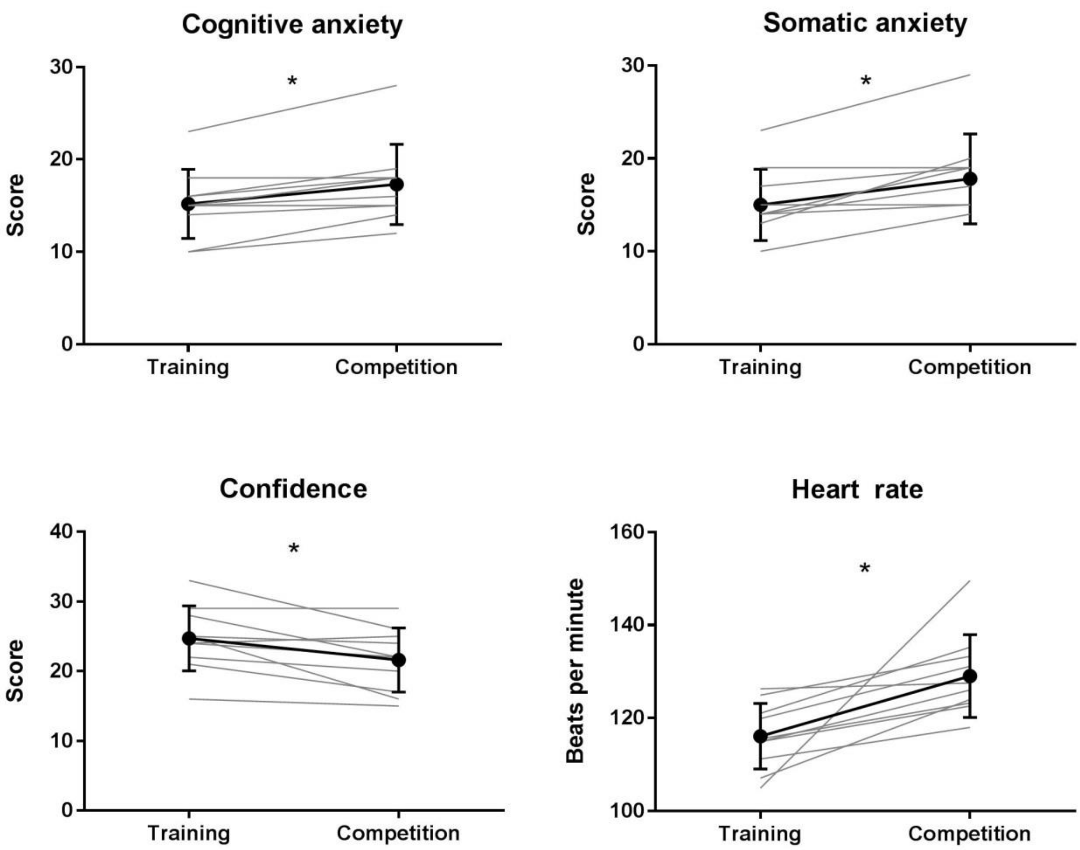

Figure 4.1. Greater levels of cognitive anxiety were reported in the competition condition (M = 17.3, SD = 4.35) compared to the training condition (M = 15.2, SD = 3.73); t(9) = 3.99, p < .05, d = 1.26.

Greater levels of somatic anxiety were reported in the competition condition (M = 17.8, SD = 4.85) than the training condition (M = 15.0, SD = 3.83); t(9) = 3.38, p < .05, d = 1.07.

Confidence levels were lower in competition (M = 21.6, SD = 4.60) compared to training (M = 24.70, SD = 4.67); t(9) = -2.99, p < .05, d = -0.95.

One minute pre-fight average heart rate was higher in competition (M = 129.0, SD = 8.93) compared to training (M = 116.1, SD = 7.10); t(9) = 3.44, p < .05, d = 1.09.

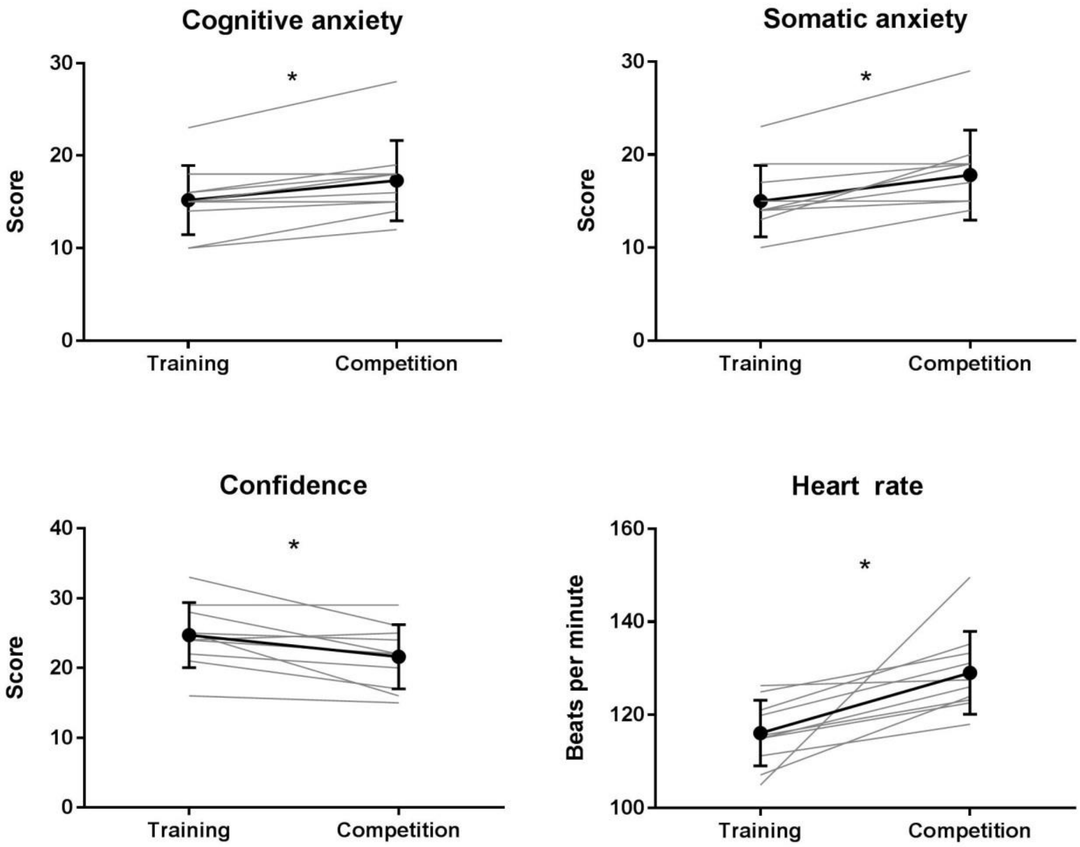

*Figure 4.1.CSAI-2 factors: cognitive anxiety, somatic anxiety and confidence, and one minute pre-fight heart rate average for training and competition fights. Mean results and standard deviations are presented in bold, individual results are presented in light grey. * Indicates a significant difference between conditions (p<0.05).*

Perceived mental effort

Fighters reported greater levels of mental effort (Figure 4.2) in the competition (M = 102.5, SD = 26.79) compared to the training condition (M = 77.5, SD = 27.87); $t(9) = 2.43$, $p < .05$, $d = 0.77$.

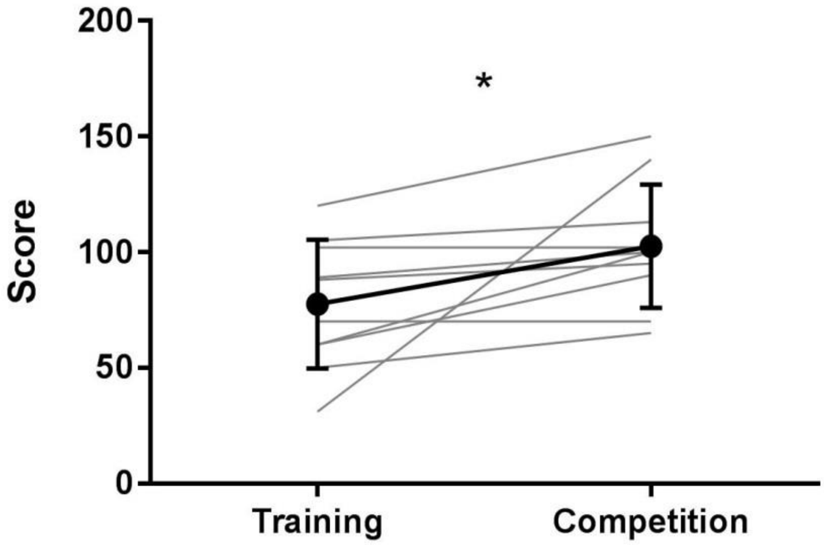

*Figure 4.2 Rating scale of mental effort results for training and competition fights. Mean results and standard deviations are presented in bold, individual results are presented in light grey. * indicates a significant difference between conditions (p<0.05).*

Variable	Training average	Competition average	t statistic	p	Mean difference	SE difference	Cohen's d	95% Confidence Interval	
								Lower	Upper
CSAI-2 Cognitive Anxiety	15.2 ±3.74	17.3 ±4.35	3.99	0.003*	2.1	0.53	1.26	0.91	3.29
CSAI-2 Somatic Anxiety	15.0 ±3.83	17.8 ±4.85	3.38	0.008*	2.8	0.83	1.07	0.93	4.67
CSAI-2 Confidence	24.7 ±4.67	21.6 ±4.60	-2.99	0.015*	-3.1	1.04	-0.95	-5.45	-0.75
Rating Scale of Mental Effort	77.5 ±27.87	102.5 ±26.79	2.43	0.038*	25	10.27	0.77	1.77	48.23
Ave Pre Fight Heart Rate (BPM)	116.1 ±7.06	129.0 ±8.93	3.44	0.007*	12.98	3.77	1.09	4.45	21.51
Number of Kicks	55.8 ±12.14	67.4 ±13.23	2.57	0.03*	11.6	4.51	0.81	1.40	21.80
Peak IPD Frequency (cm)	187.0 ±11.6	177.0 ±8.23	-2.54	0.032*	-10	3.94	-0.80	-18.92	-1.08
Peak Attack Initiation IPD (cm)	206.0 ±18.97	188.0 ±13.98	-3.86	0.004*	-18	4.67	-1.22	-28.56	-7.44

*Table 4.3 Results summary of perceived anxiety, arousal and perceived mental effort. * denotes statistical significance (p < .05).*

Movement trajectories

The linear mixed model revealed a significant fixed effect for condition, F(1, 28) = 12.408, p=0.001 (Figure 4.3). Post hoc pairwise comparisons revealed that the movement trajectories of participants was more unpredictable in competition (M = 0.15, SD = 0.06) compared to training (M = 0.11, SD = 0.03), p=.001, 95 % CI [0.01, 0.07], d = 0.84. There was no significant effect for coordinates F(1, 28) = 3.18, p=0.085.

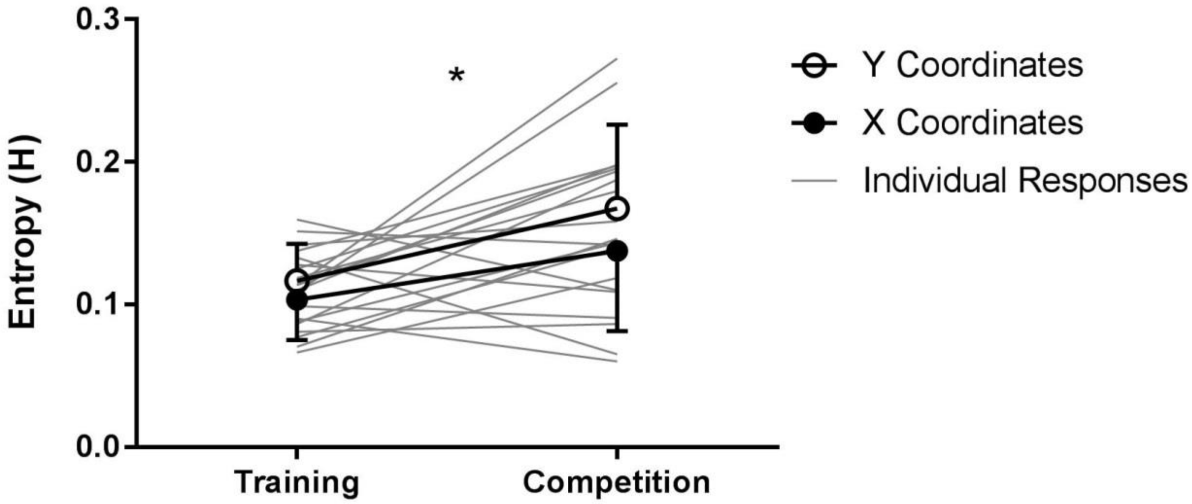

*Figure 4.3 Predictability of movement trajectories assessed using sample entropy (H) for training and competition fights. Mean results and standard deviations are presented in bold for both x and y coordinates, individual results are presented in light grey. * indicates a significant main effect for condition (p-<0.05).*

Interpersonal distance frequency

The percentage scores for time spent at each IPD (Figure 4.4) reveal that the peak region of IPD frequency was closer in competition (M = 177.0 cm, SD = 8.23) compared to training (M = 187.0 cm, SD = 11.6); t(9) = -2. 45, p < .05, d = -0.80.

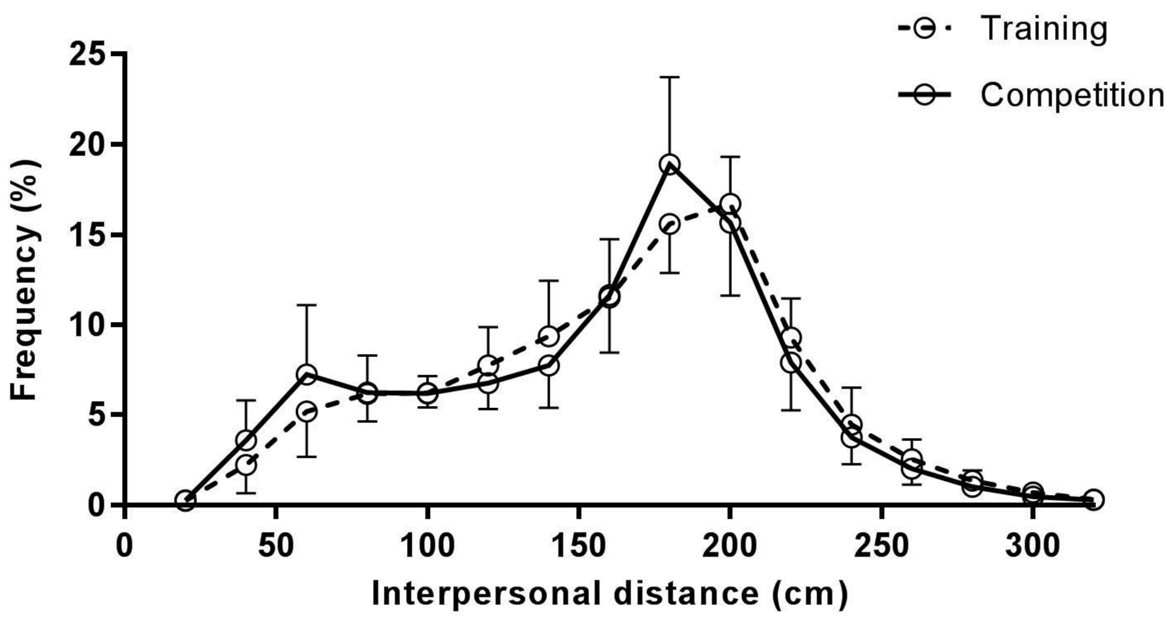

Figure 4.4 Percentage of time spent at interpersonal distances in training and competition fights. Interpersonal distances are presented in 0.20 m bins.

Attack initiation interpersonal distance

The linear mixed model revealed a significant fixed effect for condition $F(1, 981.77) = 10.631$, $p = .001$. Post hoc pairwise comparisons revealed that attack initiation IPD was closer in competition ($M = 156.87$, $SD = 47.25$) compared to training ($M = 166.62$, $SD = 48.70$), $p = .001$, 95 % CI [-16.088 -3.999], $d = -0.203$. These results can be found graphed in Figure 4.5.

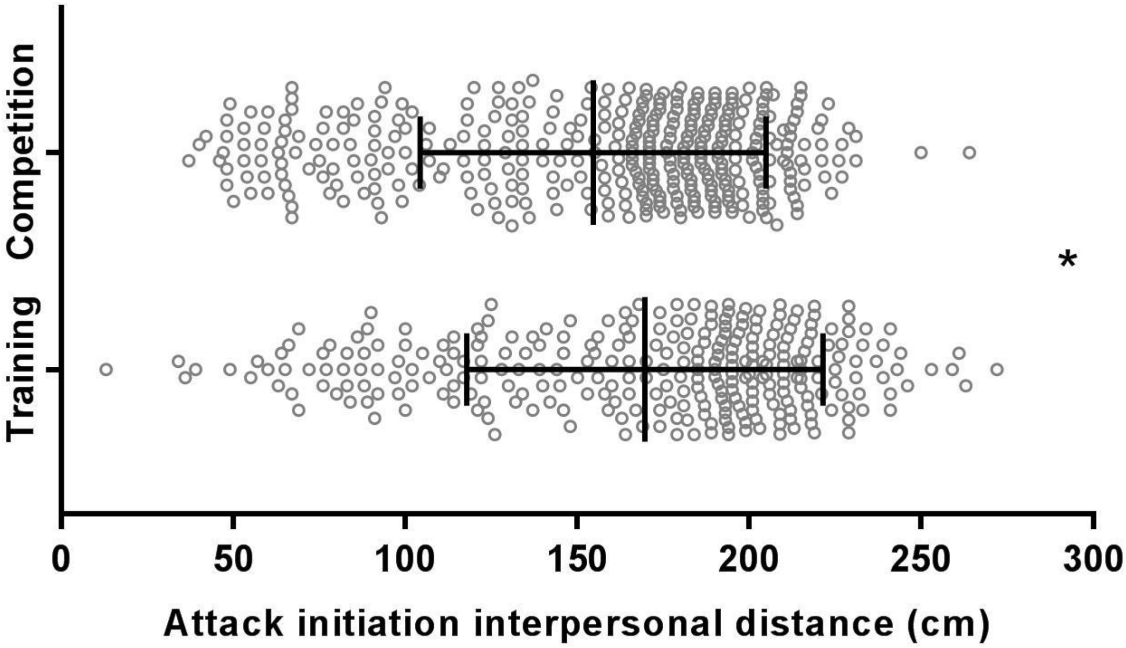

*Figure 4.5 Interpersonal distance of all attacks initiated in training and competition fights. Mean results and standard deviations are presented in bold, individual attacks are presented in light grey circles. The mean and standard deviation is presented * indicates a significant fixed effect of condition (p<0.05).*

Analysis of the peak IPD zone of attack (Figure 4.6) was closer in competition (M = 188.0 cm, SD = 13.98) compared to training (M = 206.0 cm, SD = 18.97); t(9) = -3.86, p < .05, d = -1.22.

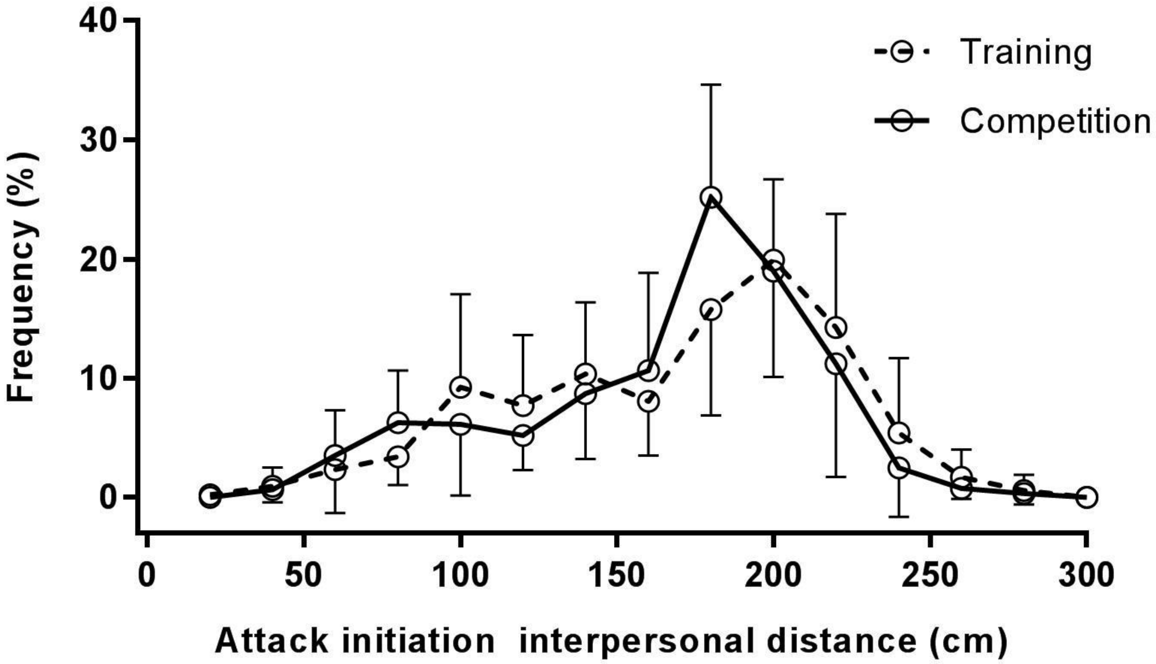

Figure 4.6 Percentage of attacks initiated from interpersonal distances in training and competition fights. Interpersonal distances are presented in 0.20 m bins.

Number of kicks

The number of kicks was greater in competition (M = 67.4, SD = 13.23) compared to training (M = 55.8, SD = 12.14); $t(9) = 2.57$, $p < .05$, $d = 0.81$.

Self-confrontational interview

Self-confrontational interview data can be seen summarised in Table 4.4 and Table 4.5.

Competition		
Dimensions	**Themes**	**EUM examples**
Arousal (20 EUMs)	High individual arousal	Feel 'switched on' and ready to fight
		Feeling fast
	High fight intensity	Defend high intensity attack from opponent
		Lift fight intensity to match opponent
Mental challenge (38 EUMs)	Problem solving	Thinking about tactics/techniques that might be useful
		Hypothesis test possible tactical/technical solution
	Opponent unfamiliarity	Surprised by opponents actions
		Unsure what tactics/techniques will be successful
	Difficulty executing own techniques/tactics	Difficulty executing technique or tactic
		Opponent able to absorb attack
Pressure (38 EUMs)	Task pressure	Under pressure due to position on the court
		Under pressure due to the score
	Opponent pressure	Feel uncomfortable due to the aggressive nature of opponent
		Concerned about head kick from opponent

Table 4.4 Synthesized interview data from the competition condition relating to affective-cognitive differences between environments.

Training		
Dimensions	**Themes**	**EUM examples**
Low arousal (27 EUMs)	Low individual arousal	Unsuccessfully attempt to enhance arousal level
		Feeling sluggish
	Low fight intensity	Low intensity attack from opponent
		Avoiding engagement
Low mental challenge (33 EUMs)	Use established knowledge of opponent	Select tactic/technique based on prior knowledge of opponent
		Anticipate opponents behaviour based on prior knowledge
	Not challenged by opponent	Able to absorb opponents attack
		Have established attack/defence solution ready

Table 4.5 Synthesized interview data from the training condition relating to affective-cognitive differences between environments.

In-fight emotions

In-fight emotion frequency results are summarised in Figure 4.7, while exemplar data is provided in Figure 4.8. Results of the linear mixed model revealed no significant interaction between emotion and condition. There was, however, a significant fixed effect of emotion, $F(4, 81) = 7.141$, p = .000, and a significant fixed effect for condition, $F(1, 81) = 16.363$, p = .000. Post hoc pairwise comparisons revealed that the mean frequency of each emotion was greater in competition (M = 3.20, SD = 2.39) compared to training (M = 1.70, SD = 1.71), p = .000, 95 % CI [0.76, 2.24], d = 0.63.

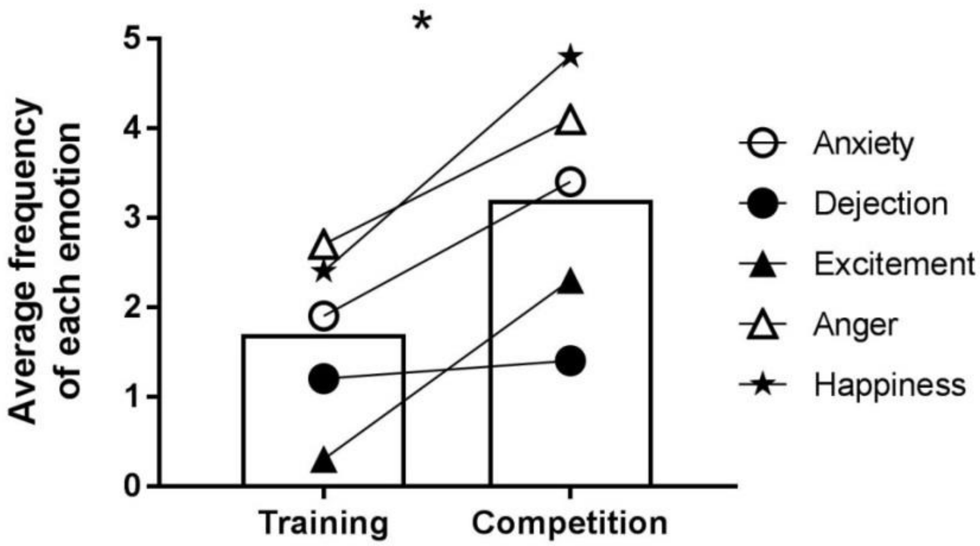

*Figure 4.7 Average frequency of each recalled in-fight emotions for training and competition fights. * indicates a significant fixed effect for condition.*

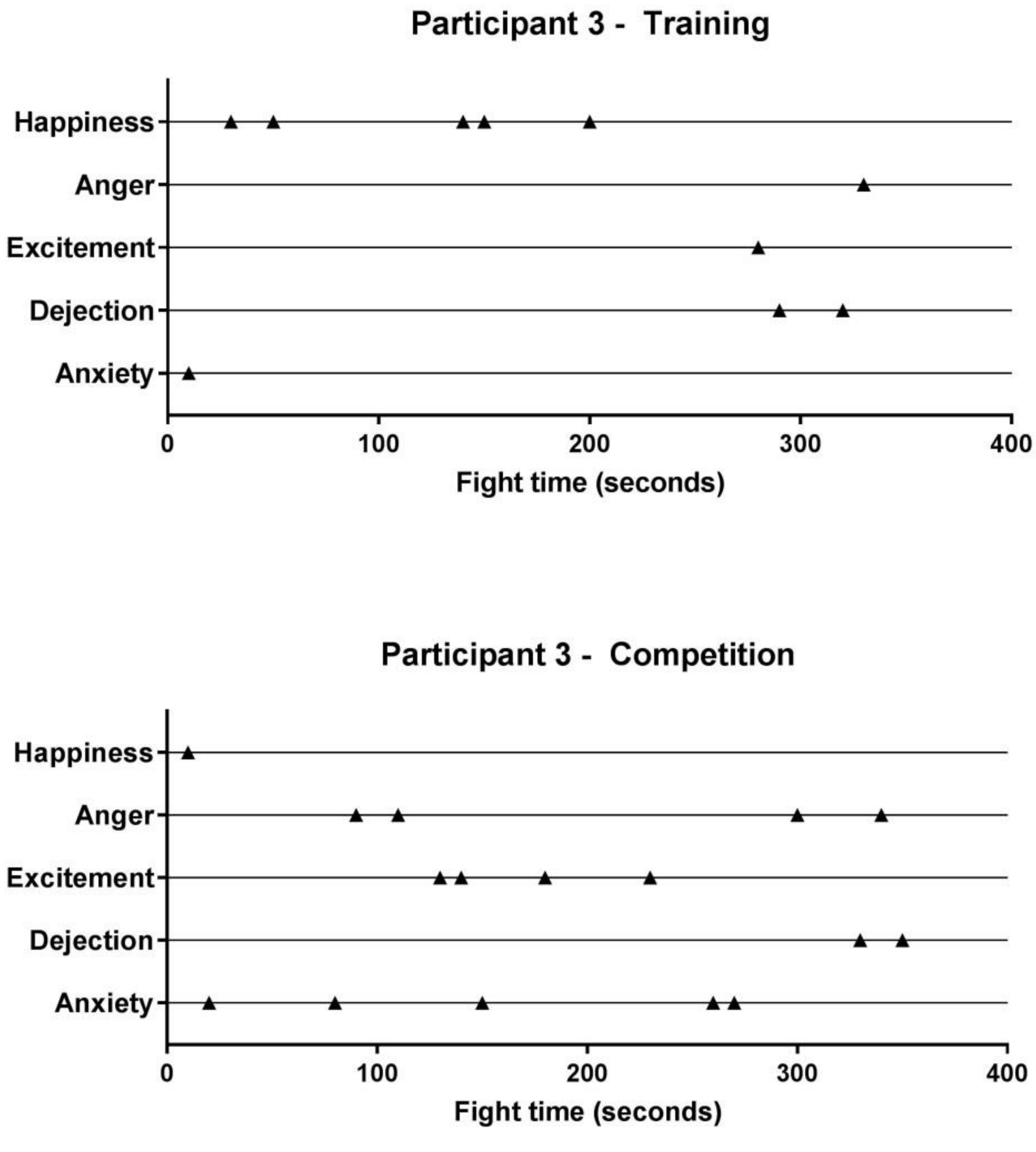

Figure 4.8 Exemplar data for the temporal arrangement of recalled in-fight emotions for training and competition fights.

4.5 DISCUSSION

Research has focused on the role of physical information when designing representative learning environments, yet has neglected the role of affect and cognition and how they might influence the representativeness of behaviour (Headrick et al., 2015; Pinder et al., 2011a). The aims of the study were to assess whether taekwondo fighting in training adequately simulates the affective and cognitive demands of competition and secondly whether the affective-cognitive demands observed in training impact on the representativeness of individual and interpersonal behaviour relative to competition.

When fighting in training, participants reported lower levels of anxiety, arousal and mental effort and reported different goals, suggesting that fighting in training does not entirely recreate the cognitive and affective demands of competition. These decreased demands were associated with individual and interpersonal behaviour of lower fidelity. In training, individual fighters performed fewer kicks and attacked from further away, whilst the fighter-fighter system generated larger interpersonal distances. The data show reductions in cognitive and affective demands are associated with different individual and interpersonal fighting behaviour in training. The discussion will first cover each factor individually (affect, cognition and behaviour) before discussing possible interactions between the three and the implications for the design of representative learning environments and skill transfer.

4.5.1 The affective demands of training

The first aim of this study involved comparing the affective demands of fighting in training relative to competition. Results from the perceptual scales, interviews and pre-fight maximum heart rate were all congruent: fighting in training has reduced affective demands relative to competition. The triangulation of these results suggests that fighting in training alone does not afford similar levels of arousal and anxiety as fighting in competition. Exemplar interview data reveals the extent of this issue with one fighter: “This is a common problem for me. I’m not very stimulated and I’m in a bad mood. Whenever I’m fighting <players of own nationality> I struggle to get stimulated – I am not challenged.” And: “I’m not in the zone, this isn’t how I would want to feel in competition”. This finding is in line with previous work that has demonstrated differences in arousal and anxiety between training and performance environments (Bridge et al., 2013; Fernandez-fernandez et al., 2015; Haneishi et al., 2007).

During the training fights participants reported a reduced frequency of emotions. These results support the dynamic nature of emotions in sport which suggests emotions emerge and decay based on performance situations (Cerin et al., 2000; Hanin, 2003; Martinent et al., 2012; Ria et al., 2011). One of the key practical applications of affective learning design is the need to design training tasks that emotionally engage athletes regardless of valence. The reduced number of emotions experienced by athletes in training suggests that fighting in training may not be as engaging compared to competition, perhaps due to absence of stimulating competition-factors like prizes, judges and a crowd. Overall, these results may have implications for the transfer of skills between performance settings. Learning to cope with emotions created by performance environments such as competition can be as important as a learning technique (Pinder et al., 2015). Research assessing the affective demands of learning environments shows that superior transfer of performance is observed when the practice environment closely simulates these demands (Nieuwenhuys et al., 2009; Nieuwenhuys & Oudejans, 2011).

4.5.2 The cognitive demands of training

The current results suggest that training fights were less cognitively demanding compared to competition. This was evident in participants' perceptions of mental effort, which was significantly lower in the training fight. Further, a dimension related to mental challenge emerged from the interview data in both training and competition. In training participants reported a low mental challenge as they used prior knowledge of their opponent to aid their own action selection and to predict what their opponent would do. For instance, one participant mentioned "If I push him on the back foot he will do something stupid. He doesn't have a good left leg under so I know I can attack. I know his game and what he's trying to do." Contrastingly, in competition, participants were less familiar with their opponents so spent time determining what their opponent was trying to do. "I'm trying to get him to move backwards. I'm cutting[2] and he's not moving. I'm thinking what's going on? Normally if I cut, he should move back, but he's not. So I'm trying to process the whole thing and I'm thinking I need to change my tactics". These results confirm previous work on in-competition courses of action which showed table tennis players spent time constructing and validating knowledge of their opponent and strive to build a model of their opponents weaknesses and intentions (Sève & Poizat, 2006). Our findings extend this literature by showing that in training against familiar opponents, players are less likely to cognitively problem solve compared to when they are fighting unfamiliar opponents in competition. In the future it would be interesting to examine whether these changes in cognitive demands would still be observed when players are fighting a familiar opponent in competition. Overall, the triangulation of these results suggests that simply fighting in training is not as cognitively demanding as fighting in competition. This has potential implications for training design, where tasks should be appropriately challenging to the individual to facilitate skill learning (Guadagnoli & Lee, 2004).

4.5.3 Individual and interpersonal behaviour

The second aim of this paper was to assess whether the affective and cognitive demands of the training environment were associated with changes in the fidelity of individual and interpersonal fighting behaviour. Behaviours are of low fidelity when they are not representative of those observed in a reference environment (Stoffregen, 2007). When behaviour in training tasks is of low fidelity compared to competition, it is likely to compromise the transfer potential of sporting skills (Barris et al., 2013a; Pinder et al., 2009). The results of this study reveal that the individual and interpersonal actions of the fighters

[2] The cut kick is a taekwondo kicking technique.

were different in training. In training, participants kicked less, initiated their attacks from further away and displayed more predictable movement displacement. The interpersonal coordination of fighters was also different as the fighter-fighter system generated larger interpersonal distances.

The larger interpersonal distances generated by the fighter-fighter system in this study would suggest that different actions are afforded and supported in training. In the combat sports, action selection is based on the scaled distance between a striker and their target (Hristovski et al., 2006b). Certain distances afford and support specific striking actions. For instance, intermediate interpersonal distances encourage flexible behaviours by affording a greater variety of striking actions (Hristovski et al., 2006b). However, at larger interpersonal distances (those approaching and exceeding an individual's maximum reach) fewer actions are afforded, and at a critical distance, no striking actions are supported (Hristovski et al., 2006b). At these larger interpersonal distances, athletes exhibit less flexible action solutions, perhaps explaining why fewer kicks were recorded in the training environment. Simply put, the distances that fighters spent their time at in training does not afford the same number of actions as the closer distances in competition did, nor does it afford players as many opportunities to develop the flexible action solutions required at smaller interpersonal distances.

These differences may also have implications for perceptual attunement and the way learners educate their attention (Michaels & Jacobs, 2007). A key aspect of learning is attuning to the most useful sources of information to support the selection and control of action (Fajen et al., 2009). As learners progress, the information they use evolves in a Darwinian sense as more useful sources of information are identified (Michaels & Jacobs, 2007). Therefore, if participants spend their time at larger interpersonal distances, they may not be afforded opportunities to attune to the most useful sources of information. The results of this study suggest that when fighting in training, taekwondo athletes are not placed under the same levels of perceptual stress as in competition, where they are forced to co-adapt to opponents movements which are more unpredictable and occur at closer distances. This has possible negative implications for transfer given that players are not practicing adapting to opponents at IPD representative of competition.

These results highlight how emergent behaviour may be shaped by a complex interaction between affect, cognition and action (Headrick et al., 2015). For instance, behaviour in the training environment is associated with lower levels of arousal and anxiety interacting with reduced cognitive demands to constrain the type of fighting behaviour that was observed: fewer attacks and more time spent at interpersonal distances further away from their opponent. These results align with earlier work in sport, which highlights how changes in affect constraints the way people perceive and act within the world (Pijpers et al., 2006). An ecological dynamics approach would suggest that learning is the product of continued agent-environment interactions that lead to the emergence of functional patterns of behaviour (Fajen & Warren, 2003). This means that sportspeople adapt to the environment and social situations they find themselves participating in (Oudejans & Pijpers, 2009; Rietveld & Kiverstein, 2014). This highlights the importance of designing practice simulations that adequately represent the affective and cognitive constraints and demands of the competition environment.

4.5.4 Implications for training design and transfer

These findings highlight a limitation of the focus on preserving or simulating perceptual information from competition to enhance skill learning and transfer (Pinder et al., 2011b). Previous work has focused largely on the information stimulus and action responses of learners; however these results suggest that practice design is a complex issue and requires consideration of other factors such as affect and cognition (Pinder et al., 2015). For instance, fighting in training satisfies principles of representative design as it is predicated upon the same ‘information’ (i.e. another opponent) as the competition environment. However, when fighting in training, taekwondo athletes are clearly solicited by a different field of affordances, which is evident in the low fidelity action responses. To ensure transfer it has been suggested that training tasks should be assessed not by the representativeness of information, but instead by the affordances on offer and the performances they support (Araújo & Davids, 2015). Araújo and Davids (2015) argued that behaviour of lower fidelity is acceptable if it ‘emerges under the constraints of the competitive performance environment. However, for this to be true, our data suggests we may need to also consider not just the informational properties, but the affective and cognitive constraints and demands (Headrick et al., 2015).

One way to sample affordances that solicit representative action, cognitive and affective responses is through following a principled approach such as affective learning design (ALD) (Headrick et al., 2015). One of the claims of ALD is that practitioners need to sample, predict and plan for the potential affective and cognitive circumstances in competition. Practically, ALD suggests creating scenarios and vignettes sampled from the competitive environment so that athletes think, feel and act like they would in competition (Headrick et al., 2015). Therefore, sampling the affordances that consider affective and cognitive demands from the performance environment is an important principle that should be satisfied for the transfer of behaviour between settings (Araújo & Davids, 2015).

4.5.5 Conclusion

This study showed that fighting in training does not entirely simulate the affective and cognitive demands of fighting in competition. These reduced demands are associated with individual and interpersonal behaviour of lower fidelity relative to competition. Therefore, we highlight the importance of considering the often overlooked aspects of affect and cognition when designing representative practice environments. Simply fighting in training does not simulate the constraints and demands of fighting in competition due to lower levels of anxiety and arousal, decreased mental challenge, and different movement behaviour. Consequently, this is likely to negatively impact on skill transfer from training to competition.

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Stage 3 of the PhD (Chapter 4) highlighted that the affective-cognitive demands of fighting in practice do not entirely represent those of fighting in competition. These results revealed that, relative to competition, practicing under reduced affective-cognitive demands lead to fighting behaviour that was of lower fidelity. The implications for learning are that coaches and practitioners need to consider how to enhance the affective-cognitive demands of practice to create truly representative practice tasks. One proposed mechanism identified in Stage 1 of the PhD was through the sampling of scenarios from competition to design emotion-laden learning tasks that simulate the constraints and demands of the performance environment (Headrick et al., 2015). These ideas are harmonious with one of Brunswik's fundamental ideas: sampling situations. Chapter 5 continues to use taekwondo as a task vehicle to explore whether the presence of situational information, such as score and time, can enhance the affective demands of practice.

5 THE PRESENCE OF SITUATIONAL INFORMATION ENHANCES THE AFFECTIVE AND ACTION DEMANDS OF PRACTICE: AN INTERVENTION WITH ELITE TAEKWONDO FIGHTERS

5.1 ABSTRACT

Designing representative learning task is one means to enhance sports practice. Recent work has highlighted how situational information could help the design of these tasks by enhancing the affective demands of practice, however this has yet to be empirically tested. This study tested this hypothesis by manipulating the presence of a scoreboard featuring time and score situational information as expert taekwondo athletes fought in practice.

Nine taekwondo fighters fought in two conditions in a counterbalanced order – with and without the scoreboard. Interpersonal behaviour was assessed by tracking fighters' location coordinates to assess fighter-fighter dyad coordination. Individual actions were assessed through notational analysis and Shannon's entropy to quantify the (un)predictability of technique use. Affect and cognition were assessed with mixed-methods that included perceptual scales measuring anxiety, arousal, mental effort, score perception, and post-fight video-facilitated confrontational interviews to explore how conditions differed.

The results revealed that the presence of the scoreboard had some significant effects on taekwondo fighting. When the scoreboard was present, fighters reported greater cognitive anxiety ($d = 0.39$, $p < 0.05$), somatic anxiety ($d = 1.11$, $p < 0.05$) and emotion intensity ($d = 0.33$, $p < 0.05$); while there were no differences in mental effort ($d = 0.18$, $p > 0.05$). The enhanced affective demands were associated with behaviour changes that included the fighter-fighter system generated closer peak IPD ($d = 0.25$, $p < 0.05$), and more predictable technique selection ($d = 1.04$, $p < 0.05$). Fighters also overestimated their perception of the score ($p = < 0.05$, $d = 1.06$). Qualitative data revealed that players felt more aroused and anxious in the presence of the scoreboard. Players also reported their actions and goals were coupled to the context of scoreboard and that they selected their actions accordingly. Overall, they felt the scoreboard lead to practice that better represented competition. This study reveals that situational information enhances the affective and behavioural demands of

practice. Further, situational sampling affords performers the opportunity to practice attuning to the relevant affordance(s) for a specific context.

5.2 Introduction

One way to enhance sports practice is through the design of representative learning tasks (Pinder et al., 2011b). Representative learning design (RLD) was adapted from Brunswik's (1956) experimental design framework and has largely focused on designing practice tasks that sample informational constraints from competition to preserve the functional coupling between perception and action (Barris et al., 2013b; Gorman & Maloney, 2016; Greenwood et al., 2016; Pinder et al., 2011a). Much of the empirical work in RLD has focused on physical informational constraints (Barris et al., 2013b; Dicks et al., 2010; Gorman & Maloney, 2016; Greenwood et al., 2016; Pinder et al., 2011a). Little work has explored how the presence (or absence) of situational information like time and score shapes the representativeness of behaviour. Sampling representative situations from competition has recently been advocated as a means to create engaging practice tasks that simulate the affective and cognitive demands of performance environments (Headrick et al., 2015; Pinder et al., 2014). The implications for learning design are that sampling situations would afford learners the opportunity to 1) experience the affective-cognitive demands in rich simulations of competition in training, and, 2) practice attuning to the relevant affordances for a given situation. In a taekwondo training environment, one of the simplest ways to sample situational information is by including a scoreboard that provides time and score information during any training fight. The purpose of this study is to explore the affective responses and fighting behaviour of expert taekwondo athletes as they fought with and without the situational-information provided by a scoreboard.

Representative learning design (RLD) allied like concepts from Brunswik's (1956) experimental design framework, representative design, and ecological psychology to provide a principled approach to practice design in sports (Brunswik, 1956; Gibson, 1986; Pinder et al., 2011b). One of the aspects of Brunswik's work that has resonated with sports practitioners is the lens model and the correlation between distal information sources (e.g. the advanced kinematics of an opponent) and a proximal event (e.g. the direction an opponent will move) (Brunswik, 1956; Pinder et al., 2011a). In that sense, sampling informational from the performance environment has been the major focus of the recent application of Brunswik's ideas to learning environments in sport (Barris et al., 2013a; Gorman & Maloney, 2016; Greenwood et al., 2016; Pinder et al., 2011a). However, one of the limitations of this approach is that experimental sampling has generally focused only on physical information sources, despite it being known that performers use other forms of information to guide their behaviour. For example, it is known that football players change their behaviour depending on their pitch location relative to the goals (Headrick et al., 2012). However, it is only by sampling a variety of pitch locations that experimenters were able to adequately understand the extent, and the situations, to which their results were generalizable.

Brunswik also acknowledged the link between context and behaviour, as in addition to sampling representative information, he believed that the study of performer-environment interactions should sample a variety of situations reflective of the demands an individual will face in the performance environment (Brunswik, 1943, 1956). Brunswik termed this 'representative sampling of situations' and advocated for the sampling of likely scenarios where performers aimed to achieve the same goal: The need to consider situational information in task design was recognised in a recent adaptation of Brunswik's lens model. In addition to the physical information provided by an opponent, Pinder et al (2014) theoretically modelled the functionality of situational information such as match context (Pinder et al., 2014) .

Considering situational information in practice design is a means to create rich affordance-laden practice tasks (Araújo & Davids, 2015; Headrick et al., 2015; Ritchie et al., 2017) that provide opportunities for learners to attune to the most useful affordances for a given situation they might experience in competition environments (Correia et al., 2012; Loffing & Hagemann, 2014; Williams, 2009). Attunement to the most useful affordances for a given context ensures performers will select a more optimal action response than they otherwise would (Correia et al., 2012; Hristovski et al., 2006b; Loffing & Hagemann, 2014; Williams, 2009). This process of picking the more optimal affordance is referred to as 'grip'; indicative of the 'grip' that skilled humans have on their environment (Bruineberg & Rietveld, 2014). A trait of a performer who has an optimal grip on their environment is not just being solicited by a preferred affordance regardless of circumstance, but being adaptive and responsive to contextual changes and appropriately engaging with new affordances that emerge (Bruineberg & Rietveld, 2014; Hristovski et al., 2006b).

Sports practice that is predicated only on satisfying principles of sampling physical information may not, in the absence of situational-information, afford opportunities for athletes to practice developing their 'grip', that is, practice selecting the most optimal action response for the appropriate contexts. For example, skilled long jumpers adjust their run-up behaviour depending on the context of the jump (for distance or for accuracy) and basketballers change their attacking behaviour depending on the urgency of the situation (Cordovil et al., 2009a; Maraj et al., 1998). Whilst providing a useful insight into the influence of context on performance, the work above has largely required performers to only "imagine" they are in a particular context. Further, there has been an absence of affective and cognitive variables which arguably provide significant insight into the underpinning processes at play. The implications for practice are that athletes need to practice under the specific situations they will encounter in competition environments so they are able to develop the most appropriate action solutions i.e. as evidenced by the great decision makers.

In addition to shaping emergent behaviour, situational information also affords specific affective and cognitive responses. Previous work has detailed how match score and time situational information influences affective cognitive responses during sport competition (Krane et al., 1994; Ria et al., 2011; Ritchie et al., 2017). For instance, in table tennis, players recalled that their intentions (cognitions) varied depending on the time left in the match (Sève et al., 2005). While in-competition examinations of basketball officials and baseball players provide examples of how the context provided by the interacting effect of time and score is directly linked to their affective responses (Krane et al., 1994; Ritchie et al., 2017). When the context was considered most critical, such as with the scores tied or little time left in the match, participants reported the highest levels of anxiety or stress. These results are in line with the recent theoretical work considering affective learning design which states that one way to enhance athlete engagement in practice might be through the design of emotion-laden learning experiences that simulate the constraints and demands of the performance environment through the inclusion of situation-specific information that provide contexts to tasks (Headrick et al., 2015). Whilst there are theoretical and anecdotal examples (for instance, a national boccia coach documented how he used situational constraints to create "vignettes" in practice that simulated affectively demanding sport-specific scenarios (Pinder et al., 2015)), empirical data is lacking.

In training, athletes often practice without a scoreboard and lack the context of the time and score information. Despite the theoretical and practical implications of designing learning tasks with context-specific information such as score and time, there are no studies that compare how training behaviour, affect, and cognition are influenced by the presence (and absence) of such situational information. One of the claims of affective learning design was that it was possible to engage athletes with emotion-laden learning tasks that through sampling context-specific information (Headrick et al., 2015; Pinder et al., 2015). The inclusion of a scoreboard is one way to achieve this, though this has not been experimentally tested. We aimed to explore how the context provided by time and score impact on athlete behaviour compared to no context.

The aim of this study is to compare how fighting with and without the situational-information provided by a live scoreboard influenced athletes affective, cognitive and behavioural responses. This aim was explored by collecting data from expert taekwondo players as they fought in the presence and absence of a live scoreboard that displayed time and score. Due to the score being visible it was expected that anxiety and arousal would be greater in the scoreboard condition. In line with the previous Chapter, it is expected these affective responses would be associated with changes in individual and interpersonal behaviour, such as players choosing to spend more of their time at, and make more attacks from, closer interpersonal distances in the scoreboard condition. It is also hypothesized that the presence of situational information would impact how performers interacted with their environment. These changes would be reflected in more predictable action selection due to the situational information constraining the field of affordances.

5.3 MATERIALS AND METHODS

The university Human Research Ethics Committee of the first author approved the protocol for this study. All participants provided written informed consent prior to the commencement of the study in accordance with the Declaration of Helsinki.

Participants

Nine international level senior taekwondo athletes (7 male, 2 female) participated in the study. The mean age of participants was 25 years (SD = 5 years). Participants were members of a national team and their demographics can be found in Table 5.1.

Participant	Highest level of competition	World ranking at testing
1	Olympic Games*	6-10
2	Olympic Games*	11-20
3	Olympic Games	11-20
4	Olympic Games	11-20
5	World Championships*	6-10
6	World Championships*	11-20
7	World Championships*	21-30
8	World Championships	101-120
9	G2 International competition	51-100

*Table 5.1 Highest level of competition and world ranking range for each participant. * denotes multiples times competing at the highest level of competition.*

Experimental task

Participants completed a taekwondo fight in two conditions: with and without a scoreboard. The fights were held in a taekwondo training facility that featured competition standard 8.00 m by 8.00 m octagon shaped courts. Each fight consisted of five one minute rounds that were officiated by a qualified referee and used the electronic scoring system consisting of instrumented protective shields, helmets and foot socks (Daedo, Gen 2). The scoring system automatically registers points when fighters kick their opponents with sufficient force. The scoring system was linked to a laptop computer (HP EliteBook) which projected its display to two televisions (Sony, 55 inch) that displayed the time and score. In the scoreboard condition, these screens were visible to participants. In the no scoreboard condition, participants were blinded to the score and the time. This was achieved by removing the screens that revealed the time and score information. Data pertaining to affect, mental effort and behaviour were collected before, during and after the fight.

Procedure

A repeated measures crossover design was adopted and fighting pairs completed each condition on two consecutive days in a randomized order. The procedure for both conditions was identical. The day before testing participants were allocated into fighting pairs and were informed of the order they would complete the conditions. Participants were allocated by the national coach into matched fighting pairs of the same gender, skill level and approximate weight category and fought the same person in both conditions. Upon arrival to the testing hall participants were fitted with heart-rate monitors (Firstbeat Technologies, Finland) and instructed to go about their usual warm-up routine before presenting to marshalling 10 minutes before the fight. At this point participants completed the Sports Competition Anxiety Inventory-2 (Jones, Swain, & Hardy, 1993). Participants then sat for one minute before entering the ring to begin their fight. During this period maximum pre-fight heart rate was collected. Official World Taekwondo Federation rules were adhered to, with one difference; participants completed five by one minute rounds instead of three by two minute rounds. This design was adopted in order to increase the number of data collection points during the fight. During the one minute intervals between rounds, participants completed the Sports Learning Emotion Questionnaire (SLEQ) and provided their perception of the match score. Video data was collected using a digital video camera (Sony HXR-NX30P) positioned approximately 4.00 m above ground level, orientated at approximately 45 degrees to the central point of the court (Bartlett, 2007). The accuracy and reliability of this camera set-up was assessed in Chapter 3. This data was to be used for notational analysis, digitising player movement trajectories to calculate interpersonal distance (IPD), and as a stimulus for the qualitative interview. None of the participants participated in another fight between data collection and their confrontational interview.

Quantitative measures

Affect

Emotion intensity, anxiety and physiological arousal were assessed. Emotion intensity was assessed using the Sports Learning Emotional Questionnaire (Headrick, 2015). The Sports Learning Emotion Questionnaire is a validated tool used to assess emotions in sports practice environments (Headrick, 2015). Anxiety was assessed using the Competitive State Anxiety Inventory-2 (CSAI-2). This scale is validated and commonly used in similar studies exploring anxiety in sport settings (Filaire et al., 2001, 2009; Martens et al., 1990a; Pijpers et al., 2005). Physiological arousal was assessed using pre-fight heart rate.

Mental effort

Perception of mental effort is an insightful measure of task demands. Perceived mental effort was assessed by the Rating Scale of Mental Effort (RSME) perceptual scale (Zijlstra, 1993). This RSME consists of a vertical axis scale with a range of 0-150 and descriptive anchors from not effortful to awfully effortful. It has shown to be reliable across a range of real life settings (Zijlstra, 1993).

Rate of perceived exertion

Borg's 6-20 scale is an accepted tool for subjective measurement of exercise effort (Borg, 1982). The scale is commonly used in exercise settings and is reliable for use with healthy adults (Eston & Williams, 1988).

Score perception

At the end of each round participants were asked to record their perception of the current fight score. They did this by writing what they thought the current fight score to be. We expected the participants to report an accurate score in the scoreboard condition, however, we were particularly interested in player's subjective perception of the score compared to the actual score in the no scoreboard condition.

Behaviour

Individual behaviour was assessed through notional analysis of technique selection and assessment of the IPD that fighters initiated their attacks from. Interpersonal behaviour was assessed by examining the IPD that the fighter-fighter system generated across the duration of the fight (i.e. the frequency of time spent at each IPD as a relative percentage of total fight time). Technique selection was determined through manually coding each attack by each fighter and the leg (front or rear) that the attack was performed with.

Qualitative measures

Qualitative data was collected following the completion of both fights. Participants were asked to complete a semi-structured interview where they detailed the differences between fighting with and without the live scoreboard. An interview guide was formulated prior to study commencement. This guide was reviewed by the lead author and another member of the research team. Open ended questions were designed for use alongside more targeted prompts and questions that would help test our hypothesis that situational information can be used to create affectively engaging practice tasks (Patton, 2002). As this study was interested in the role of situational information on affect, behaviour and cognition, the questions and were directly related to these topics. Probes and prompts were used to increase the consistency in the depth of responses from participants (Patton, 2002). The questions can be found in Table 5.2.

The interviews averaged 39 minutes in length (SD = 7 min). To increase the trustworthiness of the data the interview was performed by the lead author who had an established rapport with the participants as a sport scientist embedded with the team. Because of this established relationship he was able to better relate to the participants through a developed deep understanding of the sport of taekwondo and the use of language and terminology that were native to the sport and familiar to the participants. All interviews were recorded using a digital voice recorder and then transcribed verbatim for analysis.

	Questions
Q1	What are the major differences between fighting with and without the scoreboard?
Q2	How does knowing (or not knowing) the score and time impact the way you fight?
Q3	How does scoreboard presence impact your engagement?
Q4	How does the scoreboard presence impact your arousal levels?
Q5	How does the scoreboard presence impact your emotions?
Q6	How does the scoreboard presence impact your cognitive demands/mental effort?
Q7	How does fighting in practice with and without a scoreboard compare to a competition fight?
Q8	Is there anything else you would like to add about the differences between fighting with and without a scoreboard or anything else we have discussed today?

Table 5.2 Interview questions

Data processing

Technique selection

Notational analysis was performed to identify the time and type of attack and the leg it occurred with. Kicks were coded using video recordings of the fight and in line with coaching manuals attacks were coded as either a side, round, back, axe, vertical, punch or 'other' technique (Park & Seabourne, 1997). Any attacks that could not be determined or did not fit the definitions of one of the previous techniques were coded as 'other'. This data would be used to assess the relative unpredictability of technique occurrence in either condition using Shannon's information entropy. Coding was performed with the aid of a national level coach. Reliability of the coding process was assessed by recoding four randomly selected fights after a two week washout period. An intra class correlation coefficient (ICC) was used to assess the degree of agreement. An acceptable degree of reliability was found: the average ICC for 0.965, 95% CI [.982, .942].

Player location coordinates

Fighter-fighter IPD was determined through tracking player location coordinates. This was achieved by manually tracking players' movement trajectories using digitising software (Kinovea, version 0.8.25). This process provided x and y coordinates for each participant across the duration of their fight. The court was calibrated using the known distances provided by the 1.0 x 1.0 m jigsaw mats that made up the 8.0 x 8.0 m octagon fighting space. Digitising consisted of tracking the centre of mass, the mid-point between fighters' feet. This was chosen due to past research that had used a similar technique in tracking individual movement trajectories (Headrick et al., 2012). An accuracy and inter-reliability assessment was performed on the digitising procedure. These were documented in Chapter 3.

Interpersonal distance was determined using the x and y coordinates of each fighter and Pythagorean Theorem with the following calculation:

$$IPD = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

Following digitising, interpersonal distance was available for each 0.04 second epoch.

Qualitative data

Deductive content analysis was chosen as a methodology to inform qualitative data analysis. Content analysis is a systematic and objective approach to describing and quantifying phenomena (Cole, 1988; Elo & Kyngas, 2008; Sandelowski, 1993). A deductive approach was chosen due to the purpose of the study which was aimed at testing established theory. This approach is useful when analysis is informed by previous knowledge and the purpose of the study is testing theory (Elo & Kyngas, 2008; Hsieh & Shannon, 2005). In this case, we wished to test the theory of affective learning design that situational information (time and score) can provide more affectively demanding practice tasks (Headrick et al., 2015). A feature of deductive content analysis is that prior knowledge can be used to guide data collection and analysis. Therefore, the goal of this approach to content analysis is to validate or extend theory (Hsieh & Shannon, 2005).

To help guide data analysis an unconstrained matrix was developed. The matrix was based on previous work such as theories, models and empirical data (Hsieh & Shannon, 2005;

Sandelowski, 1993). As we were testing the impact of situational information on affective, behaviour, and cognition in practice, the categorization matrix was based on these themes (Hsieh & Shannon, 2005; Sandelowski, 1993). The matrix was informed by the literature review at the beginning of this chapter and the aims of this study. The categories that were decided upon were affective demands, cognitive demands, behaviour, and practice design. This matrix specifically helped guide the analysis process as only data that fit the matrix were coded (Elo & Kyngas, 2008; Patton, 1990). The analysis process consisted of three phases: preparation, organising and reporting (Hsieh & Shannon, 2005). In the preparation phase the researcher immerse themselves in the data. Transcripts were carefully reviewed by the lead researcher who read each of the transcripts in entirety before highlighting text that was relevant to the matrix and making notes.

In the organizing phase, the lead researcher coded the data according to the predetermined matrix categories of affective demands, cognitive demands, behaviour, and practice design. For example, text related to affect was coded as such. Data from within each category were then examined to determine if there were any subcategories required. Finally, data were reported using the matrix's structure.

One of the threats associated with deductive content analysis is the bias a researcher approaches the data with, given they are testing established theory. To limit this threat an audit process was adopted and each category was reviewed by another researcher to verify their validity to the research question (Hsieh & Shannon, 2005). Additionally, to validate the content of each category a panel of experts in skill acquisition and practice design was formed by two of the authors to review and discuss the data and categories.

Statistical Analyses

Paired t tests and general linear mixed models were used where appropriate to assess for differences and effects between condition. Any significant effects from the linear mixed models would be followed up with pairwise comparisons using Bonferoni corrected Alphas. Normality assumptions were visually assessed by constructing QQ-plots from the model residuals. Cohen's d effect size (ES) calculations were calculated using mean difference and mean pooled standard deviations and categorised as small (0.20 – 0.49), moderate (0.50 – 0.79) or large (≥ 0.80) (Cohen, 1988). All statistical tests were performed using SPSS analysis software (Version 19, IBM, U.S.A) and the level of significance was set at $p < 0.05$.

Affect

Dependent t tests were used to compare differences between the scoreboard and no scoreboard condition for the following variables: CSAI-2 factors: cognitive anxiety, somatic anxiety and confidence, and one minute pre-fight heart rate. The SLEQ scores were analysed using a general linear mixed model was to compare the effect of scoreboard presence on emotion intensity. Condition (scoreboard and no scoreboard) and round (5 levels: one, two, three, four, and five) were set as fixed factors and the participants as random factors.

Mental effort

A dependent t test was used to compare differences between the scoreboard and no scoreboard condition for mental effort.

Rate of perceived exertion

A dependent t test was used to compare differences between the scoreboard and no scoreboard condition for rate of perceived exertion.

Score perception

A general linear mixed model was used to compare the effect of scoreboard presence on score perception. Score (two levels: perceptual and actual) and player (two levels: own score and opponent score) were set as fixed factors and the participants as random factors.

Mean interpersonal distance

A linear mixed model was used to compare the effect of scoreboard presence on mean IPD. Condition (two levels: scoreboard and no scoreboard) and IPD (two levels: mean IPD frequency and mean attack initiation IPD) were set as a fixed factors and the participants as random factors. Both variables were assessed for multicollinearity with a bivariate correlation and returned an acceptable moderate association (Field, 2013).

Peak interpersonal distance

A general linear mixed model was used to compare the effect of scoreboard presence on peak IPD. Condition (two levels: scoreboard and no scoreboard) and IPD (two levels: peak IPD frequency and peak attack initiation IPD) were set as a fixed factors and the participants as random factors. Both variables were assessed for multicollinearity with a bivariate correlation and returned an acceptable moderate association (Field, 2013).

Technique (un)predictability

The (un)predictability of technique selection was assessed using Shannon's information entropy (Hristovski et al., 2006b). A general linear mixed model was used to compare the effect of scoreboard presence on technique selection unpredictability. Condition (two levels: scoreboard and no scoreboard) and action mode (two levels: technique and leggedness) were set as fixed factors and the participants as random factors.

5.4 RESULTS

Affect

Participants reported significantly greater cognitive anxiety (Figure 5.2) in the scoreboard condition (M = 15.67, SD = 5.20) compared to the no scoreboard condition (M = 13.89, SD = 4.00); $t(8) = 2.530$, $p = .035$, 95 % CI [0.16, 3.40], $d = 0.39$.

Participants reported significantly greater somatic anxiety (Figure 5.2) in the scoreboard condition (M = 16.44, SD = 1.01) compared to the no scoreboard condition (M = 14.33, SD = 2.50), t(8) = 2.418, p = 0.42, 95 % CI [0.10, 4.12], d = 1.11.

There was no significant difference in reported confidence (Figure 5.2) between the scoreboard condition (M = 18.33, SD = 3.57) and no scoreboard condition (M = 21.33, SD = 4.09), t(8) = -2.268, p = .053, 95 % CI [-6.05, 0.05], d = 0.78.

There was a significant main effect for condition on emotion intensity (Figure 5.1), F(1,81) = 9.567, p = .003. Post hoc pairwise comparisons revealed that in the scoreboard condition players experienced emotions of greater intensity (M = 0.50, SE = 0.16, p = 0.03, 95 % CI [0.17, 0.80], d = 0.33).

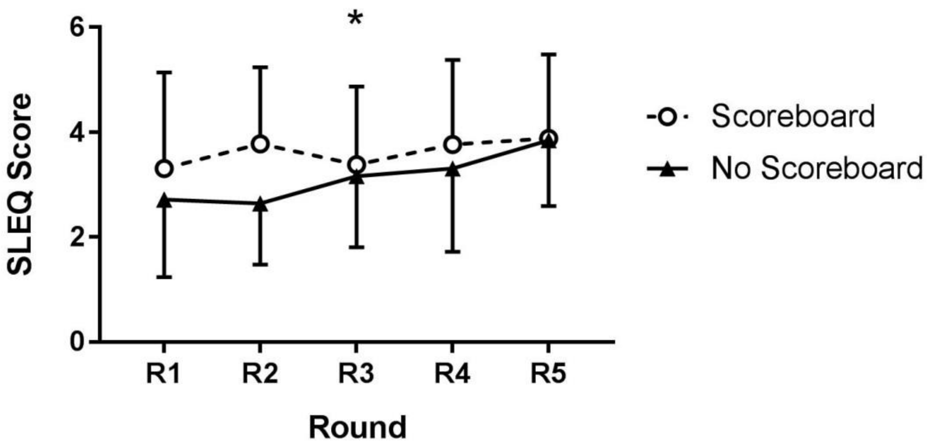

*Figure 5.1 Emotion intensity. Group mean SLEQ scores presented per round with standard deviations for the scoreboard and no scoreboard conditions. * indicates a statistically significant main effect for condition (p = < 0.05).*

There was no significant difference in one minute pre-fight mean heart rate (Figure 5.2) in the scoreboard condition (M = 125.16 BPM, SD = 5.20) compared to the no scoreboard condition (M = 114.78 BPM, SD = 9.34), t(7) = 2.150, p = .069, 95 % CI [1.12, 23.10], d = 0.27. One participant was excluded from analysis due to problems with heart rate data collection in the scoreboard condition.

Mental effort

There was no significant difference between mental effort (Figure 5.2) in the scoreboard condition (M = 89.00, SD = 15.10) compared to the no scoreboard condition (M = 79.30, SD = 14.01), $t(8) = 1.450$, $p = .184$, 95 % CI [-5.66, 25.00], $d = 0.18$.

Rate of perceived exertion

Participants reported significantly greater rate of perceived exertion (Figure 5.2) in the scoreboard condition (M = 16.1, SD = 1.36) compared to the no scoreboard condition (M = 14.8, SD = 1.30), $t(8) = 3.580$, $p = .007$, 95 % CI [0.47, 2.19], $d = 1.19$.

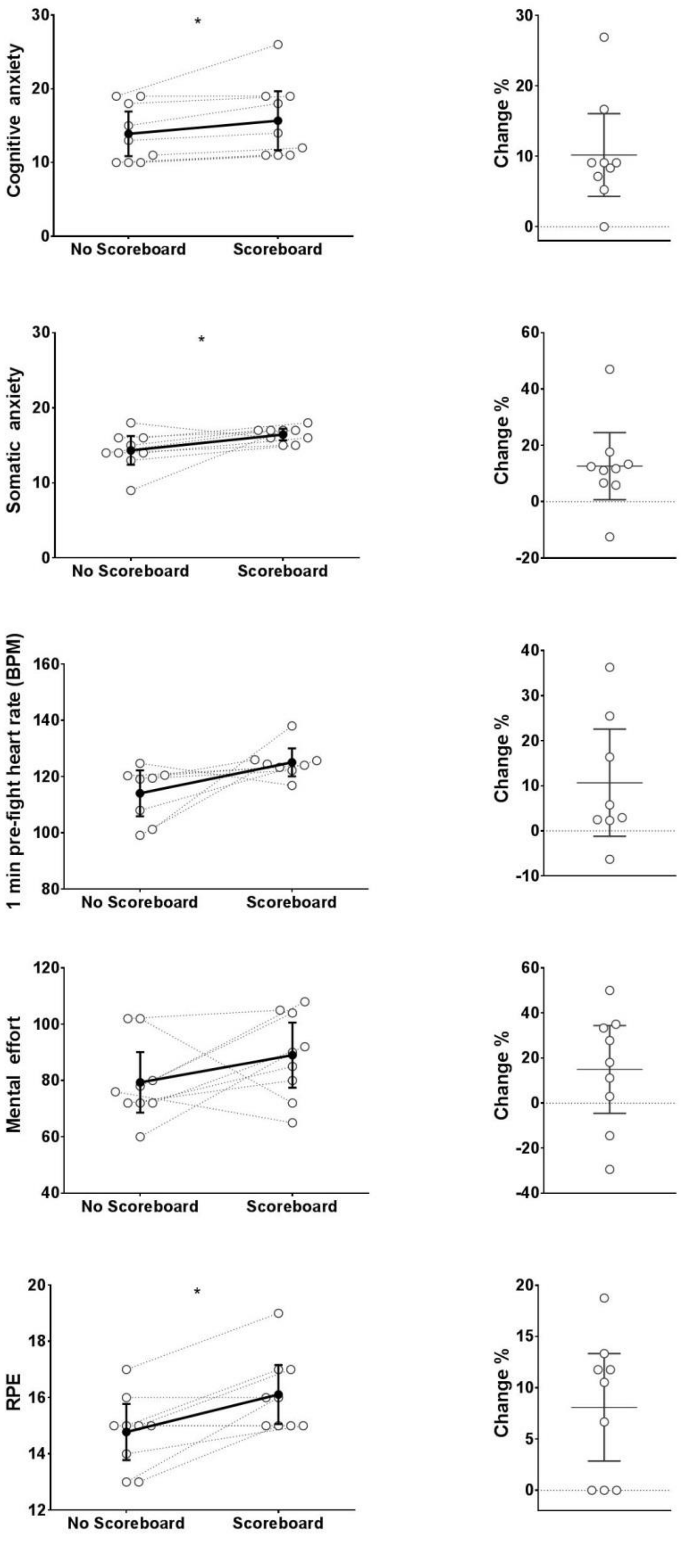

*Figure 5.2 Group and individual results for cognitive anxiety, somatic anxiety, mean one minute pre-fight heart rate, mental effort and RPE. * indicates a statistically significant difference (p = < 0.05).*

Score perception

There was a significant main effect for condition on score perception $F(1,32) = 9.553$, $p = .004$. Post hoc pairwise comparisons revealed that in the no scoreboard condition players significantly overestimated their perception of the score compared to the actual score ($M = 3.00$, $SE = 0.97$, $p = 0.03$, 95 % CI [1.02, 4.98], $d = 1.06$). Therefore, when fighting without the scoreboard, players overestimated the score by three points.

Mean interpersonal distance

There was no significant main effect for condition $F(1,24) = 0.996$, $p = .328$ or IPD $F(1,24) = 0.060$, $p = 0.808$. This suggests that scoreboard presence did not have an effect on the average IPD, and the effect did not differ for IPD frequency (Figure 5.3) or attack initiation IPD (Figure 5.4).

Peak interpersonal distance

There was a significant main effect for condition on peak IPD, $F(1, 24) = 21.600$, $p = 0.000$. Post hoc pairwise comparisons revealed that in the scoreboard condition peak IPD was significantly closer than in the no scoreboard condition ($M = 0.17$ m, $SE = 0.04$), $p = 0.000$, 95% CI [0.09, 0.24], $d = 0.26$.

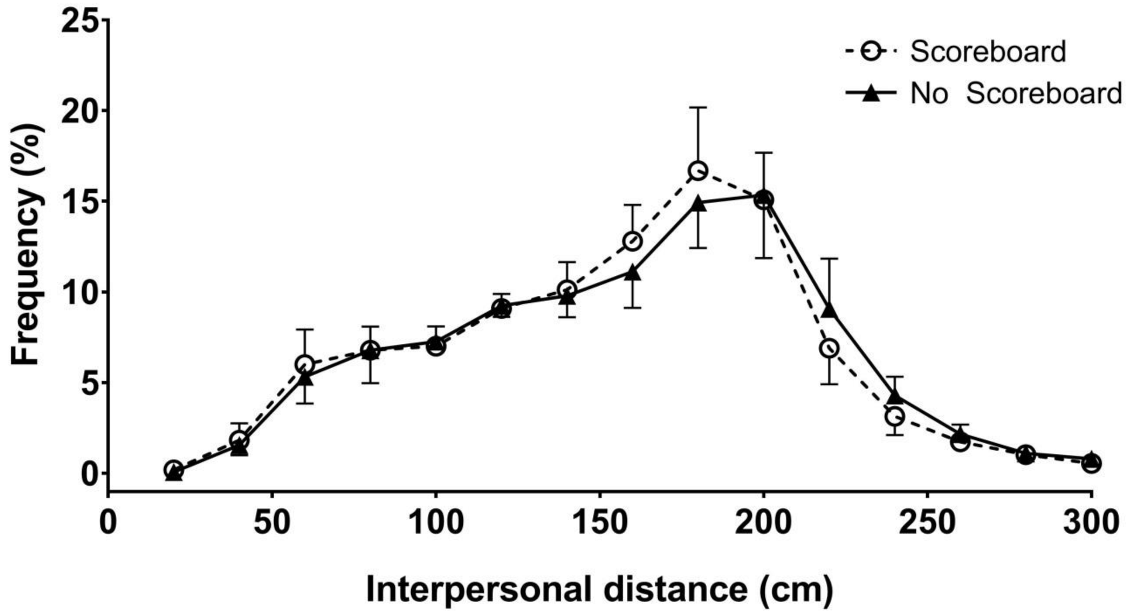

Figure 5.3 Percentage of total fight time spent at interpersonal distances in the scoreboard and no scoreboard conditions. Interpersonal distances are presented in 0.20 m bins with 95 % confidence intervals.

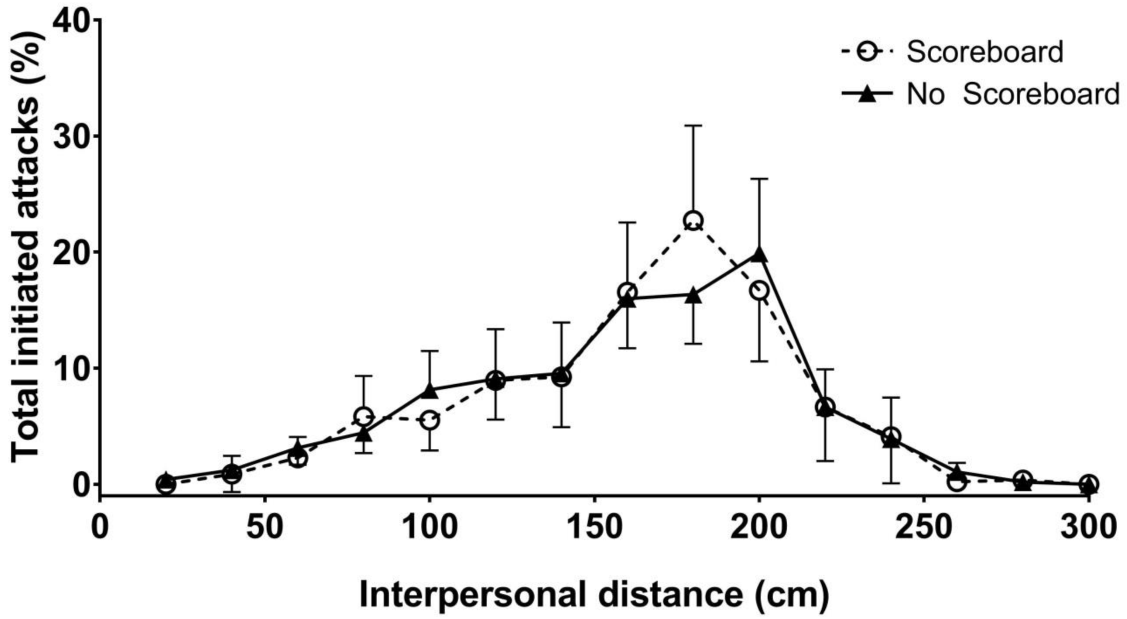

Figure 5.4 Percentage of total attacks initiated at interpersonal distances in the scoreboard and no scoreboard conditions. Interpersonal distances are presented in 0.20 m bins with 95 % confidence intervals.

Technique (un)predictability

There was a significant main effect for condition on technique (un)predictability (

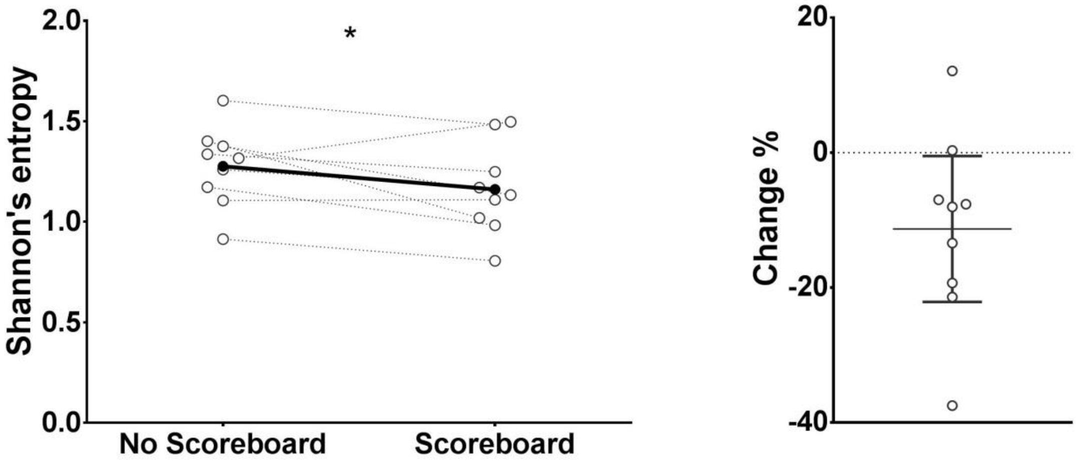

Figure 5.5), F(1,25) = 5.757, p = .024. Post hoc testing revealed that in the no scoreboard condition players technique and kicking leg selection was significantly more unpredictable compared to the scoreboard condition (M = 0.096, SE = 0.40, p = 0.024, 95 % CI [.014, .179], d = 1.04).

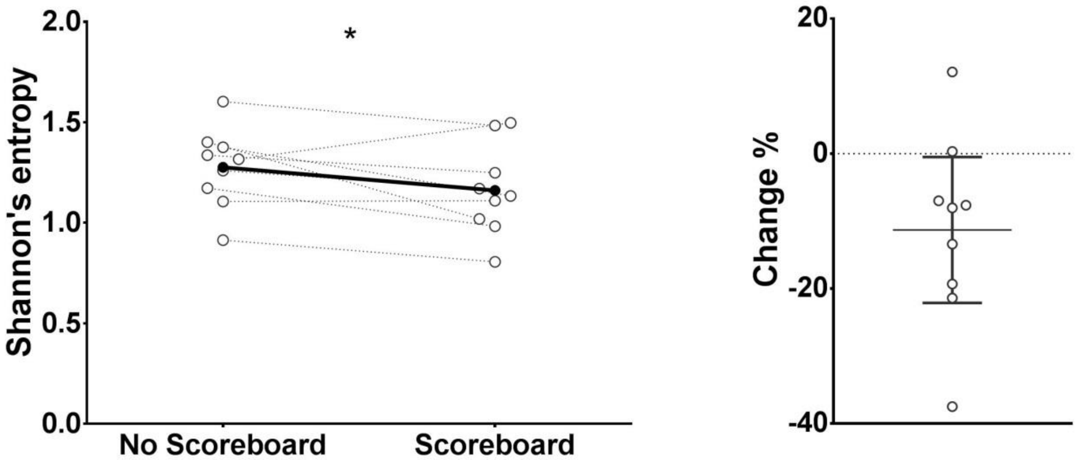

*Figure 5.5 Shannon's entropy scores for technique selection. * indicates a statistically significant difference (p = > 0.05).*

Qualitative data

Content analysis results can be seen summarised in Table 5.3. A number of higher order themes were generated relating to the differences between fighting with and without the scoreboard. These higher order themes are then expanded upon and interview data examples are provided below.

Category	Subcategory	Number of participants	Percentage of participants (%)
Affective demands	Enhanced arousal	8 / 9	89
	Enhanced anxiety	9 / 9	100
	Enhanced engagement	9 / 9	100
Cognitive demands	Enhanced mental effort	3 / 9	33
Behaviour	Constrained task goal	9 / 9	100
	Constrained action selection	9 / 9	100
Practice design	Enhanced representativeness	8 / 9	89

Table 5.3 Categorization matrix detailing categories and subcategories relating to practicing with the presence of situational information in the form of a live scoreboard

Affective demands

Participants revealed that the presence of the scoreboard increased the affective demands of the task and lead to greater amounts of engagement. All participants specifically highlighted increases in their arousal and anxiety: “It (the scoreboard) definitely increases arousal levels. You’re definitely a lot more primed. My arousal level went through the roof as soon as I knew the scoreboard was there” (participant 2). “It made me really anxious. Having the scoreboard straight away gave me a lot more anxiety than not having it there. You know, everyone is watching and it’s suddenly a lot more serious. Personally, I take it a lot more seriously” (participant 1).

The participants revealed that the emergence of anxiety and arousal was due to the presence of situational information. They revealed how time and score information interacted to create affectively demanding task situations. "When the scores are even and you know there is not long left in the round, you definitely feel that pressure that you need those points. Especially if there is only one round left and so you might feel more rushed and lose the tactics you're planning on doing" (participant 3).

Participants also revealed that when the scoreboard was present they felt greater emotional engagement in the task: "It definitely impacts your emotions across the fight. Down (on points), you can get frustrated and start charging in and start attacking. If you're up you get a feeling of contentness (sic) or happiness with what you've done. Having the scoreboard makes me more aroused and more stimulated purely for the fact that I was much more into it. It made me more interested in what I was doing and take it more seriously" (participant 8).

Cognitive demands

Mixed findings were observed for the cognitive demands of the tasks. Many players felt both tasks had cognitive demands, albeit different in nature: "I was quite stimulated by both, however in different ways. Like, I really enjoyed fighting without the scoreboard as I was challenged by playing and trying new things" (participant 9). This quote suggests that this fighter found mental challenge in both tasks.

Behaviour

All participants revealed that the scoreboard constrained both their action selection and their task goals. In respect to action selection, players spoke about how the situational information narrowed the field of affordances on offer, constraining the actions that were optimal for a given context: "With the scoreboard there, I know what's going on. I know if I need to fight harder or fight less, fight smarter. If I was winning, I would know to be defensive, if I was losing by a little, I know to aim for some sneaky points. If I was losing by a lot I would know to try some spin points" (participant 9).

Players spoke about how their task goals – how they intended to behave for the duration of the fight - were also constrained by the presence of the scoreboard. In the absence of the scoreboard they generally felt like they could explore, practice, or try something new. However, in the presence of the scoreboard they felt bound to the context of the fight. "Without the scoreboard my aim was just to practice what I was working on rather than be bound to the context of the fight. I felt like I could try what I want and not worry about match context. I'm more likely to sit and park when I'm up by a few points, while with no scoreboard I was just thinking about continuing to play. I feel like I can just try things out. There was no pressure to fight certain ways … I feel freer without the scoreboard. With the scoreboard I always feel like the pressure is there, I need to score points or I'm worried about losing" (participant 8).

Practice design

Participants believed that the training task with the scoreboard is more representative of competition. "Because it's more match-like. You knew the other opponent was wanting to outscore you and you know how many points each person is on. At the end of the day it's the most realistic training activity to the competition day itself, so we do want to practice that" (participant 1). Participants spoke about how the presence of situational information lead to the emergence of a variety of feelings, thoughts and behaviours that were more like those of competition. "It (the scoreboard) can be a good thing. If I'm under aroused that can fire me up and get me in the right place for training. Having the scoreboard it made me think okay what do you have to do? Do it properly. Take this seriously. Without the scoreboard I sort of slipped in and out of concentration. In the match with the scoreboard I was in it for the whole time. I stayed focused for the whole time that I had to. The scoreboard there makes it feel a lot more real. Makes it feel like it's sort of more important, which obviously would make me engage more in the match and be more interested as well" (participant 6).

5.5 DISCUSSION

Much of the applied research in representative learning design has focused on physical information. One factor that for many sports is always present in competition is the situational-information provided by the match score and/or time. While this factor has been touched on in in theoretical explanations of representative practice design, there is little empirical work exploring the impact of situational information. Therefore, there is little understanding around how context, or the lack of, might shape emergent training affective, cognitive and behavioural responses. The aim of this study was to compare how practicing with and without the situational-information provided by a live scoreboard influenced athletes affective, cognitive and behavioural responses of expert taekwondo fighters.

When fighting with the situational-information provided by the scoreboard, participants reported higher levels of anxiety, arousal, and emotional intensity; suggestive that sampling situational-information like time and score from the competition environment can increase the magnitude of affective responses. These increased affective responses in the presence of the scoreboard were associated with changes in individual and interpersonal behaviour. The IPD that players were most attracted toward to initiate attacks, and the IPD that the fighter-fighter system was drawn toward were both significantly closer. Additionally, fighters were more predictable in the type of kicking techniques they used. These findings are supported by interview data which revealed players felt constrained by both time and score situational-information. In relation to our aim, the quantitative and qualitative data provides evidence that practicing in the presence of live time and score enhances the affective demands which in turn leads to specific changes in behaviour as players' movement solutions are reduced to satisfy narrow situational task goals. Therefore, our findings support the theoretical modelling of affective learning design that the use of situational information can enhance affective engagement in practice tasks. These findings will be discussed alongside implications for training design, such as the use of the scoreboard as and when required depending upon practice session goals.

5.5.1 Differences between fighting with and without the scoreboard

The aim of this study involved comparing the behavioural, cognitive and affective demands of fighting with a scoreboard relative to no scoreboard. We assessed behaviour by measuring the distance-time coordination strategies of each fighter-fighter system (IPD frequency and attack initiation IPD) and through analysis of kicking technique (un)predictability. The results revealed that there was no difference in the mean IPD between fighters; however there were differences in the peak IPD regions that fighter-fighter systems were attracted towards. When the scoreboard was present, the peak IPD region the fighter-fighter system was attracted to was 0.17 m (±0.04) closer. Essentially, while the mean IPD did not change, a change in peak IPD suggests fighters preferred IPD did. These results are in line with earlier work in this thesis that suggests fighters generate smaller IPD when aroused and affectively engaged in a fight. In addition to these constraints, the situational information provided by the scoreboard also influenced the physical intensity of the fight and higher RPE values were recorded in the scoreboard condition. This is line with previous work that reveals trained athletes are more aggressive with their RPE strategies when provided with concurrent duration feedback in fixed time tasks (Swart et al., 2009).

Players were also more unpredictable with their technique selection in the absence of the scoreboard. Particular insight was provided by the qualitative data which detailed how players felt constrained by the presence of the scoreboard and felt like they had to act in certain ways. While without the scoreboard, they felt freer and able to explore and try new things. This result aligns with previous work that reveals the number of action solutions to a task can increase when the task constraints are relaxed (Hristovski et al., 2011). For example, a study of boxers revealed that by relaxing the task constraints by removing the need for conventional technique, highly innovative striking actions emerged (Hristovski et al., 2011). In contrast, practitioners can also narrow the task constraints by adding more information to facilitate the emergence of specific movement solutions. Through the use of time and score contexts practitioners can design environments that replicate the affordance field on offer during specific competition situations. This will be discussed in greater detail in the final section.

In respect to cognitive variables, the results revealed no difference in mental effort between conditions. However, in the absence of the scoreboard taekwondo athletes were poor at perceiving the actual score. Significant differences were observed between the actual score and players' perceptions of the score when they were unable to view the scoreboard. On average, fighters overestimated the number of points they had scored by three points. We believe this is a practically significant over-estimation as the previous five Olympic Games (2000 – 2016) gold medal fights have been won by an average of 2.65 points. In the absence of the scoreboard, competing players may have conflicting understandings of match context. Skilled performers are attuned to contextual information and use this information to better anticipate their opponents moves (Abernethy et al., 2001; Farrow & Reid, 2012; Williams, 2009). An incorrect understanding of match context during practice may have implications for how performers learn to couple the appropriate actions to situational information.

5.5.2 The simulation of affectively engaging practice tasks with the scoreboard

Practicing under similar affective demands to those experienced in performance environments is one way to enhance skill transfer (Oudejans & Pijpers, 2009). However, there is a lack of empirical work in sport that explores ways for coaches and practitioners to create affectively demanding practice tasks (Pinder et al., 2015). One of the key practical applications of affective learning design was the suggestion practitioners prescribe emotion-laden practice tasks that create engagement through the simulation of situations from competition. Results from the perceptual scales, interviews, and pre-fight heart rate all supported the hypothesis that fighting with the situational-information provided by time and score would enhance the affective demands of practice. Our measures of anxiety were collected at the beginning of each bout, i.e., before the fight at started, suggesting that just the mere presence of the score can create affective responses. This result is line with other experimental work which has used a scoreboard as a common anxiety manipulation in a variety of studies due to its ego-threatening nature (Mullen & Hardy, 2000; Nibbeling et al., 2014; Wilson et al., 2007b). Additionally, when the scoreboard was present the SLEQ results revealed players experienced a greater intensity of emotions throughout the fight, a finding that was also supported by the interview data. These findings provide evidence that the situational-information provided by the time and the score can enhance the affective responses of athletes in practice tasks.

5.5.3 Theoretical and practical implications for representative practice design

This data adds further support to the consideration of task sampling when designing representative learning tasks in sport. The application of this idea to skill learning tasks would include practicing a skill under all the varying contexts that can be expected to be experienced in the performance environment. By sampling situations in learning tasks, practitioners are able constrain the landscape of possible affordances on offer to individuals. As a situation becomes increasingly constrained (e.g. by the score, time, or evolving knowledge of how to score on an opponent), the number of available and functional action solutions become fewer (Fajen & Warren, 2003). That is, as more information becomes available, the way the performer must functionally interact with the environment becomes more specific (Araújo et al., 2006). Therefore, if a movement system is operating within a set of specific constraints; their set of optimal task solutions is significantly narrowed. For instance, the presence of time and score in our study constrained the movement solutions possible which was evident in the enhanced predictability of kicking techniques and the interview data. It was highlighted earlier that experts have a superior ‘grip’ over their environment, evident in their attunement to the most relevant affordances for a given context. Given behaviour is adaptive in nature, the development of an optimal grip in and the education of attention toward relevant affordances could only occur via continued exposure to these constraints (Fajen & Warren, 2003; Rietveld & Kiverstein, 2014). Therefore, the findings highlight the need to practice under the constraints and demands likely to be experienced in competition so that players can practice attuning to the relevant action solutions for a given situation (Michaels & Jacobs, 2007).

Understanding what situational-information affords in terms of behaviour can help practitioners design appropriate learning environments. Our data revealed that in the absence of context provided by score and time, players felt more able to explore, and were more unpredictable in their movement behaviour, highlighting that they were less constrained to specific movement solutions. Therefore, if the goal of the session is to explore, then having time limits or keeping score may not be beneficial. Alternatively, if the session is about practicing skills under anxiety, then the context provided by time and score could be helpful as we revealed the mere presence of the situational-information provided by the time and score leads to increased anxiety. Understanding the affective and behavioural responses afforded by certain tasks can help practitioners better align learning tasks to these needs. This satisfies one of the additional claims of affective learning design, which calls for the design of practice tasks that cater to the needs of individuals (Headrick et al., 2015).

5.5.4 Conclusion

This study reveals that situational-information sampled from competition in the form of time and score affords athletes (1) immersion in affectively engaging practice tasks, and (2) the opportunity to practice attuning to the most relevant affordances for specific contexts. When fighting with situational-information of time and score, expert taekwondo players' exhibited enhanced affective and different behavioural responses relative to when that information is absent. In summary, this study highlights how situational information can be sampled to create truly representative learning tasks that provide affectively engaging practice experiences.

6 GENERAL DISCUSSION

6.1 INTRODUCTION

To date, RLD has largely focused on ensuring that practitioners design learning tasks that sample the physical task and environmental informational constraints that support behaviour in competition. The limitation of RLD to date is the neglect of emotions in practice design. Therefore, the overarching aim of this thesis was to explore affect and representative learning design by examining the representativeness of a variety of combat sports practice tasks. To examine this issue a series of three experimental studies were conducted, reported, and discussed. This section is in comprised of two parts – a review of the findings and a general discussion. Specifically, the focus will be on an overview of pivotal findings and implications from this PhD, and how they might inform future research and practice.

6.2 REVIEW OF THE FINDINGS

6.2.1 Chapter 3: Information for regulating action selection in taekwondo: behavioural correspondence between static and dynamic opponent constraints

Stage 1 of the PhD highlighted a common non-representative combat sports task featuring a static bag or pad that lacks the kinematic information and threat provided by a live opponent. Previous work has suggested that the information provided by an opponent is a key constraint of combat sports (Davids et al., 2012; Hristovski et al., 2006b, 2009; Milazzo et al., 2016; Okumura et al., 2017). However, these findings are divergent and conflicting most likely due to experimental designs that consist of similar static or non-threatening targets (e.g. Hristovski et al., 2006b, 2011; Milazzo et al., 2016; Pozo et al., 2011). Therefore, there was a need to examine how behaviour might differ between static non-threatening and live threatening opponents. This topic was explored in a multi study Chapter: the first study replicated the work of Hirstovski et al. (2006) to examine the action selection of taekwondo players as they struck a static target. The second study examined the action selection of taekwondo players during a competitive fight.

The first study found that the emergent actions of taekwondo players were controlled by the parameter of distance to target. These findings are novel in a taekwondo task and also reveal how the unique task constraints of each combat sport lead to different performer-environment interactions. The findings of this study revealed striking behaviour emerged at different IPD compared to previous examples of kendo and boxing (Hristovski et al., 2006b; Okumura et al., 2012). Together, it is suggested that the slight variations in task constraints of the various combat sports alter the way performers interact with the environment.

Study two revealed that the threat provided by a live opponent acted as a constraint on the action selection of taekwondo fighters. Performers were sensitive to the threat provided by a live opponent and organised their behaviour accordingly. This was evident in fighters choosing to spend a large portion of their fight time at IPD beyond the reaching capabilities of their opponent. Further, large amounts of inter-individual variation in attack initiation IPD was observed, suggesting that combat performers adopt an affordance based control strategy where attacks are initiated according to the individual constraints of each fighter. Examples of these constraints include speed, power, decision making skill and intentions. The overall findings of this study provide the first evidence of the limited representativeness of combat sport tasks that lack the threat of a live opponent. Low behavioural correspondence was observed between striking a static target and striking a competitive opponent. This was evident in the competitive fight where participants initiated their attacks from a much greater IPD than the participants in the static target study. This result highlights how the threat of an opponent provided important information for regulating action in combat sports. The contribution of this study is that performer-environment interactions in combat sport are detrimentally altered by decomposing a common task through the removal of a threatening opponent. Practically, these results provide evidence for the importance of representative learning design in combat sports and highlight some limitations of common combat training tasks like pad work and unopposed or cooperative/facilitated practice that lack the threat of a live opponent (Pinder et al., 2011b).

6.2.2 Chapter 4: Taekwondo fighting in training does not simulate the affective and cognitive demands of competition: Implications for behaviour and transfer

Much of the research exploring RLD has highlighted the need for practice task constraints to represent those from the performance environment (Barris et al., 2013a; Dicks et al., 2010; Pinder et al., 2011b). This work has generally focused on external informational, task and environmental constraints, such as the presence of opponents and how this might influence movement behaviour (Gorman & Maloney, 2016; Pinder et al., 2011a). However, this line of inquiry has neglected to examine the role of affect and cognition, and how these variables might contribute to the fidelity of behaviour observed in practice tasks. Further, there is limited understanding around whether the affective and cognitive demands of typical sports practice environments and tasks represent those experienced in competition. The next study in this PhD programme explored this issue by comparing taekwondo fighting in practice with fighting in competition.

Data was collected from 10 highly-skilled Australian Taekwondo athletes as they fought in both practice and a simulated competition. The results revealed that in practice, athletes had lower anxiety, arousal, and mental effort. Qualitative data supported these findings, with confrontational interviews revealing the emergence of cognitions and affect specific to the training environment. These results were associated with changes in the fidelity of individual and interpersonal behaviour. In training, performers displayed more predictable movement behaviour, attacked less, but when they did attack they were initiated from further away.

The results provide the first evidence that typical sports practice environments may not adequately simulate the affective and cognitive demands of the same task in competition. However, perhaps the most impactful finding is that under reduced affective and cognitive demands, and despite the task constraints being identical, performers displayed decreases in action fidelity relative to competition. Overall, these results extend previous work in RLD to highlight the importance of considering the often overlooked aspects of affect and cognition when designing representative practice tasks. Practitioners must carefully consider how they create practice task that have purpose and consequence to solicit representative affective responses that will lead to action fidelity in line with that seen in performance environments.

6.2.3 Chapter 5: The presence of situational information enhances the affective and action demands of sports practice: an intervention with elite taekwondo fighters

A main focus of designing representative sports practice tasks has been adapting Brunswik's ideas related to sampling key informational cues from the performance environment (Brunswik, 1956; Pinder et al., 2011b). However, this approach has neglected one of Brunswik's other fundamental ideas – sampling situational information (Brunswik, 1943). Further, situational information has been theorized as a mechanism to enhance the affective demands of practice (Headrick et al., 2015). Previous work exploring emotions experienced during completion has highlighted that the most affectively demanding situations were those in which the scores are close and little time is remaining on the clock (Krane et al., 1994; Ritchie et al., 2017). Therefore, using information like time and score to provide context to practice tasks could simulate engaging and competition-like experiences for athletes.

This next Chapter explored this issue by manipulating the presence of a live scoreboard featuring time and score information. Nine expert taekwondo athletes fought in two conditions – with and without the scoreboard. The results revealed that the presence of situational information (i.e. time and score) lead to increases in anxiety and arousal. Further, the action fidelity of athletes improved as their behaviour more closely resembled the competition behaviour observed in the previous Chapter – more time spent at, and attacks initiated from, closer IPD. However, when the scoreboard was present, performers kicking techniques were more predictable. The qualitative interview data provided insight to this finding, revealing that performers felt their actions were coupled to the score on the scoreboard. In contrast, in the absence of any time and score information, performers felt free to explore and perform a variety of techniques.

In this study the presence of situational information clearly afforded enhanced affective demands. This is the first evidence that situational information is an effective means of enhancing the affective demands of practice tasks. It also confirms a key claim of affective learning design that situational information is a mechanism to create engaging and affectively demanding practice tasks (Headrick et al., 2015). Representative practice design is predicated upon sampling informational variables from the performance environment. These findings contribute significantly to extending the framework of RLD and suggest that to design truly representative practice tasks practitioners need to also consider sampling situations in the same way they would physical information.

6.3 DISCUSSION

This section will highlight and summarise the major themes of this PhD programme. Each theme will be identified with a heading, with findings and implications discussed within each section. Finally, the section will conclude with a discussion centred on the limitations of this PhD work and potential future directions.

6.3.1 Representative task design in the combat sports

These findings build on previous work highlighting that combat athletes organise their behaviour according to the specifying information provided by their opponent, the distance they stand from their target, and the degree of threat their opponent poses (Hristovski et al., 2006b, 2009; Milazzo et al., 2016). One of the major contributions of this body of work is some guidance guiding combat sport task design for research and practice. This is an important topic for researchers and practitioners alike, as identifying the information that combat athletes use to regulate behaviour is critical in order to design representative tasks.

This programme of work revealed a number of variables which constrain fighting behaviour. Stage 2 revealed that the presence of a threatening opponent provides specifying information that constrains the emergence and regulation of fighter-fighter dyads. In Stage 3, the affective and cognitive demands of the task constrained general behaviour of the taekwondo fighters and lead to changes in time spent at IPD, attack initiation IPD and the (un)predictability of movement trajectories. While in Stage 4, the situational information provided by fight time and score shaped the predictability of technique selection and the level of anxiety and arousal experienced by athletes. Overall, they highlight how the emergence of sporting behaviour is predicated upon a complex interaction of task, environmental and individual constraints. Practitioners and researchers need to carefully consider which aspects of competition they sample in task design and understand the potential limitations if they fail to do so.

Further, Stage 2 confirms that the measure of interpersonal distance is an order parameter representative of the state of a fighter-fighter system in taekwondo. Identifying a variable that describes the macro organisation of a movement system is of great use to movement scientists as it affords the capability to capture the organisational state of a system (Davids et al., 2006b; Turvey, 2007). This was a significant methodological advancement given previous research in taekwondo has failed to consider the organism-environment system, instead overwhelmingly focusing on the performer (Davids & Araújo, 2010). With such a variable identified, taekwondo provides an appealing task vehicle to study adaptive behaviour and test established motor learning theories and laws established using single joint and/or non-representative lab based task (Davids et al., 2006b).

Finally, much of the work exploring combat sports and IPD has been in sports other than taekwondo and provided divergent results. For example, boxers are attracted to significantly shorter IPD than kendo athletes (1.0 scaled arm lengths compared to 2.60 m) (Hristovski et al., 2006b; Okumura et al., 2012). The findings of this PhD further add to the divergent results found in the literature with the taekwondo athletes in this series of studies attracted to an IPD (1.80m or 1.75 scaled leg lengths) somewhere in between boxers and kendo athletes' preferences. However, when considered together, these findings to have some common ground and suggest the preferred IPD adopted by combat athletes is largely organised according to the length of implement an opponent wields (Dietrich et al., 2010). For example, kendo athletes prefer to stand the furthest away because their opponent has a weapon length that includes a 1.20 m stick plus some portion of the wielders arm length. This conclusion highlights that performance emerges from performer-environment interactions and reinforces the need to design representative practice and research tasks that adequately sample the constraints of each sport (Araújo & Davids, 2015; Dicks et al., 2009; Gorman & Maloney, 2016).

6.3.2 Affect, action fidelity, and designing representative practice tasks

Stage 1 of the PhD programme highlighted how practicing under affective demands such as anxiety can help protect performers from the detrimental effects of high pressure situations (Mace & Carroll, 1986; Oudejans & Pijpers, 2009, 2010). One of the implications of the review of the literature was that sports performers should practice under affective demands to facilitate skill transfer and performance under pressure in high stakes competition (Oudejans, 2008). However, a large gap in the literature was revealed as it was identified that it is unknown whether practice tasks adequately simulate the affective demands of competition and what effect practice task demands might have on perception-action behaviour. This issue was explored in Stage 3, revealing that typical practice tasks do not adequately simulate the affective demands of competition and negatively impact action fidelity. The findings have significant practical application for practice designers in that they highlight how perception and action behaviour is shaped by the interaction with thoughts and feelings.

Stage 3 of the PhD contributes significantly to a growing body of literature examining learning design in sport as it is one of the few pieces of empirical work to capture the interaction between affect, behaviour and cognition (Headrick et al., 2015). These findings build on the recent theoretical development of affective learning design, highlighting how each of these factors (affect, behaviour and cognition) act as important control parameters for performance. For example, fighting behaviour in the practice is associated with reduced arousal and anxiety interacting with mastery goal-orientations to constrain individual and interpersonal behaviour: fewer attacks and more time spent at IPD further away from their opponent. This concept is further supported by the findings of the next Stage, Stage 4. When asked to fight in the presence of the scoreboard, fighters were more aroused and anxious, which was associated with behaviour that was more similar to the competition behaviours observed in the previous Stage. These findings build on previous work examining how affect can alter the perception-action relationship (Pijpers, 2006; Stefanucci et al., 2008). Many of these studies have been in either closed or single person contexts (Lawrence et al., 2014; Nieuwenhuys et al., 2008b; Oudejans & Pijpers, 2009). This PhD highlights that this phenomenon generalizes to more complex and interpersonal sporting contexts.

These findings also extend representative practice design by highlighting how action fidelity is influenced by factors other than physical environmental and task constraints. In Stage 1 of the PhD programme examples were provided to show that practice tasks that did not represent the informational constraints of the performance environment lead to movement organisation that was of low fidelity relative to the competition task (Dicks et al., 2010; Pinder et al., 2011a). Such work formed a basis for the recommendation that preserving the fidelity of movement behaviours is an important aspect of practice design. Previous considerations of action fidelity have largely focused on the authenticity of physical information in practice simulations (Passos et al., 2017; Pinder et al., 2011a; Stoffregen et al., 2003; Travassos et al., 2012). Such findings have led to suggestions that behaviour of lower fidelity is acceptable if it emerges under the constraints of the competitive performance environment (Araújo & Davids, 2015). However, this data suggests that affect, cognition and action are intimately linked and practice designers should consider not just the informational properties of a task, but also the affective and cognitive demands (Headrick et al., 2015). These claims are supported by previous work exploring behaviour in police training tasks where behaviour changes were evident under increased affective demands (Nieuwenhuys et al., 2012b).

One of the key tenets of representative learning design is that emergent actions under practice task constraints must represent those observed in competition (Pinder et al., 2011b). However, in Stage 3 it was revealed that despite the informational constraints of practice mirroring those of competition, the fidelity of performer behaviour was negatively influenced by the reduced affective and cognitive demands of practice. When fighting under reduced affective demands, performers organised their interpersonal and individual behaviour differently than in competition as they moved more predictably, attacked less and attacked from greater IPD. Previously, empirical advances to principles of practice design had focused largely on sampling ecological informational constraints. However, the findings from this PhD highlight that in addition to sampling information, practitioners must also consider sampling affective and cognitive affordances from competition, such as the situational information explored in Stage 4 of this PhD.

6.3.3 Situation sampling: implications for practice and research

Originally intended as an experimental design framework, representative design has been contemporised and adapted to sport under the framework of representative learning design through the work of a number of researchers such as Dicks, Pinder and Barris under the guidance of Araujo and Davids (Barris et al., 2013b; Dicks et al., 2010; Pinder et al., 2011a). One aspect of Brunswik's work that has resonated with these practitioners is the lens model and the probabilistic association between distal and proximal events (Brunswik, 1956; Pinder et al., 2011a). For example, many of these studies have explored how the manipulation of distal information sources influence behaviour (Dicks et al., 2010; Pinder et al., 2011a). These studies have largely focused on perceptual information sources, despite other sources of information also contributing to the selection and realisation of affordances (Headrick et al., 2012; McCobert et al., 2011; Murphy et al., 2018). Largely absent is Brunswick's idea on sampling situations (Brunswik, 1943). These ideas were recognised in a recent adaptation of the lens model, which modelled the functionality of situational information (Pinder et al., 2014). The testing of Brunswik's idea on sampling situation and the associated extensions of RLD are perhaps the most impactful theoretical contribution of this PhD.

These ideas were tested and discussed in Stage 5 of the PhD. The findings of this Stage contribute to the debate about affordance selection and decision making in sport (Araújo et al., 2006; Fajen et al., 2009). How performers select one affordance over another has been a point of discussion within the literature (Bruineberg & Rietveld, 2014; Rietveld & Kiverstein, 2014; Withagen et al., 2012). The findings of Stage 5 of the PhD support the theorizing of Bruineberg and Rietveld (2014) that performers use situational information to guide their search for the most functional affordance for a given situation. This was evident both qualitatively, in the way performers reported their actions were coupled to the scoreboard, and quantitatively, by the increased predictability of technique use when situational information was present.

One of the main aims of ecological inspired approaches to practice task design is to ‘design in’ the same affordances present in competition (Araújo & Davids, 2015; Araújo & Passos, 2007). These findings suggest that sampling situational information may be a mechanism to achieve this. In the context of taekwondo, the information provided by time and score seems to narrow the landscape of affordances on offer, constraining the behaviours that are optimal for the given situation and shaping the way performers interact with the environment (Araújo et al., 2006; Hristovski et al., 2011). Sampling situational information would afford performers context and the opportunity to practice selecting the most functional affordances for (likely) common competition situations. These findings add support to the consideration of situational sampling, in addition to information sampling, when designing representative learning tasks in sport. The application of this idea to skill learning tasks would include practicing a skill under all the varying situations that can be expected to be experienced in the performance environment.

One hypothesis tested in this PhD was the use of situational information to create affectively demanding and engaging practice tasks. This idea had previously been theorised, however was lacking empirical data (Headrick et al., 2015). The findings reveal that sampling situations has the potential to be a successful strategy to create affectively engaging practice tasks for experienced and highly skilled performers. For example, Stage 5 revealed that even experienced taekwondo athletes with many years of international competition experienced increases in arousal and anxiety in the presence of the scoreboard. This is a significant contribution as previous experimental and practical manipulations in sporting tasks have often adopted non-representative means such as performing tasks at height or through the use of ego-threatening, punishment or reward stressors (Gray & Cañal-Bruland, 2015; Nibbeling et al., 2012a; Oudejans & Pijpers, 2009; Stoker et al., 2017).

Many of the stressors mentioned are primarily based on ego motivators (e.g. reward, judgment or punishment stressors) which are not always a sustainable or effective way to facilitate learning and/or performance (Cerasoli & Ford, 2014; Ryan & Deci, 2000; Smith et al., 2007; Vink et al., 2015; Wulf & Lewthwaite, 2016). Alternatively, intrinsically motivated performers are able to fulfil their psychological needs by engaging in tasks from which they derive a sense of personal satisfaction, competition and fulfilment (Headrick; Renshaw, 2012; Ryan & Deci, 2000). The use of situational information is a representative means to create affectively demanding and engaging practice tasks capable of fulfilling learner's needs.

While these findings have implications for the design of sports practice tasks, they also are important for scientists designing experiments. Designing appropriate experimental tasks in sport can be difficult due to low numbers, while the generalizability of results from single context experiments is no doubt limited (Brunswik, 1943; Schweizer & Furley, 2016). Brunswik also advocated the sampling of multiple variations of the task (situation sampling) to which findings are intended to generalize (Brunswik, 1943, 1956). While the majority of the recent work on representative learning design has focused on practice design, few papers have discussed the implications for experimental design (Dicks et al., 2009; Pinder et al., 2011b, 2014). While this programme of work has not extended these discussions in terms of experimental design, they do provide an interesting stimulus for future discussion. Could experiments that sample multiple situations potentially strengthen research designs by overcoming some of the common limitations of sport and exercise science research? Brunswik certainly thought so and argued that by capturing behaviour in a variety of situations scientists would have a greater understanding as to whether results are generalizable or reflect abnormal behaviour (Brunswik, 1943). In the same way small sample sizes create doubt about the generalization of results, perhaps more rigorous designs that capture performer-environment interactions in a variety of different situations could help reduce such doubt.

6.3.4 Mixed methods

One of the additional implications of this body of work exists in the use of mixed methods. This approach is growing in popularity in sport and exercise science research, with some recent examples highlighting the power of combining qualitative and quantitative approaches (Araújo & Bourbousson, 2016; Kiouak et al., 2016; Seifert et al., 2017). The adoption of mixed methods approaches affords researchers more complete and useful insights through stronger inferences and triangulation of quantitative and qualitative data to corroborate findings (Hagger & Chatzisarantis, 2011; Hesse-Biber & Johnson, 2013; Horn, 2011; Sparkes, 2015). Further, mixed methods offer researchers greater flexibility in ways they may wish to answer their research questions. This thesis provides an example of how different approaches to qualitative methodology can be used to answer specific research questions. This was evident in Stages 3 and 4 of the PhD programme where two different types of qualitative methods were purposely adopted.

In Stage 3 of the PhD program a confrontational interview technique was coupled with course of action theory to collect information on performers lived experiences during their fights. The intention of this approach was to collect data based on what performers were thinking and feeling during their performance. In this study, quantitative data revealed that performers found fighting in competition more mentally demanding than fighting in practice. This is not entirely surprising, as many studies have associated higher affective demands such as anxiety with concurrent increases in mental effort. However, the qualitative data was able to provide context to these results, highlighting that the reason for increased mental effort was due to greater amounts of problem solving undertaken by participants across their fight.

In Stage 4, a different qualitative approach was adopted with participants participating in a semi-structured interview designed and interpreted through the lens of deductive content analysis. The purpose of deductive approaches is to test theory and quantify phenomena. This approach was selected as it allowed the testing of specific research question regarding whether or not situational information enhances the affective demands of practice. Further, this approach afforded the ability to quantify the extent of a phenomena and report a percentage of total agreement from participants. For example, this study revealed that fighters' movement behaviour was more predictable in the presence of time and score information. The qualitative data revealed that this was because fighters felt their actions were coupled to the scoreboard. That is, certain scoreboard configurations afforded particular types of behaviour. For example, a close fight afforded conservative kicking actions. Without the qualitative insights these reasons would have been mere speculation.

6.4 LIMITATIONS AND FUTURE DIRECTIONS

One of the major limitations of this body of work can be found in the 2 part study featured in Stage 2 of the PhD programme where different participants were used for both studies 1 and 2 respectively. Unfortunately time constraints and limited access to the population due to their preparation for Olympic qualification ensured participants could not complete both studies. However, participants from both studies were sampled from the same population to afford some comparison.

While the empirical findings derived from this PhD have broad applicability across sports and skill levels, future research should focus on further validating these findings in various contexts. As per Brunswik's suggestions related to situational sampling, research that adopts various other task vehicles featuring participants of a variety of skill levels could provide useful insight. Future research should focus on understanding the affective demands of in other similarly demanding contact sports like rugby, Australian football, lacrosse or other combat sports. It is likely such tasks inherently have affective demands due to their confronting nature, therefore it is not known whether practice designers would need to go to effort to design in affective affordances to enhance the demands. Additionally, exploring these questions with populations of different skill levels could also be insightful. Perhaps performers with less skill and/or experience may find their practice affectively demanding due to their reduced experience and exposure to competition.

A further limitation of this work is the 'snapshot' time scales on which behaviour was captured. While Stage 4 of the PhD highlighted a mechanism to enhance the affective demands of practice, it is not known on what timescales such practice manipulations might be effective. For example, would such a manipulation cause the same affective and behavioural responses if it was regularly used? It is more likely that performers habituate to specific situations in the same way behavioural dynamics adapt to the surrounding environment (Warren, 2006). Understanding the timescales of adaptation could be a fruitful areas of future research.

Further, the scoreboard manipulation was a static one – it was either present or it was not. While useful for the purposes of a controlled experimental investigation, it is likely that the way coaches manipulate situational information in practice is more nuanced. For example, a study of experiential coaching knowledge revealed they have a variety of mechanisms to enhance the affective demands of practice tasks (Stoker et al., 2016). However, when identifying these mechanism they also stated the need to individualize their use. Therefore, it is likely coaches have principles that guide their situational sampling, the way they tailor situations to individuals, and how they periodise affective demands across the learning and competition cycle. Previous work has identified how coaching knowledge can be used to develop empirical knowledge and inform practice (Greenwood et al., 2012). Identifying these principles could be useful to help better guide the design of practice tasks in sport.

Finally, one of the strengths of this PhD programme was the ability to collect data from highly skilled performers. Highlighted at the beginning of this section was a common problem experienced when studying expertise: the difficulty accessing larger sample sizes to ensure more desirable statistical power. Alongside small sample sizes, a further issue in capturing sporting expertise is the ability to generate findings in controlled experimental settings that generalize to more complex environments (Araújo & Passos, 2007; Dicks et al., 2009; Pinder et al., 2011b; Starkes & Ericsson, 2003). Perhaps drawing on Brunswik's ideas on situational sampling and asking participants to perform a task in more contexts could increase the robustness of findings and facilitate a greater understanding of an independent variables effect on a skill. For example, when investigating how the presence of a defender influenced basketball shooting, Gorman and Maloney (2016) asked participants to perform five types of basketball shots from various locations. The findings revealed that the effect of a defender was specific to the type of shot participants were attempting. Had the design featured only one type of shot, it is likely results would either over or under generalize across shooting contexts. Future work should spend more time exploring the use of situational sampling in experimental designs and how (or if) they could contribute to solving some common problems of research in sport and exercise science.

6.5 Conclusion

This PhD programme details a series of studies that assess the representativeness of three common practice tasks in a high performance combat sport environment. Practically, the examination of these tasks relative to competition provide important insights into the role of affect in practice design for practitioners. Theoretically, the research programme is a vehicle that provides empirical evidence for the need to extend representative learning design beyond sampling physical information, and toward sampling scenarios and contexts from competition. In summary, to design truly representative practice tasks, practitioners should consider how they can sample affective and cognitive constraints so that players think, feel and act like they would in competition.

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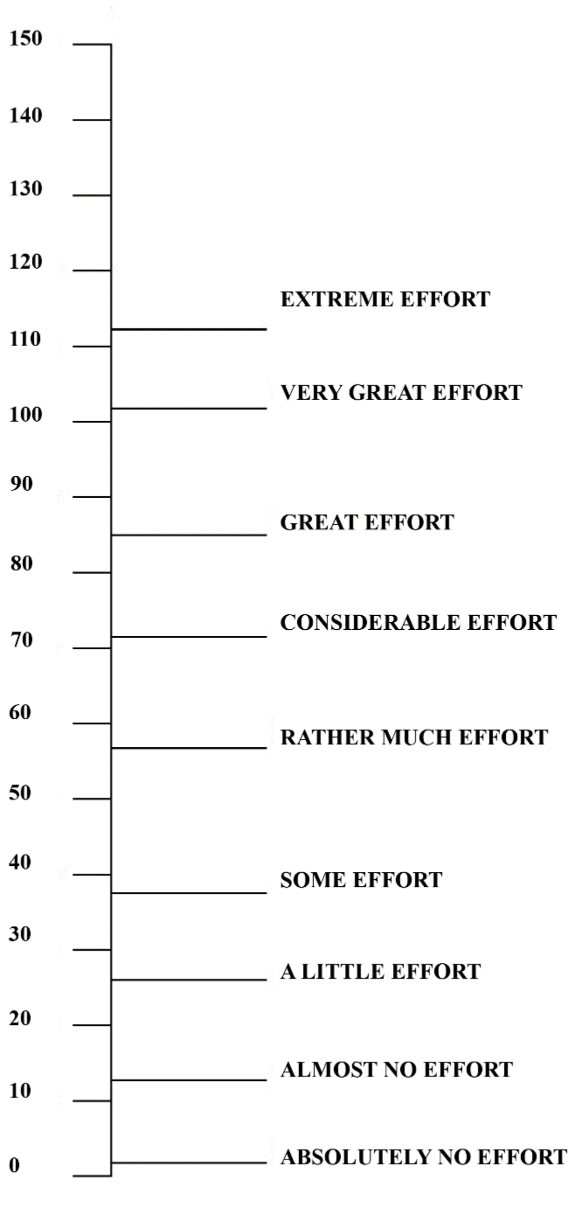
8 APPENDICES

8.1 APPENDIX A – RATING SCALE OF MENTAL EFFORT

Rating Scale Mental Effort

Please indicate, by marking the vertical axis below, how much effort it took for you to complete the task you've just finished



8.2 Appendix B – Competitive State Anxiety Inventory-2

Illinois Competition Test

Instructions: Complete the following scale on two separate occasions: during a quiet time before practice when you are fairly relaxed, and during a competitive situation that you feel is highly stressful. If you are not currently active in competition, recall such situations as clearly as possible and record your responses.

The following are several statements that athletes use to describe their feelings before competition. Read each statement and circle the appropriate number to indicate how you feel right now, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement.

	Not at all	Somewhat	Moderately so	Very much so
1. I am concerned about this competition.	1	2	3	4
2. I feel nervous.	1	2	3	4
3. I feel at ease.	1	2	3	4
4. I have self-doubts.	1	2	3	4
5. I feel jittery.	1	2	3	4
6. I feel comfortable.	1	2	3	4
7. I am concerned I may not do as well in this competition as I could.	1	2	3	4
8. My body feels tense.	1	2	3	4
9. I feel self-confident.	1	2	3	4
10. I am concerned about losing.	1	2	3	4
11. I feel tense in my stomach.	1	2	3	4
12. I feel secure.	1	2	3	4
13. I am concerned about losing.	1	2	3	4
14. My body feels relaxed.	1	2	3	4
15. I'm confident I can meet the challenge.	1	2	3	4
16. I'm concerned about performing poorly.	1	2	3	4
17. My heart is racing.	1	2	3	4
18. I'm confident about	1	2	3	4

performing well.

19. I'm worried about reaching my goal.	1	2	3	4
20. I feel my stomach sinking.	1	2	3	4
21. I feel mentally relaxed.	1	2	3	4
22. I'm concerned that others will be disappointed with my performance.	1	2	3	4
23. My hands are clammy.	1	2	3	4
24. I'm confident because I mentally picture myself reaching my goal.	1	2	3	4
25. I'm concerned I won't be able to concentrate.	1	2	3	4
26. My body feels tight.	1	2	3	4
27. I'm confident of coming through under pressure.	1	2	3	4

Scoring: This scale is called the Competitive State Anxiety Inventory-2 (CSAI-2), a sport-specific state anxiety scale developed by Martens, Vealey, and Burton (1990). The scale divides anxiety into three components: cognitive anxiety, somatic anxiety, and a related component-self-confidence. Self-confidence tends to be the opposite of cognitive anxiety and is another important factor in managing stress. To score the CSAI-2, take all the scores for each item at face value with the exception of item 14, where you "reverse" the score. For example, if you circled 3, count that as 2 points (1 = 4; 2 = 3; 3 = 2; 4 = 1). Total your scores in the following manner:

___ Cognitive state anxiety: Sum items 1, 4, 7, 10, 13, 16, 19, 22, and 25.
___ Somatic state anxiety: Sum items 2, 5, 8, 11, 14, 17, 20, 23, 26.
___ Self-confidence: Sum items 3, 6, 9, 12, 15, 18, 21, 24, and 27.

Your scores for each will range from 9 to 36, with 9 indicating low anxiety (confidence) and 36 indicating high anxiety confidence.

8.3 APPENDIX C – SPORTS LEARNING EMOTION QUESTIONNAIRE

SPORT LEARNING & EMOTIONS QUESTIONNAIRE (SLEQ)

Instructions:

Below is a list of words that represent a range of feelings that might be experienced during learning in sport. Please carefully read each word and indicate on the scale (0-4) how you feel ***right now, at this moment in relation to the current task / session***. There are no right or wrong choices. All selections should be based on your feelings alone.

	Not at all	A little	Moderately	Quite a bit	Extremely
Happy	0	1	2	3	4
Nervous	0	1	2	3	4
Satisfied	0	1	2	3	4
Annoyed	0	1	2	3	4
Fun	0	1	2	3	4
Stressed	0	1	2	3	4
Fulfilled	0	1	2	3	4
Angry	0	1	2	3	4
Joy	0	1	2	3	4
Pressure	0	1	2	3	4
Successful	0	1	2	3	4
Frustrated	0	1	2	3	4
Enjoyment	0	1	2	3	4
Fear	0	1	2	3	4
Accomplishment	0	1	2	3	4
Excited	0	1	2	3	4
Achievement	0	1	2	3	4

	SCORING INSTRUCTIONS (for researcher only)	**Score**
Enjoyment	= (happy + fun + joy + enjoyment + excited) / 5	
Nervousness	= (nervous + stress + pressure + fear) / 4	
Fulfilment	= (satisfied + fulfilled + successful + accomplishment + achievement) / 5	
Anger	= (annoyed + angry + frustrated) / 3	
	Total SLEQ	