CONSCIOUS PROCESSING OF A COMPLEX MOTOR SKILL: AN INVESTIGATION INTO THE AUTOMATICITY PARADIGM OF FULL GOLF SWING EXECUTION.

by

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Abstract

This thesis examines factors that influence the propensity to, and the utility of, conscious processing during a complex motor skill. Prevalent theories of skill acquisition and automaticity view expert performance as best executed in the absence of conscious movement control. There is substantial evidence to support this claim for simple tasks but a lack of research for complex skills is apparent. In this thesis the role of conscious processing (reinvestment) is examined in relation to the full golf swing in baseline and anxiety conditions. The early experiments in the thesis examine the effects of limiting conscious processing through a temporal restriction. Mixed performance results were evident throughout, with no support being afforded to the complete automaticity of a complex skill.

Later experiments investigated individualistic elements of personality and cognitive 'make up,' that may affect the control structures of the golf swing. In a divergence to the reinvestment literature, our results indicate that conscious processing during task performance affects individuals differently, with mediating factors of processing style and working memory capacity. A high 'verbaliser' group deteriorated while 'visualisers' showed improvement during restricted conscious processing trials. Additionally, a positive correlation was indicated between working memory capacity and task performance during the temporally restricted trials.

Overall, the results imply a positive role for conscious control in the golf swing. It is therefore suggested that a multifarious account of reinvestment would be more appropriate if it is to be applied to complex skill.

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List of Abbreviations

ATH	Attentional Threshold Hypothesis
ACT	Attentional Control Theory
aMSRS	adjusted Movement Specific Reinvestment Scale
DOG	Degrees of Freedom
CPH	Conscious Processing Hypothesis
CAH	Constrained Action Hypothesis
CMP	Conscious Motor Processing
CSAI-2	Competitive State Anxiety Inventory-2
CSAI-2R	Competitive State Anxiety Inventory-2 Revised
EEG	Electroencephalography
ELM	Experiential Learning Model
EMH	Explicit Monitoring Hypothesis
fMRI	functional Magnetic Resonance Imaging
LSQ	Learning Style Questionnaire
LTM	Long Term Memory
LT-WM	Long Term Working Memory
MS-C	Movement Self-Consciousness
PET	Processing Efficiency Theory
PPR	Pre Performance Routine
RS	Reinvestment Scale

ST-WM	Short-Term Working Memory
WM	Working Memory
WMC	Working Memory Capacity
STM	Short-Term Memory
VVVQ	Verbaliser-Visualiser Questionnaire

CHAPTER 1

INTRODUCTION AND OVERVIEW OF THESIS

Introduction to Thesis

Golf coaching has a cultural history of being highly explicit in the nature of its delivery. Given the potential complexity of the game this can easily lead to a situation of cognitive overload during practice and a debilitating reliance on conscious control (Masters and Maxwell, 2008a, Wulf, 2013) during performance situations. The term ‘paralysis by analysis’ is one that is ever familiar to golfers and coaches alike. Of recent years there has been an overreaction to this pattern with researchers and sports psychologists offering the much used blanket advice of ‘don’t think about your swing’.

Dr Bob Rotella is golf’s most prominent sports psychologist, famously helping Padraig Harrington to three major victories inside of 18 months. A key part of the Rotella doctrine repeated in his books (Rotella, 1995), is that he encourages golfers to focus their attention on the target and resist any temptation to think about their swing mechanics. In golf psychology, it is largely considered that swing thoughts are a primary source of distraction and will hamper the player’s performance. ”You cannot hit a golf ball consistently if you think about swing mechanics” (Rotella, 1995, pg 40).

Experientially, it would seem that moments of optimum performance do occur with a complete lack of technical thought. This is backed up by a multitude of anecdotal observations: When asked what he thinks about when batting, Yogi Berra, the baseball icon replied, “Think? How can you think and play at the same time (Beilock, 2011, pg 224)?” It is unlikely, however, that this common observation means that the reverse causality is also true.

Additionally, golf is taught and learned in an extremely explicit manner (Bennett et al., 2009, Rousseau, 2010, 2011), which leads to the build up of procedural knowledge (Masters and Maxwell, 2008a). To then expect the performer to execute the golf swing in the absence of conscious control is a far-reaching request that without considerable training or an effective intervention is unlikely to ensue.

The theoretical underpinnings of automaticity need further research if we are to offer a more robust performance model. This thesis lends evidence based research to this widely held position and considers the efficacy of renouncing conscious control in performance of a complex motor skill. We also test a potential intervention that could be incorporated into a golfer's pre-performance routine in the aim of reducing conscious control of the movement.

Aims of the Dissertation

General Aims

The main aim of this study is to add insights into the effect of reinvestment by elite level golfers executing the full swing. In doing so, the efficacy of popular automaticity theories will be examined in relation to a highly complex motor skill. A further aim is to increase understanding of the individual factors that may affect the propensity for and the utility of conscious processing in the golf swing.

Specific Aims

1. To examine whether reducing conscious control improves performance in experts.
2. To test an intervention that limits conscious processing during task performance, in the aim of alleviating choking under pressure.
3. To further understand the effects of conscious control during pressure and non-pressure conditions.

CHAPTER 2

A REVIEW OF CONSCIOUS PROCESSING DURING A COMPLEX MOTOR SKILL

Introduction

During the process of skill acquisition, the learner is thought to progress from an early cognitive stage toward a more automatic mode of movement control that is typically displayed by expert performers (Dreyfus and Dreyfus, 2000, Fitts and Posner, 1967). Automaticity has been defined in the literature as 'fast, stimulus-driven and characterised by a lack of intention, attention and awareness' (Saling and Phillips, 2007 p. 2). The result being that automatic movement control is effortless (Logan, 2002), free from working memory input and thus, not limited by capacity (Pashler, 1994, Pashler and Johnston, 1998). Logan's 'instance theory' (Logan, 1988, 2002) defines automaticity as behavior that is guided by direct memory retrieval. In this model, automaticity is developed as novice performers become less reliant on previously established 'algorithms' and trust the movement control to memory based processing that has the benefit of being faster and more robust than executive control. 'Consistent mapping' (Shiffrin and Schneider, 1977) suggests that this process of atomization only occurs when a consistent task requires a consistent response. Skill transfer is directly correlated with the similarity of task with any task perturbations requiring the re-assignment of executive control.

Automaticity has been characterized (Bargh and Chartrand, 1999, Bargh et al., 1996) as being fast effortless control that requires little or no technical attention. Similarly, Singer et al. (1993) describes the phenomenon as the freeing up of limited conscious capacity that results in physical actions that appear to require little or no thought.

Often viewed in the literature as the opposite of automaticity, is executive control or conscious processing, which is reliant on working memory input and categorizes acts that individuals are aware of, that are intentioned, require effort and are controllable (Logan and Cowan, 1984)

The Full Golf Swing

Golf is a self paced sport (Singer, 1988) making the exponent more susceptible to the performance effects of over thinking (Cotterill et al., 2010). Most of what we know about conscious processing in relation to golf has come from extrapolating studies on putting (Beilock and Gray, 2012, Masters et al., 1993a, Mullen and Hardy, 2010, Toner and Moran, 2011) which provides a conveniently controllable environment. However, putting does not share the same mechanical complexity and demands as the full golf swing. A number of uniquely challenging aspects of which have been highlighted and include; the velocity of the club making it difficult to apply closed loop theories of motor control, the sequential coordination requirements of numerous sub-movements, the different clubs used and the high degree of accuracy required in a “sensorimotor control task during which a movement has to be aligned according to an external goal” (Jäncke et al., 2009, p.1).

Most pertinent to this study though, is that the full golf swing is typically taught and learnt in a highly explicit manner (for example see Bennett et al., 2009) making it an epitomical task to conduct our study into conscious control during a complex motor skill.

Motor Learning Overview

High level motor performance is distinguished by the economy of both movement and thought. Throughout the acquisition and development processes of a motor skill, certain key patterns emerge. From a physical standpoint, the movement pattern augments over time and practice, to deliver enhanced output. Degrees of freedom (DOF) that were previously restrained as a necessity to basic control, are later given back to the movement in a coherent coordinated structure (Jordan, 1990) that allows for greater efficiency and power. At this advanced stage, a greater number of DOF are linked with increased ‘good variability’ (Wu and Latash, 2014) within the movement. This is an essential part of the process that serves to self-organize (Kelso, 1997, Williams et al., 1999) and provide a higher level of output consistency over a broad range of environmental and task restraints. While the movement structure is becoming more refined, so too are the cognitive processes controlling the pattern which become far less resource dependent (Hatfield and Hillman, 2001). At the expert end of performance, cognitive load is greatly reduced from the earlier stages of learning.

Popular ‘information processing’ theories (Anderson, 1982, Anderson, 1995, Fitts and Posner, 1967) see the performer progressing through 3 discrete phases that identify a reduction in conscious control. The initial ‘cognitive’ stage involves a lot of hypothesis testing (Poletiek, 2013) that has a highly verbal-cognitive mode. By the time the learner is in stage 2, ‘fixation’, the corrections are much more subtle and the cognitive demand is reduced. After considerable time and repetition the learner would reach the ‘autonomous stage' in which the movement is largely controlled in the absence of working memory and thus utilizing a more unconscious process.

Expert-Induced Amnesia

In alignment with the atomization of a skill, experts often report a lack of memory in relation to the mechanics of the movement and find it difficult to articulate 'how' a skill was performed. 'As we get better at performing a skill, our conscious memory for how we do it gets worse and worse.' (Beilock, 2011, p. 16). This 'expert-induced amnesia' occurs as procedural memory plays a larger role in skill execution reducing the role of step by step retrieval of episodic memory (Beilock, 2011). Since procedural memory is implicit and out of conscious awareness the performer would then find it difficult to remember the explicit account of how the skill was executed. This phenomenon is often taken as a key indicator that when a skill is highly developed it requires little or no conscious input. This was the interpretation of putting studies (Beilock et al., 2002) that involved novice and experience golfers in normal and novel task conditions.

This position is criticised by Sutton (2015) in his Mesh account of automaticity, in which he highlights what is claimed to be' weaknesses within the extant skill research.' To this point, Sutton illuminates the usual and non-challenging nature of the putting task that led to expert-induced amnesia studies (Beilock et al., 2002). In this study, golfers hit 70 identical putts from the same location on a flat surface creating a situation where 'information for control has no future relevance' (Sutton, 2015, p. 26).

In the novel task where golfers used a ‘funny putter’ (Beilock et al., 2002) experts reported an increase in episodic memory pointing to cognitive and attentional involvement during task execution. On this basis, the ‘Mesh’ account of expert-induced amnesia is therefore based around the novelty of the task with ‘usual’ and repetitive tasks being likely to induce reduced memory. However, once the task becomes more challenging then enhanced memory retrieval is likely. Some aspects of movement control may remain out of awareness but there will be a clear retrieval of memory relating to ‘higher order control’. From this perspective a task may be highly familiar but if it has any degree of novel constraint then complete automaticity is unlikely to ensue.

The Development of Expert Skill

Where traditional motor learning models see automaticity as the pinnacle of motor performance, Ericsson (Ericsson, 1998, 2006b) views the third and automatic stage as being a performance asymptote and in contrast, describes expert performance has having significant cognitive input.

In his own model (Ericsson, 2006a, Ericsson, 2007) of ‘experience and deliberate practice’ (Ericsson, 2006a, Williams and Ericsson, 2005), Ericsson makes the distinction between ‘expert’ and ‘everyday’ tasks. For everyday tasks Ericsson’s 3 stages are consistent with that of Fitts and Posner (1967), suggesting that the goal in learning an everyday task is to get to an autonomous stage as quickly as possible in order to carry out the task with minimal effort. This represents the lower level of skill acquisition. To gain a higher level of expertise the learner must be continually developing higher order cognitive skills and incorporate increasingly complex representations that serve to further enhance the skill. Significantly, Ericsson sees automaticity as an undesirable state that reduces conscious control of an action, subsequently making development and alterations of the skill difficult. If at any point the learner/expert settles at an autonomous stage then he is seen to be in a state of ‘arrested development (Ericsson, 1998). For Ericsson, the learner is on a constant progression of adjacent states that have physical and cognitive properties that support each other. When a jump to the higher state is achieved through deliberate practice (Ericsson et al., 1993a) it may be down to a physiological change or a cognitive improvement in monitoring and/or mediating the action through ever changing internal representations. The challenge with the ‘experience and deliberate practice’ stance is that while it gives a credible account of skill development, it is somewhat ambiguous as to whether elite performance is best achieved with online conscious control or not.

This ground is however, deeply assimilated within the literature on ‘flow states’. The presence of which, is associated with peak performance. (Jackson and Roberts, 1992). Flow has been defined as “a state of consciousness where one becomes totally absorbed in what one is doing, to the exclusion of other thoughts and emotions. A harmonious experience where mind and body are working together effortlessly, leaving the person feeling that something special has just occurred” (Jackson and Csikszentmihalyi, 1999, p. 5).

Within their seminal work in the area Jackson and Csikszentmihalyi (1999) describe the experience of flow as having nine dimensions: *challenge-skills balance, action-awareness merging, clear goals, unambiguous feedback,* *concentration on the task at hand, sense of control, loss of self-consciousness, transformation of time and an autotelic experience.*

Although not explicitly cited as a dimension of flow, automaticity is often closely associated to the experience (Koehn et al., 2013b, Swann et al., 2012). This is typified by a study of elite golfers (Swann et al., 2015) where automaticity was reported as being part of the flow experience and is linked to the flow dimension of action-awareness merging (Jackson and Csikszentmihalyi, 1999). An over-emphasis given to the presence of automaticity within flow experience has been criticized as ‘representative of many theorists and practitioners who privilege one aspect or feature of the phenomenology of flow as if it captured the entire phenomenon (Sutton et al., 2011, p. 78). Furthermore, within their 9 dimensions of flow, Jackson and Csikszentmihalyi (1999, p. 105) suggested that self-awareness was an important dimension of this experience as it allows performers to process ‘information about the fine nuances of our involvement in the activity’ (Toner et al., 2015). Once again we are left with phenomenological accounts that relate automaticity to optimal performance but no direct casual links.

Conscious Control

Until recently, the general consensus in the literature has been with the self - focus accounts of conscious control. That is to say that the focus of attention on one’s movement/technique during performance to either control (Masters et al., 1993b) or even just monitor (Beilock and Carr, 2001) the movement will cause a breakdown in performance due to an ‘unpacking’ of the unconscious processing and a reversion back to a more primitive and conscious form of control. Early self-focus theories (Allport, 1980, Kahneman, 1973, Logan, 1985, Schmidt, 2003) have been brought together by Masters and Maxwell (2004, 1993b) under the term ‘reinvestment’ which they latterly defined as the “manipulation of conscious explicit, rule based knowledge by working memory to control the mechanics of one’s movement during motor output” (p208, Masters and Maxwell, 2004) This concept is at the heart the Conscious Processing Hypothesis (CPH, Masters et al., 1993b) which follows that the reinvestment of declarative knowledge serves to reverse the learning process and break down the proceduralised movements into smaller chunks where they no longer operate with the same level of efficiency. Reinvestment is said to be most likely when the performer is under pressure and most prevalent in expert performers due to the amount of explicit knowledge that has built up over time and practice. (Discussed in detail in chapter 4).

Attentional Focus

Conscious processing has been linked with theories of attention (Schmidt and Lee, 2013) which is central to concentration and has been and defined as “what we are aware of at any given moment” (Schmidt and Lee, 2013, p.98). The prevalent research into the effects of the loci of attentional focus (Wulf, 2007, Wulf, 2013, Wulf et al., 2015) make the distinction between focusing one’s attention on the movement (internal focus), and focusing on the effect/ intended outcome of the movement (external focus). This differentiation forms the basis behind the ‘Constrained Action Hypothesis’ (CAH, Wulf et al., 1999, Wulf et al., 2001, Wulf et al., 2000) which views a clear distinction in cognitive load, learning and performance effects between the two attentional loci. The

CAH is greatly in favour of an external focus of attention that accordingly, “allows unconscious, fast, and reflexive processes to control the movement” (Wulf, 2007, p.113). In contrast, internal focus is thought to disrupt the automatic control processes and cause skill breakdown in a similar vein as the reinvestment theory.

The theoretical background behind the hypothesis is associated with the way motor actions are coded in long-term memory (Land et al., 2014). External focus is thought to create a closer connection between action and effect (Cappuccio, 2015). This has been linked to ‘Common Coding Theory’ (Prinz, 1990, cited in Peh, 2010) in which performance is best served when perception and action are coded in the same medium. External focus has also been associated with more advanced/elaborate formations of task related internal representations (Bläsing et al., 2009) that are akin to skilled performers. That is, an external focus facilitates the formation of an expert like organized hierarchy of skill representations that convey associations between an action and its effect (Schack, 2004).

The CAH has been given credence from research involving a multitude of tasks (Chow et al., 2014, Maddox et al., 1999a, McKay and Wulf, 2012, Wulf et al., 2007) including a number of experiments in golf related movements (An et al., 2013, Perkins-Ceccato et al., 2003, Poolton et al., 2006, Wulf et al., 1999, Wulf and Su, 2007). The golf related studies have been largely supportive of the CAH, although, Perkins-Ceccato et al. (2003) found the effects to be skill dependent. Contrary to the CAH, in a golf pitching task, low-skill participants performed better in the internal focus condition. A separate study using golf pitch shots (Bell and Hardy, 2009b) introduced a further distinction to the attentional focus literature by splitting external focus into external distil focus (the flight and direction of the ball) and external loci focus (position of the clubface throughout the swing). Even with this further dimension, the results from this study (Bell and Hardy, 2009a) and a similar three dimension attentional loci set up in dart throwing (McKay and Wulf, 2012), both supported the more target orientated distil external focus.

The central claim of the CAH is that external focus promotes automaticity within the movement control structure. While this is supported by a number of studies (Kal et al., 2013, Wulf et al., 2001) Oliveira et al. (2013) set out to specifically test this aspect of the hypothesis with a golf putting task that involved both learning and performance trials. From the perspective of learning under external focus, the evidence did not support the 'automation hypothesis' with participants showing no greater level of automaticity in retention trials. It was also noted that internal focus proved to be most beneficial in a straightforward learning/retention set up. External focus was however preferable for performance once the skill has been learned.

Critics of the attentional focus literature (Peh et al., 2010) claim the paradigm to be overly dichotic to be universally applicable, citing task constraints and skill level as mediating factors. The participant's familiarity of attention loci is also brought into question with a study that found the optimal attentional focus (internal or external) to be the one that the participant normally adopts (Maurer and Munzert, 2013) with no bias for either an internal or external focus.

A naturalistic investigation of golfer's attentional foci support this view with claims that "the foci of expert golfers is more diverse and more specific than the kinds of foci examined in the literature” (Bernier et al., 2011, p.336). A framework is suggested that further categorises attentional focus into content and modality.

With the CAH being heavily connected to theories of automaticity, this study will add valuable insight to this field by bringing new data to the areas of reinvestment propensity and the utility of autonomous control for a complex skill.

Working Memory

Conscious control of the golf swing is believed to be handled in working memory (WM, Baddeley, 2007) which is tasked with the control of attention while also being able to store and process information. The popular multi-component account of WM outlined by Baddeley and Hitch (1974) comprises four discrete aspects that either process different information types or have strategic involvement in the system (Discussed in detail in chapter 8). It is thought that WM has a limited capacity that restricts the amount of declarative knowledge that can be stored and processed at any one time (Alloway et al., 2005). This is highly relevant to the current thesis since the capacity of one’s WM may affect the way we learn (Buszard, 2014) and how we subsequently control or monitor our skilled movement patterns (Mullen and Hardy, 2000b, Mullen et al., 2005). WM capacity is also thought to be a key determinate in the ability to perform under pressure (Beilock and Carr, 2005, Beilock and DeCaro, 2007). In this scenario, it is hypothesized that individuals with high WM capacity are too reliant on processing information declaratively and use complicated strategies where a more instinctive approach would be more suited to the task (see chapter 8).

Opposing the capacity models of WM, Ericsson and Kintsch (1995) offered their theory of ‘Long Term Working Memory’ (LT-WM) in which WM is only limited for simple unskilled tasks. In the LT-WM model, expert performers are able to access information held in long-term memory through skilled processing of retrieval cues in what they term ‘short-term working memory.’ In chapter 8 of this thesis we examine the relationship between conscious processing and WM and extrapolate to the co-existence of both WM and LT-WM constructs.

Implicit Learning

With evidence to support the reinvestment theory ever increasing, it has been the intention of some researchers to evaluate the learning process with a view to lessen the propensity for reinvestment during performance (Liao and Masters, 2001, Masters et al., 2008, Reber, 1993). The underlying hypotheses being that, a reduction in declarative knowledge build up through the learning stages would lower the propensity of reinvestment under pressure. This direction of thought has led to a considerable body of studies in the area of ‘implicit learning’ (Lam et al., 2010a, Liao and Masters, 2001, Masters and Maxwell, 2004, Rendell et al., 2011), which has been described as “increases in performance that are not accompanied by an ability to consciously reflect on (or verbally communicate) about the movement dynamics associated with performance” (Lam et al., 2010a, p.1543). In contrast, explicit learners have made a conscious effort to learn and are aware of the “underlying mechanisms and processes of increases in performance”(Lam et al., 2010a, p.1544).

The reduction in declarative knowledge build-up during the learning stages has been shown to increase resilience under pressure for relatively simple motor skills. Criticized (Winter et al., 2014) for its outright performance, speed of learning, practical application and relevance for a complex task, this position is unlikely to find its way into applied settings. However, a derivative of implicit learning is analogy learning, where a number of sub-components of a technique can be consolidated in one over-arching representation/metaphor that relates to a familiar movement to the learner (Liao and Masters, 2001). On account of its information rich but low cognitive load qualities, in both skill acquisition and performance, analogy learning has been shown to overcome some of the reported issues associated with pure implicit learning, while also being more robust under pressure than explicit learning conditions (Lam et al., 2009, Liao and Masters, 2001, Maxwell et al., 2000). It must be noted that the retention trials typically involve a forced explicit condition that is not necessarily representative of an applied setting (Koedijker et al., 2011). Other studies have found analogy learning to plateau after only 1400 trials which represents relatively little practice (Koedijker et al., 2007). The explanation made by Koedijker et al. (2007) is that the learning isn’t as deep or detailed as the explicit instructions. In accord with this position, it would appear that, due to its low cognitive loading, analogy learning can be very effective for quick retention testing as occurs in research but is unlikely to represent deeper understanding of complex movements as is required over time in elite performers (Ericsson et al., 2007). Therefore, if we are to accept that declarative knowledge build up in motor learning and especially golf, is unavoidable, then finding ways to limit any negative effect and regulate conscious control during task performance would seem to be the central challenge. With an exhaustive amount of information available across media platforms (Bennett et al., 2009, Pelz and Frank, 2000) and an ever enthusiastic coaching community, it is unlikely that golfers can carry out a sufficient volume of purposeful practice (Ericsson, 2006a, Ericsson et al., 1993b, Ericsson et al., 2007) without acquiring a large degree of declarative knowledge. It is therefore our aim to better understand the effects of reinvestment under pressure at an elite level, where a vast declarative knowledge build up is assumed.

The Dual Task Paradigm

The favoured method of research in automaticity (Wulf et al., 2001) is the dual task paradigm. The process of reinvestment involves the use of WM, which retrieves the declarative knowledge and holds it in temporary storage during shot execution. By adding a dual task, such as random letter generation (Baddeley, 1966), the use of WM is diverted. If the attentional demand of the primary task is high then the results of the dual task would suffer. Once the participant can perform the primary task automatically then attention can be shared effectively between the tasks. Therefore, a good score on both the primary and secondary tasks would indicate a high level of automaticity. However, the dual task paradigm is criticized (Allport, 1980, Sanders, 2001) on a number of levels (see chapter 4) and presents difficulties in real world application (Jackson et al., 2006, Winter et al., 2014) .

In an aim to circumvent the methodological and real world application issues with these interventions, we are controlling conscious processing using a temporal restriction intervention that has been shown (Beilock et al., 2004a, Beilock et al., 2008, Beilock et al., 2004b, Bell et al., 2013) to successfully reduce reinvestment and improve task performance in golf putting.

Measuring conscious processing

The neurobiological approach to measuring conscious control is to collate measures of brain activity using mainly electroencephalography (EEG) or functional magnetic resonance imaging (fMRI). EEG works by recording electrical activity from the scalp to detect activity inside the brain (Cooke, 2013, Harmon-Jones and Peterson, 2009). This provides indications of asymmetries in hemispheric and regional cortical activations (Cooke, 2013, Hatfield et al., 2004, Milton et al., 2007). One of the measures taken with EEG is spectral power, which is the frequency of the waveforms. Sport related studies generally focus on the Alpha band (8-12 Hz) which is understood to be an indication of information processing in movement preparation (Cooke, 2013). It is widely accepted that there is an inverse relationship between cortical activity and alpha power (Pfurtscheller, 1992), with an increase in alpha power indicating a decrease in brain activity in that region and vice versa. A number of alpha power studies (Kerick et al., 2004, Kerick et al., 2001) have been carried out on marksmen during the final few seconds before pulling the trigger. These studies consistently point towards decreased verbal analytical activation in the few seconds prior to pulling the trigger. However, this does not seem to be the case for all motor tasks and not so for golf. In the four seconds before hitting a putt Babiloni et al. (2008) reported a decrease in alpha power at sites directly over the pre-motor and motor cortex, suggesting more recourses being allocated to the programming of movement parameters such as the strength and line of the putt (Cooke, 2013, Cooke et al., 2014). This trend proved to be even stronger on successful putts than on missed putts.

This neurobiological evidence stands in stark contrast to the traditional views on automaticity (Fitts and Posner, 1967, Hatfield and Hillman, 2001) but has been corroborated by related follow up studies (Babiloni et al., 2008, Cooke et al., 2014) that measured the alpha power of golfers performance having missed the previous putt. In accord with the reinvestment theory, this study also showed that elite level golfers are more likely to be subject to increased conscious control under pressure.

A common limitation to the ‘spectral’ studies is that while they offer an insight into the amount of cortical activity, ‘alpha power’ does not show how the resources are being allocated (Cooke et al., 2014). On this theme, a possible explanation for the ‘non-automaticity’ results, is that decreased alpha power could be related to focus on external cues (Cooke, 2013, Cooper et al., 2003) and not necessarily conscious control.

A more qualitative approach to EEG scanning is to measure alpha coherence in the preparatory time leading up to shot execution
(Baumeister et al., 2008a, Gaudreau et al., 2010, Milton et al., 2007, Thorpe, 2010).

High EEG coherence implies a level of communication between regions of the cerebral cortex which has been viewed as a marker of verbal cognitive involvement during learning (Zhu et al., 2010). Low coherence levels are indicative of regional autonomy (Reiterer et al., 2005, Weiss and Mueller, 2003) and less verbal cognitive input. Specifically, conscious control of a movement is measured by the coherence between left temporal region, associated with verbal-analytical and language processes (Kerick et al., 2001, Springer and Deutsch, 1985) and frontal midline region which is connected is the promoter area of the cortex and is linked to the planning of motor tasks (Miller and Cummings, 2007, Stuss and Knight, 2013, Zhu et al., 2011).

Once again and consistent with Fitts and Posner's (1967) model, a study into expert and novice marksmen found lower coherence in expert marksmen than their novice counter parts. This was reported as evidence that the experts were less engaged in verbal-cognitive processes (Deeny et al., 2009). It is arguable that although infinitely challenging in its own right, rifle shooting has less moving parts to sequentially co-ordinate and is less explicitly learned than the golf swing. We should therefore, be cautious of conscious processing data taken from other fields.

Coherence studies in golf support the 'reinvestment' view with high co-activation levels reported for novice golfers that also score highly on the reinvestment scale (Zhu et al., 2011). The same study also reported reduced coherence for golfers that learned to putt in an errorless, implicit condition.

In spectral analysis researchers also measure theta band (4-8Hz) power in the fontal midline area, which is linked to focused attention (Gevins et al., 1997, Smith et al., 1999, Zhu et al., 2010). In studies on golfers (Baumeister et al., 2008a) and marksmen (Haufler et al., 2000) it was reported that experts, over their novice counterparts, showed increased levels of frontal midline theta power. This has previously been associated (Smith et al., 1999) with a concentrated focus of attention visiomotor and sensorimotor tasks (Baumeister et al., 2008b) and is vital for the input of central executive functions like decision making and reinvestment.

The golf study (Baumeister et al., 2008a) also reported a disparity in Alpha 1 and Alpha 2 power between expert and novice groups. These two factors were taken to indicate that novices process task irrelevant stimuli while the experts channel their cognitive activity more efficiently. This outcome suggests that experts may not necessarily be involved in less cognitive input, but are just more discreet in their cognitive process with an attentional focus of mainly task relevant stimuli.

Neuroscience has given us great insights into brain activity during motor skill acquisition and performance. The prominent theories to emanate from EEG testing are that expert golfers activate more cortical resources prior to hitting a putt and engage in more external information processing than novices (Cooke, 2013, Cooke et al., 2014, Cooke et al., 2011, Moore et al., 2012). Indicated by decreased theta power in the seconds prior to putting, it is thought that experts allocate more resources than novices to achieve heighted attentional focus.

What EEG can’t measure with scalp electrodes is activity deeper in the brain (Davidson, 2004). This is problematic in our study since areas such as the basal ganglia and limbic structures that are thought to be central in the control of attention and working memory (Milton et al., 2007, Ravizza and Ivry, 2001). Both cortical and sub-cortical areas are accessible by functional magnetic resonance imaging (fMRI) but it is impractical to perform a complex motor skill while inside an fMRI scanner. That said, some studies (Bernardi et al., 2013, Milton et al., 2007, Ross et al., 2003) have found ways to take fMRI measurements on fairly simple motor tasks or through novel experimental design such as movement imagery (Ross et al., 2003). In a study of novice and expert golfers, Milton et al. (2007) found the experts to be more able to direct a quietly focused attention to the task whereas the novices where pre-occupied by task irrelevant stimuli. This was consistent with (Bernardi et al., 2013) and (Ross et al., 2003) studies that reported qualitative and quantitative differences in expert processing.

EEG and fMRI have given us great insights into brain activity during task performance but it remains difficult to understand how the activity is allocated. What we can start to hypothesize is that there are differences in processing efficiency between expert and novice performers. A likely factor in this effect is brain plasticity (Dayan and Cohen, 2011) where neuronal circuits discreetly related to task performance, grow stronger and disproportionately to the population at large. This is best explained by the adage that 'neurons that fire together, wire together' (Keefe, 2003, pg 171) to create more efficient processing in domain specific tasks. This has been shown in musicians (Han et al., 2009) and typists (Cannonieri et al., 2007) where higher grey matter volume was reported in brain areas related to the task.

This has also been shown to be the case in golfers (Jäncke et al., 2009) where a difference in grey matter was reported and related to the amount of practice. It was also suggested that anatomical changes in a golfer's brain seem to occur in the first 800-3000 hours practice but then reach an asymptote with further practice hours not affecting brain architecture.

Overall, the evidence provided by the neuroscience literature proposes that experts have different brain architecture that aids in processing efficiency during task planning and performance. Without an understanding of how these resources are allocated, there is no evidence to suggest that experts should or should not consciously attend to their movement during task performance.

For evidence of this sort, researchers have turned to ‘think aloud’ (Schack, 2012, Toner and Moran, 2011) protocols which produce feedback of a more qualitative nature. Simply put, participants are stopped mid-trials and asked to recall all task related thought while in preparation and shot execution. The data are then categorized, in the case of Toner and Moran (2011), into the broad themes of attentional focus: external, internal, environmental and rhythm/timing. This thesis is concerned with more quantitative data but in future research the think aloud protocol may prove a useful addition.

Effects of Anxiety on Performance

The study of how anxiety affects performance has received much interest in the literature. Not least on the topic of ‘choking’ (see Hill et al., 2010 for review) under pressure, defined as “performing below one’s and others’ expectations in consideration of previously demonstrated ability” (Carson and Collins, 2015, p. 1). Studies relating to motor skill execution have shown anxiety to lead to numerous and varied effects that include; visual gaze patterns/fixation periods (Nieuwenhuys et al., 2008), movement variability (Collins et al., 2001, Pijpers et al., 2005), attention, (Masters, 1992) heart rate and grip force (Cooke et al., 2011). Although all these effects do not necessarily lead to a negative correlation with performance (Eysenck et al., 2007b). It has been reported (Cooke et al., 2011) that mild anxiety can enhance performance before realizing a drop off as anxiety raises to higher levels.

Perceptual motor accounts of the anxiety-performance relationship have been centered around the contrasting views of ‘self focus’ (Beilock and Carr, 2001, Masters and Maxwell, 2008a) and ‘distraction’ (Eysenck et al., 2007b, Mullen and Hardy, 2000a) theories (see chapter 4). Of late, attempts have been made to look beyond this debate in search of a more ‘integrated’ understanding of the effects of anxiety on perceptual motor control (Carson and Collins, 2015, Nieuwenhuys and Oudejans, 2012, Nieuwenhuys et al., 2008). In view of this, Carson and Collins (2015) criticise the extant literature as being overly focused on emotional and cognitive issues at the expense of ‘motoric’ considerations. To reconcile this, Carson and Collins (2015) propose a further dimension of the anxiety-performance relationship as being the level of ‘skill establishment that could act to negate the debilitating effects of anxiety. Nieuwenhuys and Oudejans (2012) make a broader criticism of the dichotic debate (distraction vs self focus) as only pertaining to the attentional effects of anxiety during the execution phase, when influences at an earlier stage may have already jeopardised the performance. If perception is affected by anxiety (Nieuwenhuys et al., 2008), which then results in the selection of a sub optimal, then the attentional issues at execution become somewhat incidental.

In this study we evaluate the effects of anxiety on attention, by way of conscious movement control, and its effects on full golf shot performance.

The Current Thesis

It appears that conscious processing and in particular, the amount one thinks about ‘how’ a task is executed, plays a major role in sporting performance. That said the exact role and value of conscious control in elite performers is unconfirmed. There is a need to further understand the individualistic factors that may affect the application of self-focus theories to complex motor skills. This thesis aims to explore these issues in a series of related studies that may go some way to helping identify best practice for performance interventions for optimal focus.

CHAPTER 3

GENERAL METHODS

Introduction

Throughout this thesis common methods are used and adjusted accordingly to fit the requirements of each experiment. So as not to repeat the same methods section in each chapter, the common procedure, instruments and data analysis are outlined in this chapter. Any adjustments of which are highlighted in each experimental chapter.

General Procedure

Testing took place on the driving range at Wycombe Heights Golf Centre and in a controlled practice room at Edgbaston Golf Club. In each experiment the participants hit a total of 28 full swing shots with a 5 iron. This club was chosen on the basis that there is no ambiguity in regard to the requirement of a ‘full’ swing. The 5 iron places a premium on both distance and accuracy and was considered to give sufficient performance variability to provide meaningful data.

Participants were given 10 minutes to warm up in their own manner in which the opportunity to freely hit shots was provided. During the trials, participants hit 7 shots with a 5 iron in each condition. Both baseline and anxiety conditions were repeated pre and post intervention (Figure 3.1). Measures of performance anxiety (Competitive State Anxiety Inventory-2R) and conscious processing (adjusted Movement Specific Reinvestment Scale) were administered immediately after each trial.

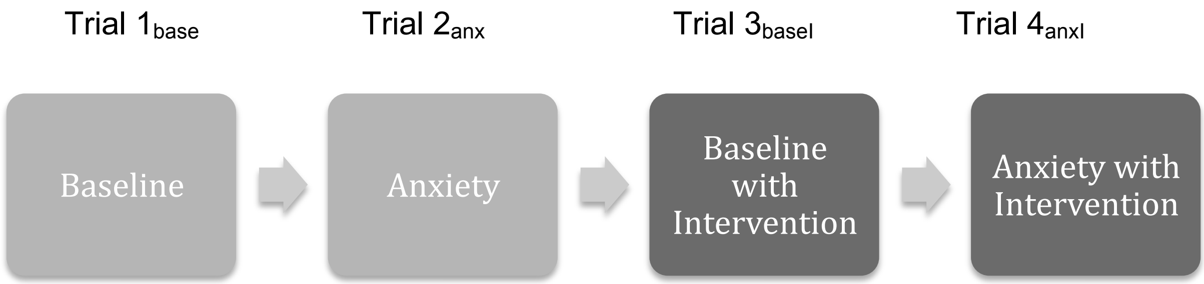

Figure 3.1 Experimental Conditions

Baseline Condition $_{(base)}$

Baseline performance was measured with players being instructed to hit the ball their normal distance and as accurately as possible to a virtual target taken as the centre line.

Anxiety Condition $_{(anx)}$

A scoring regime was developed via two mini pilots (*n* = 6) using the Competitive State Anxiety Inventory-2 (CSAI-2, Martens et al., 1990) to measure the change in anxiety between the normal and self-conscious condition. Anxiety was measured on the basis that increases in anxiety through competition pressure have been linked to increased self-consciousness and therefore a rise in conscious processing (Masters and Maxwell, 2008a). The primary measure used from the CSAI-2 was the cognitive anxiety value. Participants completed the CSAI-2 after both base line and anxiety trials with a significant disparity between the two indicating that the design was inducing the required state anxiety.

Participants took part in a format designed to induce anxiety during shot performance. The results were displayed on site in view of all competitors. Participants paid £6.00 into a prize fund with £3.00 being used as a stake for each competition, which coincided with the anxiety trials.

The competition scenario required the participants to hit toward a virtual target to be displayed with a large diagram on site (Figure 3.2).

The target is a virtual fairway that starts at 100 yards and is 10 yards either side of the centre point. A secondary scoring zone (semi-rough) is a further 5 yards out but parallel to the fairway on both sides. Any ball that lands further than 15 yards from the centre point will be in scoring zone 3 (rough).

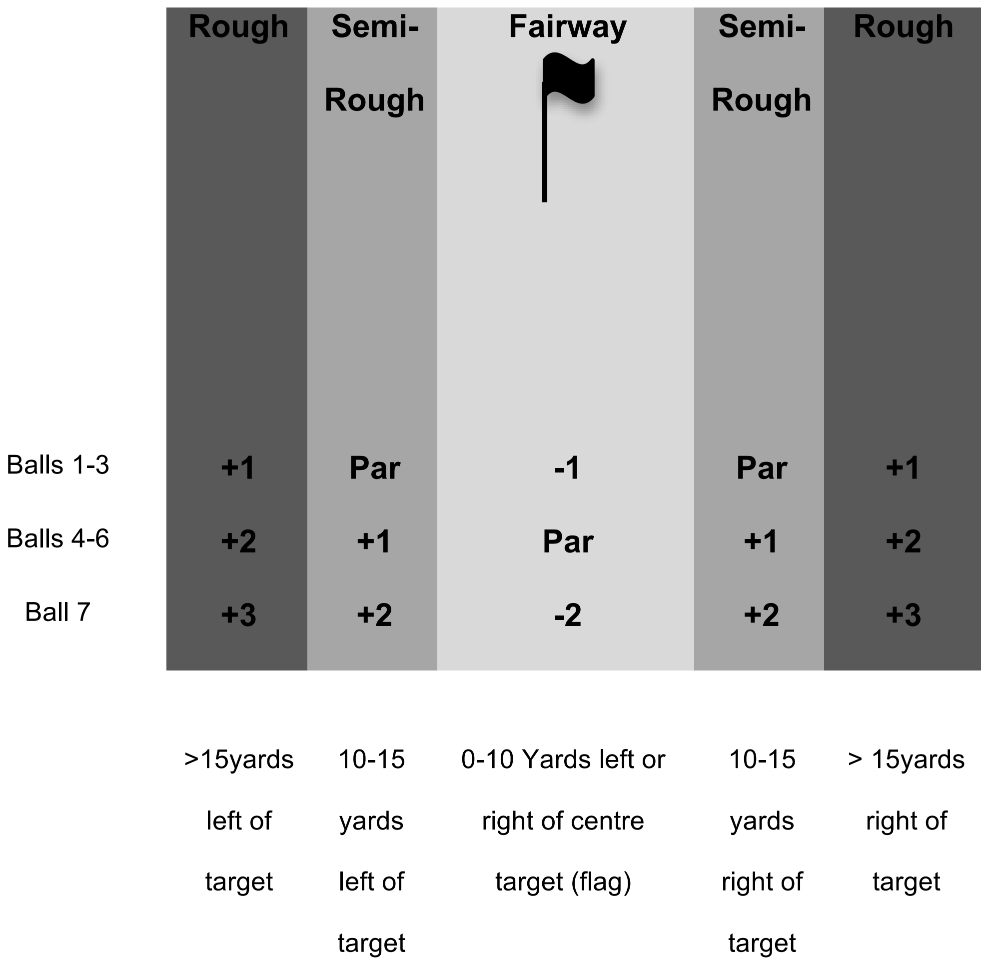

Figure 3.2. Target and scoring system for anxiety condition.

For the first 3 balls the participants score -1 if the ball landed in the fairway, par for the semi rough and a ball landing outside the target will be counted as a bogey (+1). The scoring for the second 3 balls changes so that the fairway zone is now par, the semi rough is +1 and outside the target is +2. The final ball represents an ‘all or nothing’ scenario with the score of -2 being awarded for the fairway, +2 for the semi rough and +3 for the rough. This change in scoring occurs to increase the pressure and subsequent conscious processing in the second half of each trial. Scoring was set so that a final score of par for each anxiety trial resulted in the return of their £3.00 stake. A final score below par and the participants double their money. However, if a participant finished over par then they would lose their money. Monetary prizes were immediately redistributed at the end of the data collection and the £6.00 stake was returned to all participants regardless of score.

Intervention

During the 2 ‘post intervention’ trials participants were required to conform to a temporal restriction. Throughout these trials time afforded to the test participants during the execution stage of their Pre Performance Routine (PPR) was limited to 5 seconds. A 3 second restriction has previously been implemented for a study on putting (Beilock et al., 2004a) but it is felt that 5 seconds is more appropriate for this study. The rationale being that 5 seconds is restrictive enough to limit conscious processing but allowed sufficient time for the greater degree of preparation required in the full swing. Within this time frame, participants were required to walk towards the ball from the starting position a few steps back, set their address position and then initiate the swing.

The instructions were to use their normal preparation prior to the shot but then execute the shot within the time allowance given.

The time allocation was measured from commencement of their approach to the ball until they began their swing. The beginning of the swing was defined as the moment the club was swung away from the ball. Any shot that did not fall in the prescribed time limit was discounted and replayed. The participants were briefed on the intervention with emphasis being made to be continuous in their movement. A further 10 minutes free practice time was given for the participants to familiarize themselves with the restriction and be able to gauge how best to use the 5 seconds. During this time, feedback was provided only on the length of time taken on each practice trial.

Equipment

Participants used with their own 5 iron, conforming with the Royal and Ancient rules of golf (R&A, 2012). The balls for all trials were 'grade 1 range balls' and consistent in their flight characteristics.

Shot accuracy was measured using a Foresight Sports GC2 Launch Monitor which was aligned according to the user manual with the target taken as the 'centre line.'

Capture Range

Ball Speed: 2.0 - 200.0+ mph. Distance: 8 inches - 500+ yds.

Launch Angle: 70.0 degrees

Accuracy Tolerance

Vertical Launch Angle: +/- 0.2 degrees. Ball Speed: +/- 0.5 mph. Back Spin: +/- 50.0 rpm.v. Side Spin: +/- 50.0 rpm. Azimuth: +/- 1.0 degrees.

Instruments

Having used the CSAI-2 (Martens et al., 1990) in our pilot and initial research (see Chapter 4), it was subsequently decided that the updated CSAI-2R (Cox et al., 2003) would be an improved measure of anxiety and was administered immediately after each of the 4 trials. This is a revised, 17 item version of the original CSAI-2 and is widely considered a reliable indicator of performance pressure in sport (Fernandes et al., 2013, Jones and Uphill, 2004, Lundqvist, 2006, Lundqvist et al., 2011, Mellalieu et al., 2003) . The CSAI-2R consists of 3-subscales, measuring self-confidence (5 items), somatic anxiety (7 items) and cognitive anxiety (5 items). Participants are asked to indicate, “how you felt only at the time when you were hitting shots in the trial.” Values for each item are marketed on a 4-point likert scale ranging from ‘not at all’ to ‘very much so.’

The items for each subscale are summed to give a score for each component of performance anxiety. An example for cognitive anxiety is “I was concerned about losing.” Somatic anxiety statements petered more to the physical effects of anxiety, “I felt my stomach sinking.” The self-confidence subscale is measured with questions such as “I was confident of coming through under pressure.”

The alteration made (Cox et al., 2003) to the original CSAI-2 was the addition of a 7 point bipolar direction scale (Jones et al., 1994). This required the participant to mark on a likert scale how they perceived the effect of their answer to each CSAI-2R question with 3 being neutral, -3 = very debilitative and +3 = very facilitative.

Conscious Processing

State reinvestment was measured using an adapted, 6 item version of the Movement Specific Reinvestment Scale (MSRS, Cooke et al., 2011, Orrell et al., 2009). The MSRS includes questions on 2 dimensions of reinvestment; Movement Self-consciousness and Conscious Motor Processing. The adapted version used in this study contained items only relating to Conscious Motor Processing and included questions such as; ‘I thought about my swing as I hit the ball’ and “I reflected on my technique a great deal”. Participants reported a score on a 5 point likert scale ranging from 1 = never and 5 = Always. The item scores was summed and the mean value determined the participant’s state reinvestment.

Data Analysis

All data was tested for approximation to the normal distribution using a single sample Kolmogorov-Smirnov test. CSAI-2R subscales were assessed for reliability using Cronbach alpha calculations. A Cronbach alpha of >0.7 was deemed to show internal reliability of a subscale (Nunnally, 1962).

The intensity scores of the CSAI-2R subscales were calculated by comparing each pair of baseline and anxiety scores. The traditional method of analysis for the CSAI-2R is to measure the direction and intensity scales separately by simply summing all scores of each subscale. Issues have been highlighted (Lundqvist et al., 2011) with the interpretation of these results on the basis that facilitative scores have in the main, been attributed to low intensity scores. This indicates that the participant is reporting a facilitative effect of low anxiety and not the anxiety itself. Therefore, the combined intensity/direction method (Lundqvist, 2006, Lundqvist et al., 2011) was used by splitting high (>2) and low (≤ 2) intensity scores before measuring the direction for both. Reinvestment effects were calculated using multiple comparisons across the 4 trails.

For the analysis of the performance data, it was felt that simply aggregating the 7 balls would result in too much noise from the inherent variability of full golf shots. For this reason the accuracy value of the 7th ball of each trail was used, as this was the deemed to be the shot with the most pressure.

In order to best test the effect of the intervention, performance in the baseline trials was calculated by comparing the each participant's trial 1_{base} and trial 3_{basel} scores. The same procedure was followed to compare the anxiety scores. Trial 2_{anx} and trial 4_{anxl} were compared. To test for effect of intervention on resilience to pressure, the difference between (alpha) trial 1_{base} and trial 2_{anx} was calculated and compared to the alpha of trial 3_{basel} and 4_{anxl}. A positive value in the alpha comparisons indicates an improvement in the post trials.

All comparisons were carried out using mixed factorial, repeated measures ANOVAs where the overall type I error rate for each analysis was set at α = .05. Where Mauchly's test was violated, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Any post-hoc multiple comparisons were adjusted for using Bonferroni.

CHAPTER 4

THE EFFECTS OF COERCED AUTOMATICITY AMONGST ELITE LEVEL GOLFERS

Abstract

It is understood that motor skills are best performed in the absence of the reinvestment of explicit rules that would have previously built up during the learning phases (Masters and Maxwell, 2008a). Strongly linked to reinvestment theories are the effects of anxiety, which stimulate the desire to consciously control one's actions, leading to a "choking" scenario. In the current study, data were collected from 26 highly skilled level golfers (Handicap <4.4 M_{age} = 25) hitting full shots with a 5 iron in both base and anxiety trials. The experimental group were placed under a temporal restriction intervention with the aim of limiting cognitive input and encouraging automaticity during both conditions. The aim of the experiment was to gauge the effects of conscious control under pressure in a complex motor skill.

The results demonstrated a wide disparity in individual performance gains but no significant differential between groups. This study raises further questions into the efficacy of complete automaticity as an optimal performance paradigm for complex motor skills. These results also question the transferability of results from putting studies (Beilock et al., 2008) into full swing. Further research is suggested to better understand the utility of conscious processing in relation to a complex motor skill and the effect of temporal restrictions.

Introduction

On the way to becoming elite performers, professional golfers have all dedicated a substantial number of hours to purposeful practice (Ericsson et al., 1993b) enabling them to progress through several stages of learning as highlighted in the skill acquisition literature (Anderson, 1992, Fitts and Posner, 1967, Gordon and Burch, 1975). In these models the learner progresses through stages of competence acquiring a build up of explicit knowledge. Explicit knowledge has been defined as ‘facts and rules that we are specifically aware of and therefore able to articulate” (Masters, 1992, p. 343).

Ultimately the skill progresses to a level where the conscious reinvestment of explicit knowledge is no longer necessary. Through the phase models of skill acquisition the learner is gradually amassing and piecing together fragments of declarative knowledge formulating new and constantly evolving hypotheses. Throughout this introspection, information is held in working memory (Baddeley, 2007) until such time that there have been enough successful trials for the movement pattern to be stored in long-term memory. Working memory (see Chapter 8) is made up of a central executive and functions as an interim storage of information for short-term purposes until the information is actioned (Williams and Hodges, 2004). Once the movement pattern has been successfully transferred to long-term memory then the need for working memory input is negated. This level of unconscious control has been described as “automatic processing that is controlled largely by procedural knowledge that cannot be verbalized” (Mullen et al., 2007, P. 141) and is typically perceived as automaticity (Gorman, 2008).

Whilst the role of working memory enables the learner to build a schema through the early learning stages, it has long since been hypothesized that at the more advanced stages of skill acquisition, such input is not desirable. The involvement of working memory to use the previously useful declarative knowledge will result in the de 'automatisation' of the skill and be detrimental to performance (Baumeister, 1984, Beilock and Carr, 2001). Leading theorists in this area (Masters and Maxwell, 2008a) have attempted to bring together 'conscious control' theories and unify them together under the label of 'reinvestment' which they (2004 ,p.208) defined as 'Manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of one's movements during motor output'. Masters (1992) explains the debilitating effects of this process as a reversal of the way that Anderson (1952) outlines the process of skill acquisition. A movement sequence is compiled of a number of sub movements that are integrated and able to run as one uninterrupted pattern. Once reinvestment occurs, the pattern is broken back down into its component parts akin to the earlier stages of learning. "Once broken down, each unit must be activated and run separately, which slows performance and, each transition between units, creates an opportunity for error that was not present in the integrated control structure" (paraphrased by Beilock and Carr, 2001, p. 715). Masters' own Conscious Processing Hypothesis, (CPH, Masters, 1992) contends that any effort to consciously control a movement pattern will lead to the aforementioned disruption. A similar and well documented self-focus theory is the Explicit Monitoring Hypothesis (EPH. Beilock and Carr, 2001) which takes the concept even further by suggesting that not only conscious control but indeed the mere online monitoring of one’s movement is enough to cause the pattern to break down. An alternative view of ‘conscious processing’ also promotes the capitulation of cognitive input, but from a different perspective than the ‘reinvestment’ effect. The ‘attentional resource’ viewpoint highlights the added demands placed on working memory.

The Attentional Threshold Hypothesis (ATH. Mullen and Hardy, 2000b) contends that anxiety caused by performance related pressure consumes a portion of working memory. The reinvestment of declarative knowledge takes up another ‘chunk’ of attention and a performance drop off occurs when the attention threshold is depleted. Although both self-focus and attentional resource theories have had parallel support (Eysenck and Calvo, 1992, Eysenck et al., 2007b, L. Beilock, 2002), few studies have been able to juxtapose the two standpoints (Mullen and Hardy, 2000b, Mullen et al., 2005, Wilson et al., 2007). One such study (Gucciardi and Dimmock, 2008) did set out to do just that by prompting condition groups to attend to task relevant (arms, weight and acceleration) or task irrelevant cues (three colours). A performance drop in only the task relevant group was witnessed lending support for CPH.

A further investigation contrasting self-focus with capacity theories (Wilson et al., 2007) involved the Processing Efficiency Theory (PET. Eysenck and Calvo, 1992) which is an attentional resource model that contends that in addition to placing demands on working memory, the effects of anxiety also have a motivational value that increases effort directed to the task that can totally negate the debilitative effects of cognitive loading (Eysenck and Calvo, 1992). PET is focused on the efficiency of processing by contrasting the performance with the cognitive effort. Therefore, in a dual task set up it would be predicted that the primary task performance would stay robust by recruiting extra resources. This would be evident in a drop off in the secondary task performance, thus indicating diminished processing efficiency. Using a dual task driving set up, such an effect was recorded by Wilson (2007) lending support for the PET model. The debate between the ‘conscious processing’ and ‘capacity’ theories has a long way to go before being conclusive but one thing they all have in common is that they all promote the performer to relinquish online cognitive input. This is easier said than done, especially when the skill had been learned explicitly (Masters, 1992).

Ericsson (2003, 2007) argues that for expert performers, automaticity induces a state of arrested development. Furthermore, to continue developing, experts need to resist automatic processing and be aware of their movements enough to be able to continually refine and adapt technique (Carson and Collins, 2011, Carson et al., 2013).

When an athlete sets about a change of technique for long-term gain, reinvestment and its related effects are almost inevitable. There are suggested methods to avoid the heavy use of working memory in this process (see Chapter 2) (Koedijker et al., 2011, Masters and Maxwell, 2004) but typically, heavy reinvestment is required (Jenkins, 2007). As a result, a drop down to an earlier and heavily self-conscious stage of learning is witnessed. This in turn, results in a loss of form until enough trials have taken place to enable the re-atomization of the movement pattern.

Another well documented reinvestment scenario occurs when an athlete is feeling the effects of performance related pressure (Masters and Maxwell, 2008b). It is hypothesized that performance anxiety increases the athlete's level of self consciousness which leads to an inward focus of attention that involves the performer attending to or monitoring their movements (Hill et al., 2010). As a result, the hypothesized detrimental effects occur and the performer is heading for a 'choke'. Choking has been defined as 'performing more poorly than expected, given one's skill level, in situations where performance pressure is at a maximum (Beilock and Gray, 2007). Reinvestment in the form of both 'self focus' and 'attentional resource' theories dominate the choking literature (Gimmig et al., 2006, Hill et al., 2010). For their differences (Gucciardi and Dimmock, 2008), all the above theories promote automatic processing during task performance and share a few of the same methodological and theoretical issues (see Chapter 2) that we seek to overcome in this study with the use of a temporal restriction as a means to limit conscious processing.

Temporal restrictions have previously been utilized in this line of research with one such case (Beilock et al., 2004a), comparing results of novice and expert golfers in a putting task under an accuracy condition (no time restriction) and a speeded condition (3 second restriction). The novice group performed worse in the speeded condition while the expert groups score improved in this condition. It was hypothesized that the novice golfers were still reliant on working memory and didn't have time to access declarative knowledge. The assumed reduction in conscious processing is what enabled the expert group to improve as their movements were fully proceduralized. In a later experiment utilizing a golf putting task (Beilock and Gonso, 2008), a distinction between preparation and execution phases was drawn with both conditions being temporally restricted. Once more, the sample included both experts and novices. The results were consistent with the earlier experiment (Beilock et al., 2004a) with the experts improving in the speeded trials for both preparation and execution phases. Meanwhile, the novices demonstrated performance decrements under the temporal restriction. The hypothesis that novices benefit from online cognitive input while experts perform better in the absence of conscious control was once again given credence.

In a study involving table tennis forehand shots (Koedijker et al., 2011), accuracy of novice and beginners under time restriction was assessed. The set up involved an automatic serving machine set at 30 balls per minute (30/min) and then 40/min. While the novice group showed an increased margin of error under the speeded condition the expert group reported no significant difference. This compounded the similar results (Beilock et al., 2004a, Beilock and Lyons, 2008) reported on both shot preparation and execution.

A persistent methodological restraint (see Chapter 2) in the existing literature is the testing of comparatively simple or contrived motor skills (Winter et al., 2014). From a golfer's perspective there is a heavy bias of studies carried out on putting (Beilock et al., 2004a, Beilock and Gonso, 2008, Masters, 1992, Toner and Moran, 2011). It is convenient and not without validity to study putting but the extrapolation of results into the complex skill of full swing is tenuous. Putting is highly demanding on perceptual skill, no more so than when tasked with calculating the optimal relationship between line and speed across steep slopes (Pelz and Frank, 2000). In this scenario the golfer is challenged with making fine adjustments to movement parameters. However, this scenario is not reflective of how putting is used in the research setting where repeated straight putts are commonplace (Beilock et al., 2002). Furthermore, the mechanical complexity of the full swing is considerably greater than that of putting (see Bennett et al., 2009 for example) leading to a potential differential of cognitive control mechanisms.

It has been suggested (Masters et al., 1993b) that there lies a positive relationship between task complexity and the debilitating effects of reinvestment (see Chapter 2). However, the complexity of the full golf swing coupled with the vast amount of explicit knowledge an expert has absorbed may point toward an alternative schema that involves some degree of conscious control and internal focus. Along the lines of recent criticisms (Peh et al., 2010) of the attentional focus research, the dichotic nature of the studies in this field may belie an optimum attention strategy that utilizes a mix of external/internal focus and the appropriate use of working memory (Bernier et al., 2011).

Objections aside, the overwhelming majority of research in the field of reinvestment points towards its mal-effects for expert performers. Taking this into consideration with the congruent results above and from similar studies involving temporal restrictions (Beilock et al., 2004a), our predictions for this study are in line with the CPH. We hypothesize that the temporal restriction used in this study will limit the capacity of the performer to engage in conscious movement control with the resultant improvement in performance. This could in turn lead to the development of practical interventions for an applied setting.

The lack of manipulation check for conscious control is recognized as a limitation of this study and is addressed in subsequent chapters.

Methods

Participants

26 trainee PGA golf professionals hcp < 4.4 participated in the study. Recruitment was from 90 first year PGA trainees attending a residential course. The participants were selected randomly from the 38 responses to a recruitment email sent to all 90 professionals outlining the study and requesting participation. The participants were randomly allocated to either control (n=13) or experimental groups (n=13). Before the study all participants gave written informed consent (Appendix 1) and the study was approved by the Local Research Ethics committee.

Measures and Apparatus

All shots were struck with the participant's own 5 iron conforming with the Royal and Ancient rules of golf (R&A, 2012). The balls for all trials were 'grade 1 range balls' and consistent in their flight characteristics. Shot accuracy and distance were measured using a TrackMan Pro milli-wave doppler radar launch monitor.

TrackMan Pro Range and Accuracy Tolerance:

- Ball carry range: 3-400 yards
- Vertical launch angle: +/- 0.2 degrees

- Ball speed: +/- 0.1 mph
- Ball accuracy (carry) +/- 0.5%
- Sidespin Rate: +/- 15 rpm

The radar was calibrated according to the user manual with the target taken as the ‘centre line.

Procedure

All testing took place on the driving range of the PGA National Headquarters. A mixed repeated measures design with a between subjects factor of group (experimental, control) and within subjects factors of time (pre, post) and condition (baseline and anxiety) was carried out. The procedure followed that laid out in the general methods section (chapter 3) with the omission of a direction scale relating to the CSAI-2R and the aMSRS questionnaire.

Data Analysis

All data were tested for approximation to the normal distribution using a single sample Kolmogorov-Smirnov test. CSAI-2R subscales were assessed for reliability using Cronbach alpha calculations. A Cronbach alpha of >0.7 was deemed to show internal reliability of a subscale (Nunnally, 1962). Calculated Cronbach alphas showed that all subscales of the CASI-2R were internally reliable somatic anxiety (α = 0.87) cognitive anxiety (α = 0.81) and self-confidence (α = 0.92). Participant subscale scores were calculated by multiplying a participant’s mean score for each subscale by 10. Any effects of condition and group on subscale scores during pre-intervention testing were explored using repeated measures MANOVAs.

The effects of the intervention on performance via shot distance and accuracy, were analysed using a Mixed ANOVA with a repeated factors of intervention (pre, post) and test (normal, self-conscious) and a between-groups factor of group (control, experimental). The overall type I error rate for each analysis was set at $\alpha = .05$. Post-hoc tests for all analyses were carried, where appropriate, using the Holm-Bonferroni correction to adjust the level of α for multiple comparisons. Huynh-Feldt corrections for lack of sphericity were used where appropriate. All data and reported as mean ± standard deviation unless otherwise stated.

Distinct from the general procedure, this study looked at both shot distance and accuracy by taking the mean value of each 7 ball trial.

Results

There was a significant effect of test on the subscale scores of the CSAI-2R questionnaire (Wilk's $\lambda = 0.40$, $F_3 = 4.69$, $p = .01$), with scores increasing significantly in both the somatic ($F_1 = 4.48$, $p =0.045$) and cognitive anxiety ($F_1 = 14.53$, $p=0.001$, ANOVA) subscales in the post intervention anxiety condition (table 1) compared with the baseline condition. There were no changes in the self-confidence subscale ($F_1 = 2.70$, $p=0.11$) between the pre and post anxiety conditions. The change in the somatic and cognitive subscale scores was similar between groups with no interaction effect found for group (Wilk's $\lambda = 0.87$, $F_3 = 1.05$, $p=0.39$).

Group	Pre Somatic	Pre Cognitive	Pre Self-Confidence	Post Somatic	Post Cognitive	Post Self-Confidence
Experimental	13.3 ± 3.2	16.0 ± 4.8	28.3 ± 5.0	15.6 ± 5.1	19.4 ± 5.2	28.3 ± 5.7
Control	13.6 ± 2.9	16.7±5.7	27.5 ± 5.5	15.4 ± 4.5	20.2 ± 4.5	24.8 ± 5.4
ALL	13.4 ± 3.0*	16.3 ± 5.2$	27.9 ± 5.2	15.5 ± 4.7*	19.8 ± 4.8$	26.6 ± 5.7

Table 4.1. CSAI-2R mean subscale scores in the pre and post intervention anxiety conditions. *,$ indicate significant difference between pair. Data are mean ± standard deviation

There was a significant effect of test on shot accuracy (Wilk's λ = 0.60, F_2 = 7.79, p=0.003) this was shown to be the result of the ball being hit less distance after the intervention in both groups and conditions (F_1 = 14.50, p=0.001, ANOVA, table 2) with no changes in accuracy (F_1 = 1.26, p=0.27).

Group	Distance (yds) Pre Baseline	Distance (yds) Post Baseline	Distance (yds) Pre Anxiety	Distance (yds) Post Anxiety	Accuracy (yds off target line) Pre Baseline	Accuracy (yds off target line) Post Baseline	Accuracy (yds off target line) Pre Anxiety	Accuracy (yds off target line) Post Anxiety
Experimental	167 ±13	161 ± 11	166 ± 13	161 ± 15	11 ± 4	10 ± 4	10 ± 5	9 ± 3
Control	168 ± 14	163 ± 13	164 ± 14	163 ± 12	10 ± 6	11 ± 3	12 ± 4	9 ± 3
ALL	168 ± 13	162 ± 12	165 ± 13	162 ± 13	10 ± 5	11 ± 4	11 ± 4	9 ± 3

Table 4.2. Mean shot distance and accuracy measurements for each condition pre and post intervention. Accuracy is given as yards off the central target line. Data are mean ± standard deviation.

No main effects were found on either distance or accuracy for the repeated factor condition (Wilk's $\lambda = 0.86$, $F_2 = 1.91$, $p=0.17$). Nor were there any first or second order interaction effects in any combination between test, condition and group. Scatter plots (Figures 4.1 and 4.2) showing individual differences in accuracy and distance indicate a disparity of intervention effect within the test group and the positioning of outliers within the sample.

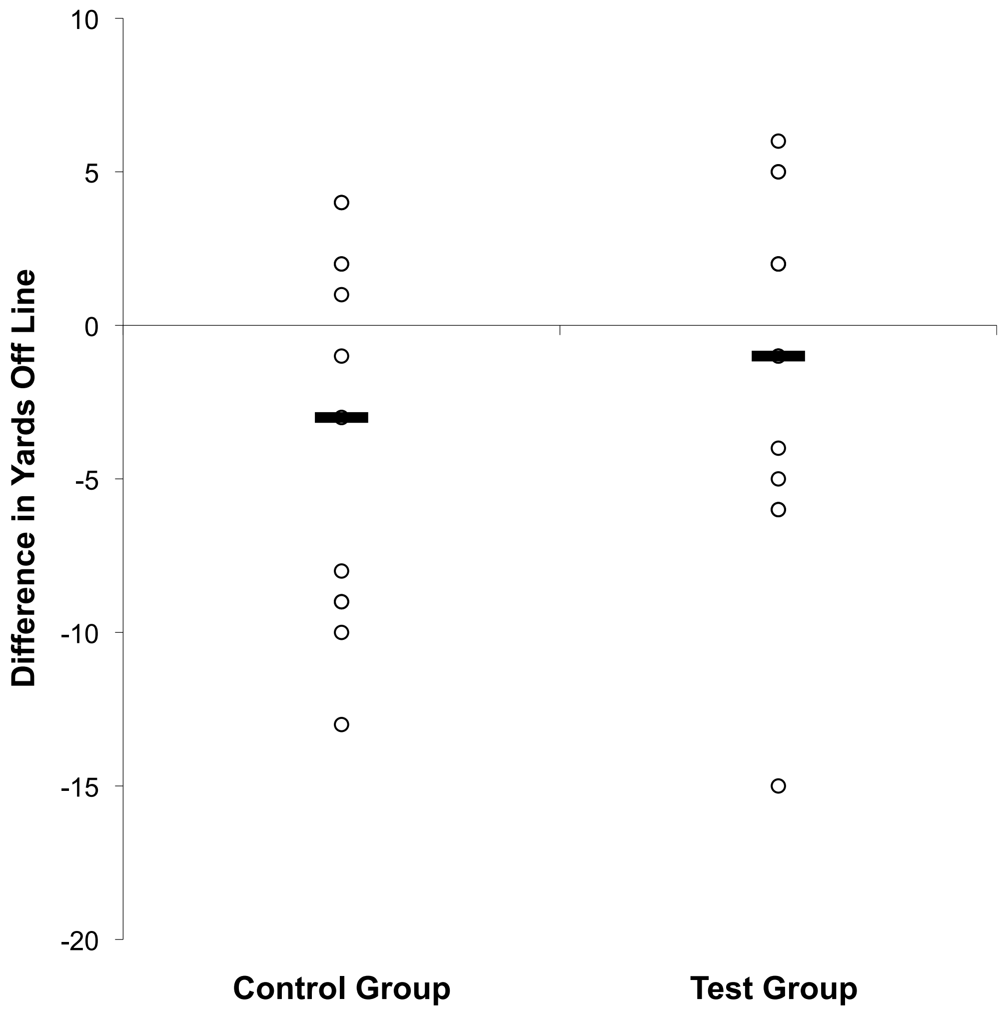

Figure 4.1. The difference in accuracy between pre and post anxiety trials. Negative values indicate less yards offline in the post trial. Shows a disparity of intervention effect within the test group and a trend of improved accuracy.

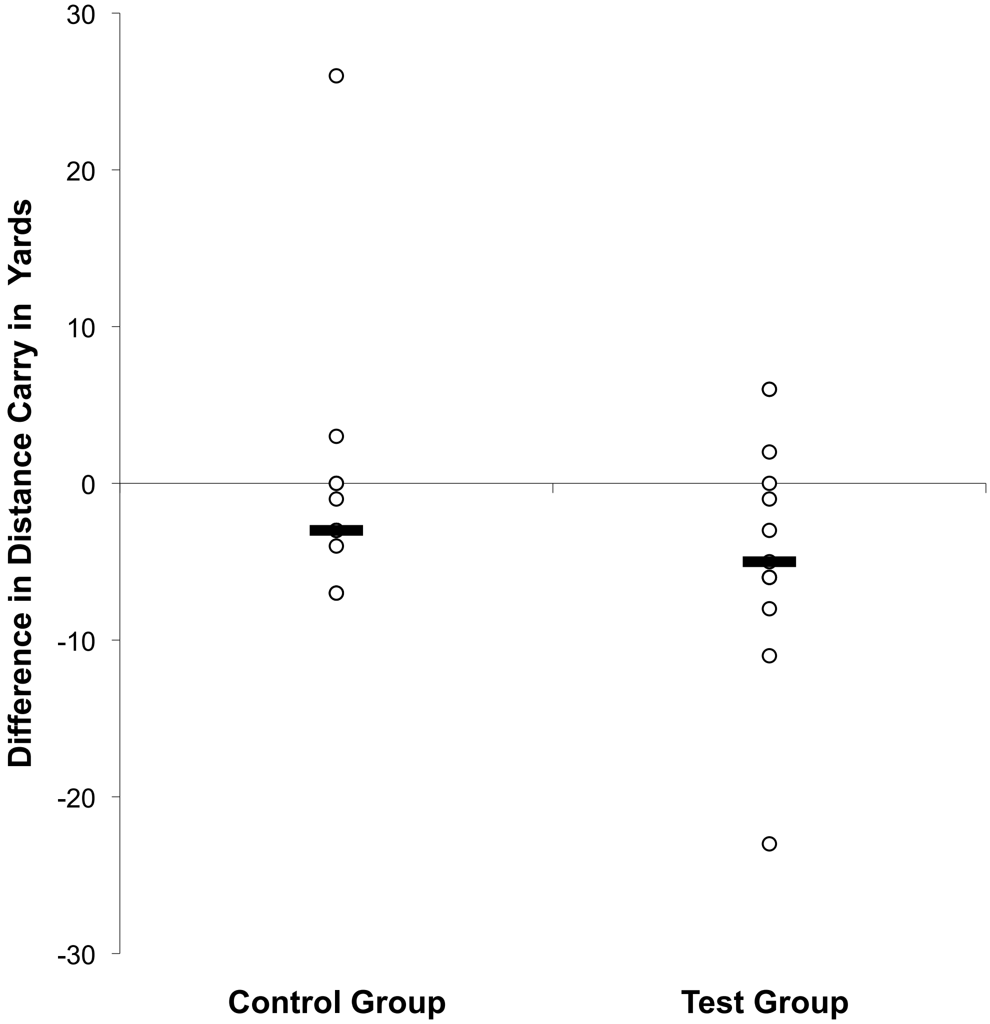

Figure 4.2. The difference in distance between pre and post anxiety trials. Negative values indicate less distance in the post trial. Shows the presence of two outliers within what is otherwise a null effect of intervention.

Discussion

The aim of this study was to examine the performance effects of an intervention designed to promote automaticity within the execution of the full golf swing, under baseline and pressure conditions. With previous work in this area being heavily biased towards putting trials and reliant on the dual task paradigm that has been widely criticized for its ecological validity (Baddeley, 1996, Christensen et al., 2015, Winter et al., 2014), this study aimed to address these issues. The unique aspects of this study are the complexity of the task by means of the full swing and a temporal restriction as the method to encourage autonomous performance. The main findings of the study show that even though the test group was placed under a strict and unfamiliar time restraint their performance, as a whole, remained stable in comparison to the control group. This rejects our earlier hypothesis that, in accord with the CPH, predicted the test group to perform better with limited reinvestment. These results tentatively raise questions about the efficacy of reinvestment theory in relation to complex skills.

A methodological limitation of this study is recognized by way of a lack of manipulation check relating to conscious control. It is possible that the null effect in the current study is attributed to the ineffectiveness of the intervention to reduce conscious movement control. It is recommended that future experiments of this nature circumvent this issue by means of a measure of state reinvestment to be administered on every trial.

Another factor that could have influenced the null effect was the potentially jarring nature of the temporal restriction on many of the sample. The intervention would have limited their previous cognitive strategy (swing thoughts, timing cues, holistic swing cues), which some participants may have found distracting and potentially stressful. The purpose and essence of the intervention was to limit the reinvestment and cognitive load during task performance. However, if a number of the sample still attempted to use their normal cognitive strategy under the time restraint then the intervention would have been very uncomfortable in a manner that would not necessarily have been reported in the CSAI-2R. The intervention relies on a level of confidence in the their skill establishment and in the process of automaticity (Carson and Collins, 2015). Without which, they would be unlikely to relinquish conscious control of their golf swing. For some, this confidence may have been immediately gleamed from the brief practice trial while others may need a lot longer. It is felt that if the jarring nature of our set up is reduced then the time restraint may well be as effective as in previous studies on putting (Beilock et al., 2004a). Future study in this area should look to overcome this effect with a long-term learning and transfer period to incorporate the time restricted intervention.

Other key factors leading to a null effect could be individual differences within the sample (Figures 4.1 and 4.2) that may be attributed to the disparity of intervention effect and the presence of outliers. The propensity for reinvestment could well be linked to personality factors (Masters et al., 1993b) and as such be prone to individual differences. Masters (1993) compiled a questionnaire that could act as a tool to predict reinvestment in individuals. This ‘reinvestment scale’ questionnaire was put together using previously tested measures that included a ‘self- consciousness’ scale’ (Fenigstein et al., 1975a) and the ‘Cognitive Failures Questionnaire (Broadbent et al., 1982). The personality factors represented in the reinvestment scale may be a strong determinant in reinvestment but are by no means exhaustive. Working Memory Capacity (WMC) (see Chapter 8) has also been hypothesized as a factor in determining propensity for conscious processing (Buszard, 2014). The early hypothesis, is that in tasks that invoke a high demand on working memory it is individuals with a larger working memory capacity that possess a higher propensity to choke (Beilock and Carr, 2005, Buszard et al., 2013, Gimmig et al., 2006). The difference in working memory capacity of the participants in the current study may have led to an individual disparity in results that caused the null effect. Later in this thesis (Chapter 7) and along this individualistic approach, we also test for a number of dimensions of learning style against propensity to and utility of reinvestment.

A key methodological restraint in this study was the lack of a measure of state reinvestment for each of the trials. We have assumed, as with previous studies (Beilock et al., 2004b, Beilock and Gonso, 2008), that a shorter time afforded for shot execution means limited reinvestment. Although instinctive, we cannot say for sure that this was the case and that our intervention was effective to this aim. Not sufficiently reducing conscious processing remains a possible reason behind the null effect. Before looking further into the individual factors pertaining to reinvestment, a deeper understanding of the relationship between time and conscious processing is required. Chapter 5 looks at the reinvestment and performance effects of 3 different temporal corridors. Furthermore, subsequent experiments in this thesis (Chapters 5-8) have an adjusted procedure that includes a measure of conscious processing immediately after each block of trials. This is taken from the ‘Conscious Motor Processing’ (CMP) dimension of the movement specific reinvestment scale (MSRS, Orrell et al., 2009) and is adapted to suit the task (Cooke et al., 2011) (Chapter 3).

A broader limitation of this and study is the lack of information available on the starting differential of the sample. Individual differences would allow for further analysis and potentially highlight key features of reinvestment and resilience to pressure. As with the majority of studies in this field, no measurements were taken with the aim of categorizing types of conscious processing. The dichotic nature of automaticity research has previously been criticized (Furley and Memmert, 2010, Winter et al., 2014). If an optimal cognitive strategy is to be proposed then more work is needed to understand the qualitative elements of reinvestment (Furley and Memmert, 2010), particularly in light of the multiple resource (Sanders, 2001) and crosstalk (McLeod, 1977) and cognitive load (de Jong, 2010) theories. The introduction of a questionnaire may be able to draw out the value and nature of reinvestment more accurately. Subscales of content (result, technique or state awareness) sense (visual, auditory, kinesthetic, auditory digital), or level of abstraction could be more useful in identifying an optimum cognitive strategy (Bernier et al., 2011, Jenkins, 2007).

Whilst there is a lot of prior research on the effects of pressure upon performance in golf, the majority of this work has been carried out on putting (Beilock et al., 2004a, Jackson et al., 2006, Jackson and Willson, 1999, Masters, 1992, Masters et al., 1993b, Mullen et al., 2005) with some additional studies looking at chipping (Wulf et al., 1999). The closest of these putting studies to the present set up was carried out by Beilock (2004a). A time constraint of 3 seconds was used during the test condition. In this case the results were positive in favor of the temporally restricted group. It should be noted that there was no anxiety set up and no baseline measure that allowed the participants to use their own cognitive strategy. Instead, the test condition was measured against a forced technical focus set up that required the participant to say “straight” at impact. This of course could have had a cognitive loading or distraction effect. That said, the main disparity between this and the present study remains the comparatively simple nature of putting. With the task being as technically simple as the putting stroke, one could argue that the role of working memory is practically redundant and therefore its over use easily leads to the negative reinvestment effect. However, Masters (2008) believes that the more complex skills will show a greater propensity to for disruption, “reinvestment is more disruptive to complex tasks with many components that must be coordinated, than simple tasks that are easily proceduralised” (Masters and Maxwell, 2008a, p.174). If this statement is to be true then results on reinvestment in full swing tests should be even more substantial than for the numerous studies on putting. If this is not the case then the reinvestment paradigm for complex skills may need to be re-addressed. It is possible that a skill as complex as the full golf swing may benefit from the contribution of working memory (see Chapter 8).

In summary, the anxiety condition in this study did cause a significant level of cognitive anxiety but our hypothesis was disproven as the intervention did not positively affect performance in either shot accuracy or distance.

We can imply from this that the application of the reinvestment model may be more complicated when considering complex motor skills than in comparison to relatively simple skills such as putting.

Conclusion

This study examined the performance effects of a temporal restriction aimed at reducing conscious processing during the execution of the full golf swing. Although there was a null effect of performance measures in both distance and accuracy, the individual effect differential suggests that there are additional factors that need to be considered.

Future research is needed using a longer transfer time between learning the intervention and being tested. Also, additional research is necessary from an individualistic perspective, taking into account differences within the sample prior to the study. Differences of working memory capacity, personality and learning styles would bring forth further understanding to the field.

CHAPTER 5

THE EFFECT OF TEMPORAL RESTRICTIONS ON CONSCIOUS PROCESSING AND FULL GOLF SWING PERFORMANCE

Abstract

It is generally agreed that during the execution phase of a complex motor skill optimum performance is best achieved with a high level of automaticity.

The purposes of the present study were to firstly, explore the relationship between the duration of the execution phase of a full golf swing and the level of automaticity experienced by the golfer in pressure and non-pressure conditions. Performance was also measured by way of shot accuracy.

Highly skilled golfers (n=13) (<5 handicap) hit 5 iron full swing shots within 3 different temporal restraints for both baseline and anxiety conditions. There was a significant result of time on reinvestment in both the baseline, $F(2, 24) = 13.31$, $p = <.001$, and anxiety, $F(2, 24) = 5.27$, $p = .013$, conditions. However, despite affecting reinvestment levels, performance remained stable over all 3 temporal restrictions.

This study raises further questions in to the design of Pre Performance Routines to best enhance performance and increase resilience to pressure. We also raise questions about the Conscious Processing Hypothesis (Masters and Maxwell, 2004) in relation to a highly complex motor skill. Further research is suggested to explore the link between time, reinvestment and performance. Furthermore, lack of research is highlighted in these areas from both a qualitative and an individual / personality perspective.

Introduction

At the elite level of competitive sport where margins between success and failure are fine, it has long been understood that psychological attributes play an increasingly important role (Hill et al., 2010). This study is focused on the full swing execution in golf, which is an entirely self-paced skill and thus allows the performer ample preparation and execution time. Self-paced skills have been defined as having characteristics that include a relatively stable environment, the situation is predictable, and there is little concern for rapid perceptual adjustments (Singer, 1988).

In these environments the action is entirely instigated by the performer, placing a weight of significance on mindfulness (Gardner and Moore, 2004): the 'ability to attend to a task without distraction' (Mrazek et al., 2013, p.776), and flow (Csikszentmihalyi, 1997) which has been defined as 'a deeply rewarding and optimal experience characterised by intense focus on a specific activity to the point of becoming totally absorbed in it, and the exclusion of all other thoughts and emotions' (Swann et al., 2012, p.3). Paradoxically, it appears to be the self-paced skills that present the toughest challenge in cognitive readiness by affording the temporal freedom for the mind to wander from a resolute task focus (Singer, 1988). Theories of 'speed, accuracy trade off,' (Glazebrook et al., 2015, MacKay, 1982, Schmidt and Lee, 2013) would predict that extra time in self-paced skills would be advantageous in allowing the performer to fully consider their movements. In fact, it could be that the indistinct time constraints allow for the performer to engage in debilitating cognitive strategies that involve task irrelevant thoughts and behaviors (Boutcher, 1990) or procedural ‘rules’ that can interfere with a well learnt unconscious process (Masters and Maxwell, 2008b). This notion of ‘over thinking’ is supported by the automaticity literature where it is widely agreed that optimum performance occurs in the absence of the working memory input (Beilock and Carr, 2001, Chell, 2005, Eysenck et al., 2007b, L. Beilock, 2002). In bringing earlier self-focus theories together Masters and Maxwell (2008a, 1992, 2004) fashioned the term ‘reinvestment’ to describe the input of declarative knowledge via working memory during skill execution. Their Conscious Processing Hypothesis (CPH, Masters and Maxwell, 2004) remains the prominent theory in the field and describes heavy working memory input during skill execution, as a means to deconstruct an otherwise deeply learnt procedural process. During skill acquisition multiple movements become proceduralised and run as one uninterrupted pattern. As the performer reinvests explicit knowledge through working memory input the skill gets broken back down into its component parts, which slows down functionality and creates gaps where errors occur.

Other, more qualitative studies of task focus (Carson and Collins, 2014, MacPherson et al., 2008, MacPherson et al., 2009, Mullen and Hardy, 2010, Nicholls and Polman, 2008, Winter et al., 2014) also discourage detailed focus on one’s movements during skill execution. In particular, these studies highlight the distinction between focus on part skill and a more beneficial holistic movement focus. The Constrained Action Hypothesis (CAH, Wulf, 2007) makes a clear distinction between internal and external focus. Internal focus is the focus on one’s movements during task execution while a preferred external focus directs attention towards either the target or the environmental effects of one's actions (e.g. ball trajectory) and thus leaves the mechanics of the movement to an unconscious process. The CAH suggests that internal focus breaks down the natural processes of a movement production in a similar way to the reinvestment literature.

The undesirable effects of actively controlling or even just monitoring (Beilock et al., 2004a, Jackson et al., 2006, Masters and Maxwell, 2008a) one's movements during task execution are at the heart of the dominant mechanistic views in choking under pressure (Hill et al., 2010). If this is such then the development of Pre Performance Routines (PPR's) that act to facilitate automaticity during the execution stage is a much needed research direction.

It is widely regarded that the few seconds prior to action in self-paced skills can be crucial to the performance outcome (Boutcher, 1990, Glazebrook et al., 2015, Spiegel et al., 2012). As such, the use of PPR's is commonplace as a framework to channel attention and focus by way of cognitive and behavioral cues (Cotterill, 2010). PPR'S have been defined as a sequence of task relevant thoughts and actions an athlete systematically engages in before performance of a sport skill (Moran, 1996). There is a considerable body of research in this area with a large focus on temporal considerations (Kingston et al., 2001, Lonsdale and Tam, 2008). Early studies focused on the duration of routines and pointed towards a positive correlation between PPR duration and the level of expertise. (Boutcher, 1990, Boutcher and Crews, 1987). Counter theories proposed that shorter routines with fewer behavioral components would provide a more optimum preparation (Southard et al., 1989) by way of less reinvestment. Critically, observational studies of real life performances in football penalties (Jordet et al., 2009), NBA basketball free throws (Lonsdale and Tam, 2008) and in world cup rugby kicker's PPR's (Jackson, 2003) found there to be no significant difference in duration between the best and worst performers.

Parallel studies in the area have focused on the consistency of PPR's with the suggestion that the more consistent the routine is then the more consistent the performer's cognitive strategy and state of readiness (Wrisberg and Pein, 1992) would be. Studies in golf (Boutcher and Crews, 1987, Crews and Boutcher, 1986) did initially support this stance with a reported positive correlation between the skill level of the golfer and the consistency of PPR behaviors and duration but thus far no causal link has been established. In fact, Cotterill (2010, p.141) has made the point that the consistency of PPR duration observed in elite players may be "merely a function of time spent practicing".

Other studies of PPR temporal consistency found no causal link (Kingston et al., 2001, Southard and Miracle, 1993). In line with this view it is suggested (Holder et al., 2003, Jackson, 2003, Jackson and Baker, 2001, Lonsdale and Tam, 2008) that the duration of a PPR is relative to the difficulty of the task and individualistic factors. During the Jackson (2003) study it was observed that rugby players would take longer over a goal kick in proportion to the distance and acuteness of angle from the posts. This variability of difficulty is seen a lot in golf where a tee shot can be a relatively simple shot that can be easily reconstructed in practice and may not take a lot of extrinsic consideration. Meanwhile an approach shot played from a side hill stance with a strong crosswind presents an environmental predisposition for further calculation.

While much of the early PPR literature concerned itself with the temporal factors there is now more support (Holder et al., 2003, Mack, 2001, Mesagno and Mullane-Grant, 2010) for a view that favours the qualitative significance of the behavioral elements of the routine than the time taken or even behavioral consistency (Czech et al., 2004).

While a lot of the early PPR literature make no distinction between different stages of a routine, in Murphy's (1994) four step performance management model the readying and execution of the skill are separated within the PPR by way of a 'preparation' and 'performance' stage. The PPR is further segmented in a separate 'five step model for self paced actives' (Singer, 2000, Singer, 2002). In this model, readying, imaging, focusing attention, executing and evaluating all form discrete parts of the PPR that are significant distinctions in the context of this study. Golfers may share the similar preparation phase requirements as other sports but during shot execution the absence of a run up and the demand for correct orientation creates ample opportunity for online explicit monitoring and distraction.

Where the PPR literature is consistent, is in offering a fundamental message that the purpose of a PPR is to facilitate optimal focus and automaticity (Boutcher and Rotella, 1987, Cotterill, 2010). Studies that have distinguished between preparation and execution phases (Fischer, 1997, Holroyd et al., 2005, Koedijker et al., 2011, Lam et al., 2010b, Singer, 2000) also share the consensus that for elite players it is the preparation that is more cognitively demanding than the execution stage. The suggestion is that, in line with the CPH and CAH; online monitoring during execution is not necessarily required or even desirable.

If this is such then the development of PPR's that act to facilitate automaticity during the execution stage is a much needed research direction. Currently considered interventions to promote automaticity during this phase, include the use of cue words/ meta swing thoughts (MacPherson et al., 2008, Mullen and Hardy, 2010), rhythmical cues (MacPherson et al., 2009), external focus and like this study, temporal restrictions (Beilock et al., 2004a, Mesagno et al., 2009, Wulf et al., 2000, Wulf and Su, 2007).

Cue words have been used to discourage a 'part-movement' focus that suffers from the effects of conscious processing outlined in the reinvestment literature (MacPherson et al., 2008). A more 'holistic focus' that represents the whole movement has been shown to counter the negative affects of explicit monitoring while conveying key information about the intended movement. (Winter et al., 2014). To this end, the holistic focus can incorporate individual sub-units of the movement into one global representation that facilitates smooth and automatic movement execution (Mullen and Hardy, 2010). While this method would seem to have applied efficacy, in relation to the study of automaticity, it has been argued that holistic focus strategies still represent a level conscious processing (Moran, 2014, Toner et al., 2015, Toner and Moran, 2011).

Predominantly, research settings induce automaticity by the way of a dual task (L. Beilock, 2002, Land and Tenenbaum, 2012, Masters, 1992, Mullen et al., 2007). This set up serves to cognitively load the participant with a secondary task leaving little or no working memory capacity for the primary task. Not without its drawbacks (Baddeley, 1996, Gabbett and Abernethy, 2012), the dual task paradigm does have a distracting effect on the performer but would prove an impractical intervention during a sport setting.

Within research there have been studies that use temporal restrictions to limit cognitive reinvestment (Beilock et al., 2004a, Beilock et al., 2008). During these studies elite golfers performed better in a simple putting task under a temporal constraint than in regular conditions. The surprising results pointed towards the reinvestment paradigm in that the golfers had less time to 'over think' the action and disturb the unconscious processing associated with elite level skill execution. Predominantly, these studies use putting as the 'complex' motor skill but we should be cautious in extrapolating the findings into the full golf swing, which carries a considerably greater mechanistic complexity.

There are two aims of this study. Firstly, to observe any relationship between time taken in the execution phase and the levels of automaticity. If we can establish a link between these factors then we will be closer to a paradigm from which to design effective PPR's. In an observation and interview-based study of elite golfer's existing PPR's, it was reported that a largely individual approach to PPR's is currently prevalent. A prominent theme that was found however, is that the golfers interviewed agreed that a key function of the PPR is to control the allocation of attentional resources and, as a result, "manipulate and control attentional focus" (Cotterill, 2010, p. 62). The results of this study could lead to temporal factors involved in this aim. Our hypothesis is that there will be a linear relationship between time and reinvestment up to a certain threshold. Thereafter, reinvestment will level out as the performer feels that they have readied themselves.

The second aim of this study is to analyze task performance in relation to duration of the execution phase and level of automaticity. If we do achieve high levels of automaticity amongst our elite golfers we would need to corroborate that this does in fact aid in performance as the automaticity and PPR literature would point to. This result would also allow for a more valid transfer of results from previous conscious control studies in putting.

Methods

Participants

13 golfers handicap (<6) participated in the study. Recruitment was from golfers studying at two universities in the United Kingdom. During the study, participants hit full swing golf shots within 3 different temporal parameters. Before the study all participants gave written informed consent and the study was approved by the Local Research Ethics committee.

Procedure

Participants hit 42 full swing shots with their own 5 iron conforming with the Royal and Ancient rules of golf (R&A, 2012) down an open air golf driving range. The balls for all trials were 'grade 1 range balls' and consistent in their flight characteristics. Shot accuracy and distance were measured using a milli-wave doppler radar launch monitor (Track Man Pro™, TrackMan A/S, Denmark). The radar was calibrated according to the user manual with the target taken as the 'centre line.' Testing took place on the driving ranges of the PGA National Academy at the Belfry and Wycombe Heights Golf Centre. Participants were given 10 minutes to warm up in their own manner in which the opportunity to freely hit shots was provided. Participants hit 7 shots with a 5 Iron in each condition. Both baseline and anxiety conditions were repeated in each of the 3 time corridors. The time corridors were selected in random order (Figure 1). Measures of performance anxiety (Competitive State Anxiety Inventory-2R) and conscious processing (adjusted Movement Specific Reinvestment Scale) were administered immediately after each trial (see Chapter 3).

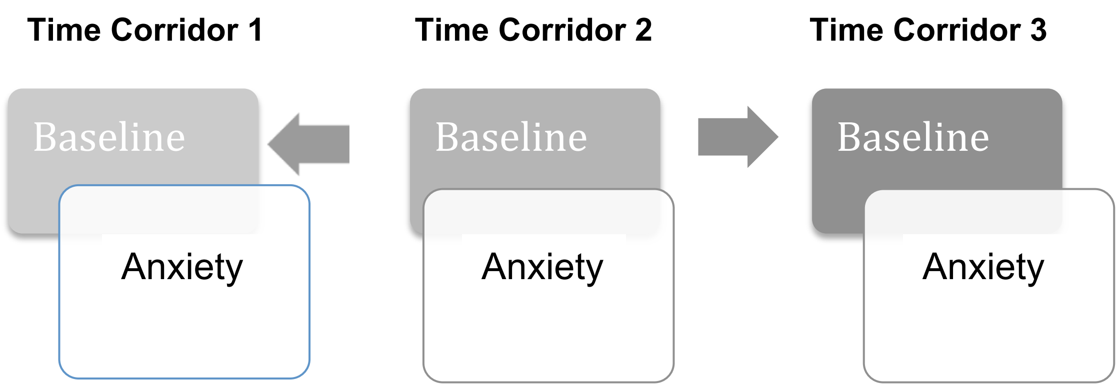

Figure 5.1. Experimental Conditions

Baseline Conditions (base)

Baseline performance was measured with players being instructed to hit the ball as accurately to a target as possible and to their normal 5 iron distance.

Anxiety Conditions (anx)

Participants took part in a competition format designed to induce anxiety during shot performance. The results of the competition were displayed on site in view of all competitors. The competition scenario is outlined in the general procedure (Chapter 3) with the only exception being that the £6.00

stake was split into 3 x £2.00 denominations to be pledged against each anxiety trial.

Instruments

All instruments are as per the general procedures outlines in Chapter 3.

Intervention

Time afforded to the test participants during the execution stage of their PPR was manipulated to within 3 parameters. The instructions were to use their normal preparation prior to the shot but then execute the shot within the time allowance given.

Time Corridor 1 < 5 seconds *(TC1)*

Time Corridor 2 6-10 seconds *(TC2)*

Time Corridor 3 >10 seconds *(TC3)*

The time allocation was measured from commencement of their approach to the ball until they began their swing. The beginning of the swing was defined as the moment the club was swung away from the ball. Any shot that did not fall in the prescribed time limit was discounted and replayed**.**

During the initial baseline trial a customary time period was established for each player, which fulfilled one of the parameter conditions. Having completed both a baseline and anxiety trial in this time corridor they were then randomly assigned the other two temporal parameters.

Data was recorded for all participants under baseline and anxiety condition for each of the three temporal restrictions.

Data Analysis

Data was analyzed as per the general procedure (chapter 3). A comparison was calculated between the 3 time corridors in both baseline and anxiety trials. To test the gross effect of the intervention on the participant's robustness to anxiety, Δ scores were calculated by subtracting the anxiety score from the baseline score in each time corridor.

All comparisons were carried out using mixed factorial ANOVAs where the overall type I error rate for each analysis was set at $\alpha = .05$. Greenhouse-Geisser corrections for lack of sphericity were used where appropriate. Any post-hoc multiple comparisons were adjusted for using Bonferroni. All data and reported as mean ± standard deviation unless otherwise stated.

Results

CSAI-2R Reliability

Calculated Cronbach alphas showed that all subscales of the CASI-2R were internally reliable; somatic anxiety (α = 0.75) cognitive anxiety (α = 0.88) and self-confidence (α = 0.82). All aMSRS (reinvestment) alphas also show high internal reliability.

Block	**1**	**2**	**3**	**4**	**5**	**6**	**Overall**
Cognitive Anxiety	.77	.82	.87	.78	.83	.85	.88
Somatic Anxiety	.72	.76	.64	.82	.71	.75	.75
Self Confidence	.81	.69	.83	.87	.83	.87	.82
Reinvestment	.73	.76	.90	.87	.93	.67	.83

Table 5.1. Cronbach's α values across all 6 trials. The original Cronbach's α value for the somatic scale in trial 1 was 0.59. Through subsequent analysis of the item total statistics, item 15 was removed to give an improved Cronbach's α value of 0.72.

CSAI-2R Subscales

Cognitive Anxiety

Pair 1_{TC1} showed no significant effect, $F(1,11) = 0.14$, $p = .71$, but there was a significant effect for cognitive anxiety between the baseline and anxiety conditions in pair 2_{TC2} $F(1, 11) = 5.56$, $p = .03$ and pair 3_{TC3}, $F(1, 11) = 4.66$, $p = .05$

	TC 1		**TC 2**		**TC3**	
	Base	**Anx**	**Base**	**Anx**	**Base**	**Anx**
Intensity	2.3 ± .74	2.29 ± .67	1.45 ± .56	2.22 ± .82	1.57 ± .55	2.02 ± .69
Direction	-.54 ± 1.32	-.14 ± 1.29	1.17 ± 1.34	.25 ± 1.79	1.09 ± 1.22	.07 ± 1.43

Table 5.2. CSAI-2R mean scores for cognitive anxiety in the pre and post intervention anxiety conditions. Data are mean ± standard deviation.

Somatic Anxiety

There was no significant effect of somatic anxiety on any of the 3 comparisons. Pair 1, $F(1, 11) = 0.66$, $p = .8$, pair 2, $F(1, 11) = 5.76$, $p = .09$ or pair 3, $F(1, 11) = 1.99$, $p = .19$.

	Pair 1		**Pair 2**		**Pair 3**	
	Base	**Anx**	**Base**	**Anx**	**Base**	**Anx**
Intensity	1.67 ± .62	1.64 ± .45	1.33 ± .50	1.6 ± .50	1.29 ± .30	1.60 ± .55
Direction	-.54 ± 1.31	-.14 ± 1.29	1.17 ± 1.34	.25 ± 1.79	1.09 ± 1.22	.76 ± 1.43

Table 5.3. CSAI-2R mean scores for somatic anxiety in the pre and post intervention anxiety conditions. Data are mean ± standard deviation.

Self Confidence

There was no significant effect of self confidence on any of the 3 comparisons. Pair 1, $F(1, 11) = 0.7$, $p = .42$, pair 2, $F(1, 11) = 0.67$, $p = .43$ or pair 3, $F(1, 11) = 3.98$, $p = .54$.

	Pair 1		Pair 2		Pair 3	
	Base	**Anx**	**Base**	**Anx**	**Base**	**Anx**
Intensity	.92 ± .52	3.03 ± .64	2.95 ± .86	2.69 ± .95	2.8 ± .86	2.7 ± .81
Direction	1.42 ± .99	1.57 ± .94	1.57 ±1.45	1.14 ± 1.56	1.52 ± 1.41	.52 ± 1.72

Table 5.4. CSAI-2R mean scores for self confidence in the pre and post intervention anxiety conditions. Data are mean ± standard deviation.

CSAI-2R Direction

The Lundqvist et al. (2011) method for handling direction data shows a clear direction scale disparity for high and low intensity scores. The high intensity scorers all have a reported debilitative effect with low intensity scores all reporting the effect, or lack of, to be facilitative.

		Pair 1		Pair 2		Pair 3	
Condition		**Base**	**Anx**	**Base**	**Anx**	**Base**	**Anx**
Cognitive	High Intensity	-1.23 ± 1.08	-.57 ± 1.2	-.70 ± .14	-.69 ± 1.3	-.40 ± NA	-.80 ± .55
	Low Intensity	0.37 ± 1.06	.6 ± 1.3	1.36 ± 1.09	2 ± .66	1.42 ± 1.00	1.3 ± 1.00
	Sig.	.027	.139	.28	.002	.113	.001
Somatic	High Intensity	.24 ± .64	-.48 ± .36	.07 ± 1.31	-1.14 ± .20	1.43 ± 1.12	-.71 ± .40
	Low Intensity	1.13 ± 1.18	1.29 ± 1.30	1.52 ± 1.03	1.01 ± 1.23	N.A	1.27 ± 1.31
	Sig.	.252	.049	.107	.038	N.A	.067

Table 5.5. CSAI-2R merged intensity and direction scale mean scores. Data are mean ± standard deviation.

Reinvestment

There was a significant result of time on reinvestment in both the baseline, $F(2, 24) = 13.31$, $p = <.001$, and anxiety, $F(2, 24) = 5.27$, $p = .013$, conditions. Thus, there is significant evidence to reject the null hypothesis.

Follow up tests on the baseline trials indicated that pairwise differences were significant in comparisons from condition 1 (< 5 s) to condition 2 (6 – 10 s), $p = <001$ and between condition 1 and condition 3 (> 10 s), $p = .001$. The pairwise comparison between condition 2 and 3 was not significant, $p = .40$.

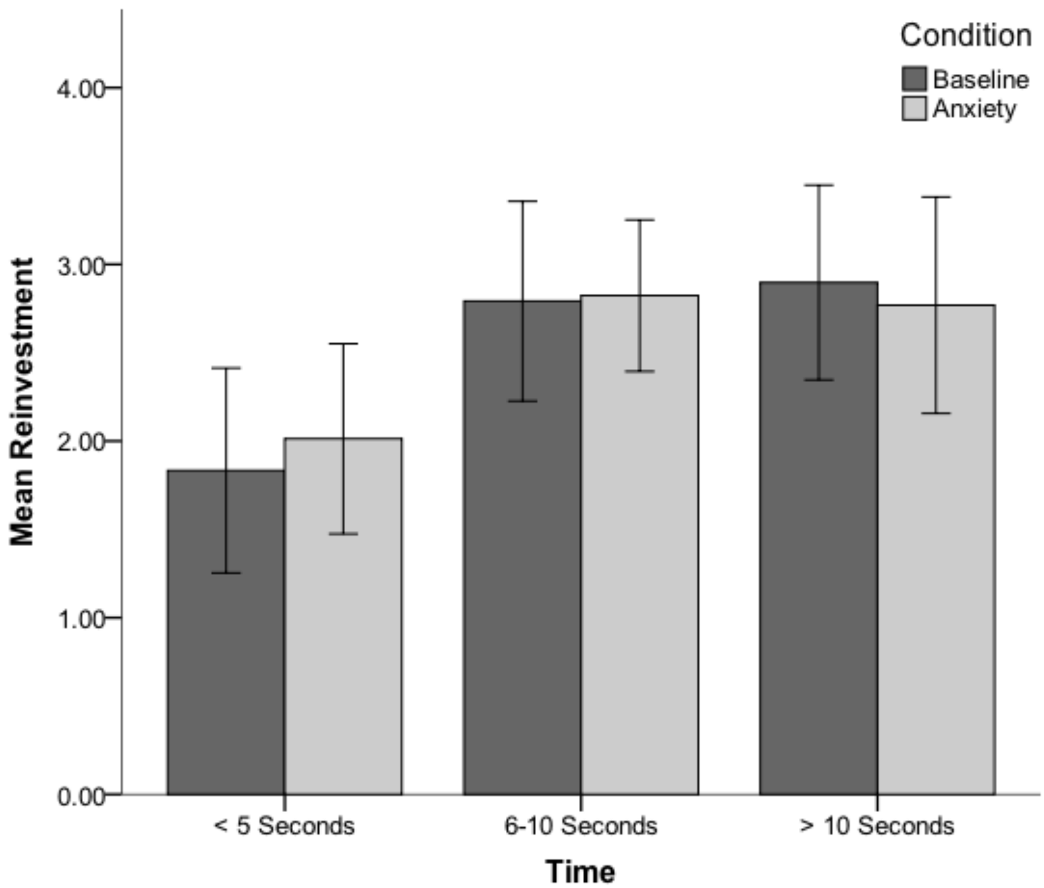

Figure 5.2. Error Bars: 95% CI. The effect of time taken in shot execution on reinvestment under baseline and anxiety conditions. The < 5 seconds condition has significantly less reinvestment than the other 2 conditions.

Follow up tests on the anxiety trials indicated that pairwise differences were significant in comparisons from time condition 1 to condition 2, *p* = 009 and between condition 1 and condition 3, *p* = .006. The pairwise comparison between conditions 2 and 3 was not significant, *p* = .88. This suggests that reinvestment is reduced when time is restricted below 6 seconds but does not increase above that threshold (Figure 5.2).

Performance

The accuracy scores indicate no main effects in either baseline, $F(2, 22) = .69$, $p = .512$, or anxiety, $F(2, 22) = .039$, $p = .962$, conditions for the repeated factor of time. Further pairwise comparisons across all conditions did reveal a significant effect in time corridor 3 between the baseline and anxiety accuracy scores $p = .016$. There were no first or second order interaction effects in any combination between test, condition and group.

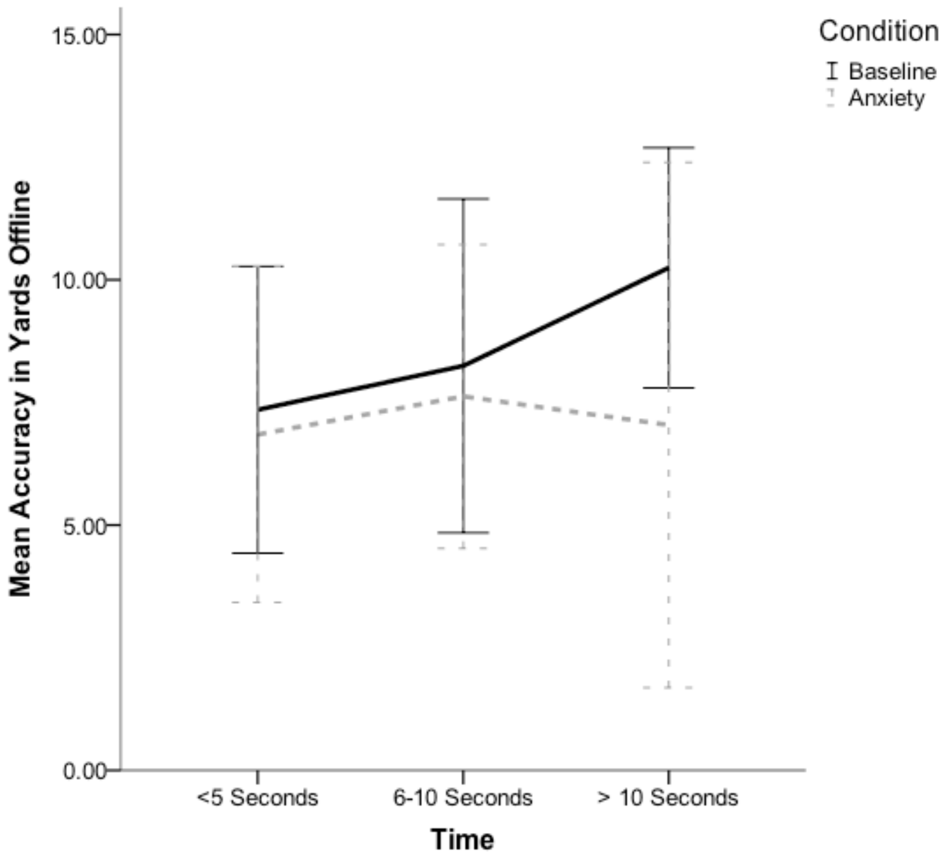

Figure 5.3. Error Bars: 95% CI. The effect of time corridors on shot accuracy measured in yards carry from the centre line. Time corridor 3 (>10 seconds) shows a significant improvement in accuracy during the anxiety condition over baseline performance.

Performance Deltas

The delta scores reported no main effect $F(2, 22) = 2.39$, $p = .115$. Nor were there any first or second order interactions despite a sharp increase in delta 3 compared with delta 1, $p = 0.86$ and delta 2, $p = 0.97$.

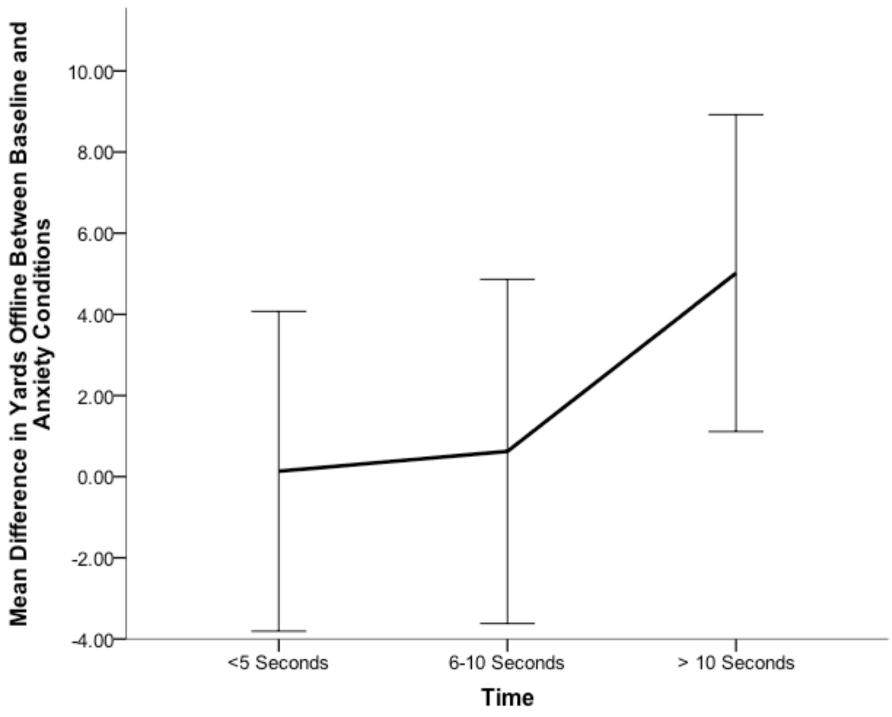

Figure 5.4. Error Bars: 95% CI. The difference between baseline and anxiety scores in the 3 time corridors. Delta 3 (>10 seconds) shows a sharp improvement during the anxiety trial but there are no significant comparisons

Discussion

The aim of this study was to examine the effects of time taken during the execution of the full golf swing. Measured against the 3 temporal restrictions, in anxiety and baseline conditions, were the levels conscious processing via the MSRS questionnaire and performance by means of shot accuracy.

Unique to this study was the use of multiple time corridor conditions. Previous studies that have used temporal restrictions (Beilock et al., 2004a, Koedijker et al., 2011) have taken a more dichotic approach assuming a linear relationship between time and reinvestment. The complex nature of the task is also relatively unique given that previous studies have been criticized for using ‘simple or overly contrived tasks (Winter et al., 2014, p. 104). Little is known about reinvestment in relation to complex motor skills that has not been extrapolated from studies on less technically demanding skills such as golf putting (Beilock and Carr, 2001, Maxwell et al., 2006). When the task is as complex as the full golf swing, a different understanding of the reinvestment paradigm may be necessary.

The main findings indicate that time taken during shot execution does have an effect on reinvestment but the pattern is not linear. Reinvestment was significantly reduced below a certain threshold, as shown in TC1. However, above that threshold reinvestment remained stable between the mid and upper time conditions of this study (TC2 & TC3). This supported our earlier hypothesis although the non-linear aspect represents a new insight. The performance effects across the 3 time corridors were not as expected with no main effect but an improvement in $TC3_{anx}$ over $TC3_{base}$ was reported.

On the basis that TC1 showed significantly less reinvestment than the other time conditions, the CPH (Masters and Maxwell, 2008a) would predict significant performance gains in this condition. Not only was this not shown but the improvement during the anxiety condition of TC3 leads us to reject our performance hypothesis and with it, cast doubts about the CPH (and related self-focus theories) in relation to highly complex motor skills.

Time

The non-linear effect of time on reinvestment suggests that in the few seconds while readying themselves and executing the shot, the golfers engage in a somewhat habitual cognitive strategy (Bläsing et al., 2009, Land et al., 2014). We cannot be sure of the qualitative nature of these cognitions but could surmise form the results they involve some amount of conscious processing. When there is not sufficient time to fully engage in this process then reinvestment is reduced, leaving a more unconscious level of movement control. Otherwise, the golfers take the required time to complete this process and then initiate the swing. When forced to take longer, as in TC3, the players did not engage in more reinvestment but merely waited to begin their cognitive strategy. There may have been other additional cognition such as performance anxiety but this did not manifest itself in additional reinvestment. These results explain more about the relationship between time and reinvestment but the wider efficacy of temporal restrictions, as a means to limit reinvestment, needs further consideration.

Performance

Given that the reinvestment was severely limited during the shorter time corridor, the major theories (Beilock and Carr, 2001, Eysenck and Calvo, 1992, Masters, 1992, Wulf, 2007) pertaining to automaticity and attentional focus would predict superior performance in this condition. This was not the case as no effect of temporal restriction on performance was reported.
We postulate that this null effect could imply that a skill as complex as the full golf swing requires a certain level of technical focus for optimal performance (Bernier et al., 2011, Toner and Moran, 2014). However, if this were the case then we may have expected to see a performance drop off at TC1 when reinvestment was severely restricted. This was not reported. In fact, the only significant performance result was the improvement in $TC3_{anx}$ on $TC3_{base}$. Notably, in TC3 there was a marginal drop in reinvestment during the anxiety condition, which could be attributed to the improvement in performance. However, other studies of a similar nature (Buszard, 2014, Cooke et al., 2011) reported heightened performance during pressure trials and no link between pressure and conscious processing (Cooke et al., 2011). Therefore we cannot adopt this interpretation of the result in TC3. It is also considered that the difference between the baseline and anxiety performance in TC3 was mainly down to the $TC3_{base}$ getting worse rather than the anxiety scores improving with more time afforded to cognition. The authors surmise that the deterioration of $TC3_{base}$ is due to a drop in arousal (Kerr, 2014) while waiting to begin their normal cognitive pattern. During the anxiety condition,

participants would have experienced enough arousal to maintain focus enough to perform in a way that was consistent with the other time conditions. The non-significant change in the performance factors, suggests that either the intervention had minimal effect across the group or alternatively, the spread was too large to deem significant. The data from the members of the group that improved with the intervention, could have been negated by others that got worse as result of less reinvestment (see chapter 4). This leads us to consider other more individualistic factors.

It may be the case that when it comes to complex skill execution, some individuals perform at their best with a certain level of conscious processing, thus, making the objective to condense swing based cognition down to the key meta themes (Mullen and Hardy, 2010). This would place the optimal performance paradigm not on complete automaticity but more along the lines of flow and mindfulness frameworks where the player is fully task oriented allowing their focus to fall solely on the relevant stimuli (Gardner and Moore, 2004, 2012).

When considering an action as complex as the full golf swing, it is sagacious to take into account the cyclical pattern of the player within the stages of learning framework (Anderson, 1982, Anson et al., 2005, Ericsson, 2003, Ericsson et al., 2007, Fitts and Posner, 1967). Due to the complexity of the skill, a golfer's full swing technique is constantly under scrutiny and continually evolving (Carson et al., 2013). According to the 3 phase model of Fitts and Posner (1967) each conscious adjustment would take the player somewhat back to stage 1 which is highly cognitive in nature. Through repetition and purposeful practice (Ericsson et al., 2007) the player moves gradually back to stage 3 which is indicative of a largely automatic control of the movement. To force a player at the cognitive stage of this process into a temporal restriction and automatic mode of control could realize a performance drop off. Likewise, we would expect for players at the autonomous stage of the cycle to be fairly comfortable with the letting go of conscious control. This is consistent with a recent addition to the automaticity literature (Carson and Collins, 2015) in which the 'motoric influence' of 'skill establishment' is proposed as a key mediator in the anxiety-performance relationship. As a proposed addition to the 3 dimensional model by Cheng et al. (2009), skill establishment is described as the 'level and consistency of movement automaticity together with a performer's confidence in this specific process' (Carson and Collins, 2015, p. 1). In line with our view on 'stages of learning' above, highly developed skill establishment is seen as potentially negating any debilitative effects of anxiety. Within this framework Carson and Collins (2015) expand the idea to suggest that in light of the skill establishment concept, conscious control may not always lead to a negative effect on performance.

With this in mind, we recognize a limitation of this study being the lack of understanding of each participant's baseline level of skill establishment. Kinematic measurements of movement variability at the start of the study would have allowed us to control for this dimension of the anxiety-performance relationship.

Limitations

Further to the limitation above, there are a number of restrictive elements to this study that could be resolved in future research. Notably, the natural variability of reinvestment effect within the group may currently be creating too much noise to gain a tangible outcome. To alleviate this issue future studies need to take a more individualistic approach to automaticity by considering some of the key personality traits that may affect reinvestment levels.

Masters (1993b) reinvestment scale (RS) is considered a reliable measure of trait reinvestment and would provide an understanding of personal trends before the study begins. It is suggested that those golfers with high RS scores would gain more from the intervention than those with naturally lower reinvestment levels.

Along the individualistic approach, other key considerations are the learning styles (Honey and Mumford, 1992, Sadler-Smith, 2001, Swailes and Senior, 1999) and modality preference (Massa and Mayer, 2006, Mayer and Massa, 2003, Silver et al., 2000) within the sample (see Chapter 7).

When researching the effect of reinvestment on performance, future studies also need to consider the individual's ability to hold and process information in temporary storage. The role of working memory capacity (WMC) (Baddeley, 2007) within sport has been long overlooked (Furley and Memmert, 2010) and nowhere is it more applicable than in motor learning and reinvestment (see Chapter 8).

A salient drawback of this study was the non-significant change in cognitive anxiety during TC1 baseline and anxiety trials. In fact, table 2 shows this not to be a lack of anxiety at $TC1_{anx}$ as this was actually the highest mean score of all trials. What the table highlights is that the > 5 second temporal restriction may have caused a large amount of cognitive anxiety even in the baseline trials. This high level of anxiety could have prevented the golfers performing better in the TC1 trials. Future research of this nature needs to take into account the potential jarring nature of the temporal restriction. Having reinvestment limited so drastically would have proved distracting for many of the sample. If the player was attempting to run their normal cognitive strategy in shorter temporal condition then they would find the situation somewhat hurried leading to heightened anxiety levels. Where we might see the positive affect of almost complete automaticity is when the player trusts in themselves and in the process of disengaging in their previously habitual swing related cognition. Follow up work is required that tackles this limitation of the current design. A two-stage set up is suggested with a gap of 6 weeks between pre and post conditions. In this time the participants will be required to hit a number of balls per week to familiarize themselves with hitting within the temporal restriction. This extended learning period will also gain the reported benefits of sleep and multiple ‘incubation periods’ (Fischer et al., 2002, Sheth et al., 2008, Stickgold and Walker, 2007, Walker, 2005, Walker et al., 2002a).

A key methodological aspect of this study was the novel way in which the directional anxiety scores of the CSAI-2R were handled. Using the Lundqvist et al. (2011) model of combined intensity (high and low) and directions scales, it is clear that that the traditional method of analysis is ineffective. In the cognitive anxiety scale where this study has its effect, all the high intensity groups reported a debilitating effect with the low intensity groups being all facilitative. This casts doubts over the direction perception approach to anxiety (Mellalieu et al., 2006, Mellalieu et al., 2003, Robazza et al., 2008) which suggests that the player's level of self-confidence can cause symptoms of anxiety to be perceived as being facilitative. In this study, the participants seemed to only report 'lack of anxiety' as facilitative.

Conclusion

The current work examined the relationship between time and reinvestment and consequently its effect on performance. Severely restricting time significantly limits reinvestment but allowing more time does not have the opposite effect. This provides us with a reliable method for testing in future reinvestment studies without having to use the more contentious dual task set up. Away from the research environment, the short temporal restriction, as in this study, could have some more practical uses. As part of a purposeful practice design, restricting reinvestment in this way could speed up the player's graduation back to autonomous stage 3 after a swing change. The temporal restriction could also be used in designing Pre Performance Routines and be adjusted to fit the player's optimal level of reinvestment dependent on the personality and learning stage factors mentioned above. We also examined the performance effect of time and reinvestment. To this end the results were far less conclusive with accuracy levels remaining stable throughout the temporal restriction and anxiety conditions. The fact that performance didn't drop off during the shorter temporal restriction must pose questions of its own but so far the data in this study largely rejects our hypothesis and the applicability of the CPH to complex motor skills. Further study of a more individualistic and qualitative nature is recommended. In particular, relating reinvestment to personality factors including learning styles, learning modality preference and working memory capacity. This study is to be repeated with adjusted design elements that account for individual factors (Chapters 7 & 8) and with the addition of a learning phase (Chapter 6)

CHAPTER 6

ACCOMMODATION TO LIMITED CONSCIOUS PROCESSING DURING THE GOLF SWING

Abstract

Optimum performance of a complex motor skill assumes a high level of automaticity. Reinvestment of declarative knowledge during the execution phase of the skill has been shown to degrade performance by way of disrupting high level unconscious processing.

In Chapter 5 it was indicated that temporal restrictions can enhance levels of automaticity and potentially affect performance. The purpose of the present study was to assess the effects of a long-term learning period in which participants practice under temporal restriction.

Highly skilled golfers (n=25) (<6 handicap) hit 5 iron full swing shots under baseline and anxiety conditions in both pre and post trials with a 6 week learning period in between.

The results indicated that the temporal restriction was successful in limiting reinvestment levels in both pre $F(3,69) = 4.12$, $p = .01$ and post intervention test $F(3,69) = 3.02$, $p = .035$ scores. No performance effect was observed $F(1,17) = .705$, $p = .41$.

This study raises further questions on the role of conscious processing in complex motor skills. Further cognitive reinvestment research is suggested utilizing complex tasks and in applied settings. Furthermore, a lack of research is highlighted in this area from an individualistic perspective.

Introduction

There are convergent theories that represent a growing consensus in motor learning literature towards a desirable state of unconscious processing during the execution of a complex motor skill (see Chapters 2 and 4). Further validation of this position is derived from studies into 'flow' (Csikszentmihalyi, 1997, Nakamura and Csikszentmihalyi, 2009) which is viewed as an optimal performance state (Jackson and Csikszentmihalyi, 1999) and is characterised by effortless and automatic performance during highly demanding situations and tasks (Koehn et al., 2013a). It is largely believed that externally paced continuous sports facilitate access to flow state more readily than discreet self-paced sports like golf. (Boutcher, 1990, Koehn et al., 2013a, Singer, 1988).

Given the motor complexity of the full golf swing and the self-paced nature of the sport it is highly relevant to further understand the nature of automaticity in view of working toward an optimal performance paradigm which at this point is largely anecdotal (Rotella, 1995)

A clear omission in literature is a longitudinal study that allows for a period of learning / adjustment to interventions aimed at facilitating autonomous performance. Previous studies of automaticity have been criticized for using 'contrived or overly simple tasks' (Winter et al., 2014, p. 104) (see Chapter 2). In this study we highlight further issues with forced restrictions of conscious processing.

If the performer has a deeply habitual (Lally and Gardner, 2013, Seger and Spiering, 2011) cognitive strategy that is engaged during shot execution then any means of prevention or limitation in this process could lead to a significantly abrasive effect where the performer tries in vein to run the habitual pattern with insufficient time. The subsequent anxiety created would be enough to inhibit any level of flow state or mindfulness (Aherne et al., 2011, Gardner and Moore, 2004) and could lead to performance decrements. This would be particularly true if, as is likely in golf, the full swing has been learnt in a highly explicit manor (Masters and Maxwell, 2004, Rendell et al., 2011). In this case, the golfer may be relying on a heavy working memory input during movement planning (Moreau, 2013) and shot execution. Having the executive control severely limited may well prove too sudden a change resulting in a drop of performance for some individuals, as linked to the group null performance effects in Chapters 4 and 5. This study sought to overcome some of these methodological issues by a design that allowed for a 6 week learning period in which participants practice under the temporal restriction as used in chapters 4 and 5 (see Chapter 3).

Learning Period

Within the motor learning literature there is wide criticism of experimental designs when testing for skill retention (Walker et al., 2002b, Walker et al., 2003b). Typically, the learning and transfer tests are very close to together allowing for little embedding of the new pattern. The Power Law (Newell and Rosenbloom, 1981, Stratton et al., 2007) of practice suggests that time and quantity of trials are key to improving motor skill. Whilst we are not looking at change in a movement pattern in this experiment, we are asking the participants to adapt to a novel task constraint (Davids, 2010) and potentially a different type of processing during shot execution (Ericsson, 2006a, Ericsson et al., 2007). As such, a learning period has been incorporated to allow for key motor learning concepts of consolidation (Siengsukon and Boyd, 2009) and sleep (Fischer et al., 2002, Stickgold and Walker, 2007, Walker, 2005, Walker et al., 2002a, Walker et al., 2003b, Walker and Stickgold, 2004, Walker and Stickgold, 2006) to facilitate the customisation of novel task constraints.

A key concept relating to repetitive practice is that motor skills continue to improve after the performer has stopped practicing. (Fischer et al., 2002). This period of 'offline' improvement has been attributed to the process of memory consolidation in which recently formed memory traces are converted into more stable representations in long-term memory (Deliens et al., 2013). In relation to motor skill learning, this phenomenon would describe how an internal model of skill representation 'becomes strengthened and increasingly resistant to behavioral interference' (Fischer et al., 2002, p. 11987). Studies have shown consolidation to occur during sleep (Walker et al., 2003a) with retesting 24 hours after initial learning indicating improvements in both speed and accuracy of a sequential finger tapping task (Fischer et al., 2002, Walker et al., 2002b). More recent studies have challenged this position by proposing that motor skill may not actually continue to improve during sleep periods but are enhanced to become more robust (Cellini and McDevitt, 2015, Nettersheim et al., 2015). The literature is not yet conclusive on the exact role of sleep in motor skill development but it does seem clear that sleep facilitates positive brain plasticity (Dayan and Cohen, 2011) that results in 'offline' improvements.

Self-Organization

Dynamical Systems Theory (Newell, 1986) describes the development of movement patterns as a reaction to a confluence of constraints that are placed upon the system. These constraints range from a spectrum of organismic (physical dimensions, cognitive make up, intentions etc.), environmental (wind, acoustics, ground conditions etc.) and task (rules, equipment etc.) (Glazier, 2011) factors. Through the process of 'self-organization' the multitude of parts within a system (DOF) spontaneously adjust and adapt to each other in relation to the intended outcome. After sufficient trials 'attractors' are created where the newly organized pattern operates in a stable and functional manner.

In accordance to the change in the movement pattern, the cognitive control structure of the movement (Ericsson, 2006a) would also evolve as influenced by the constraints in which the pattern is learned and performed. Through the process of self-organization we would expect to see an adaptation to the new task constraint, the performer could potentially accommodate (Akella, 2010, Bergsteiner and Avery, 2014) new control strategies.

It is from this 'Constraints Led' (Davids et al., 2008) perspective that we may expect to see a change in the level of conscious control of the golf swing, facilitated by practice under the temporal restriction intervention. If consistent with the CPH (Masters and Maxwell, 2008a, Masters, 1992) and implicit learning theories (Mullen et al., 2007, Rendell et al., 2011), the golfers will then perform better under pressure. We hypothesize that firstly; the test group will display lower levels of conscious processing in the post trials. Consequently, we also hypothesize that this group will show an improvement in their performance under pressure during the post-intervention trials.

Methods

Participants

25 golfers handicap (<6) participated in the study. Recruitment was from golfers studying at two universities in the United Kingdom. The participants were randomly allocated to either control (n=12) or test groups (n=13). The procedure outlined in the general methods (chapter 3) was repeated for both pre and post intervention trials. Participants hit a total of 56 full swing shots with their own 5 iron, conforming with the Royal and Ancient rules of golf (R&A, 2012). There were 3 parts to the experimental design, made up of 2 test sessions separated by a 6-week learning period.

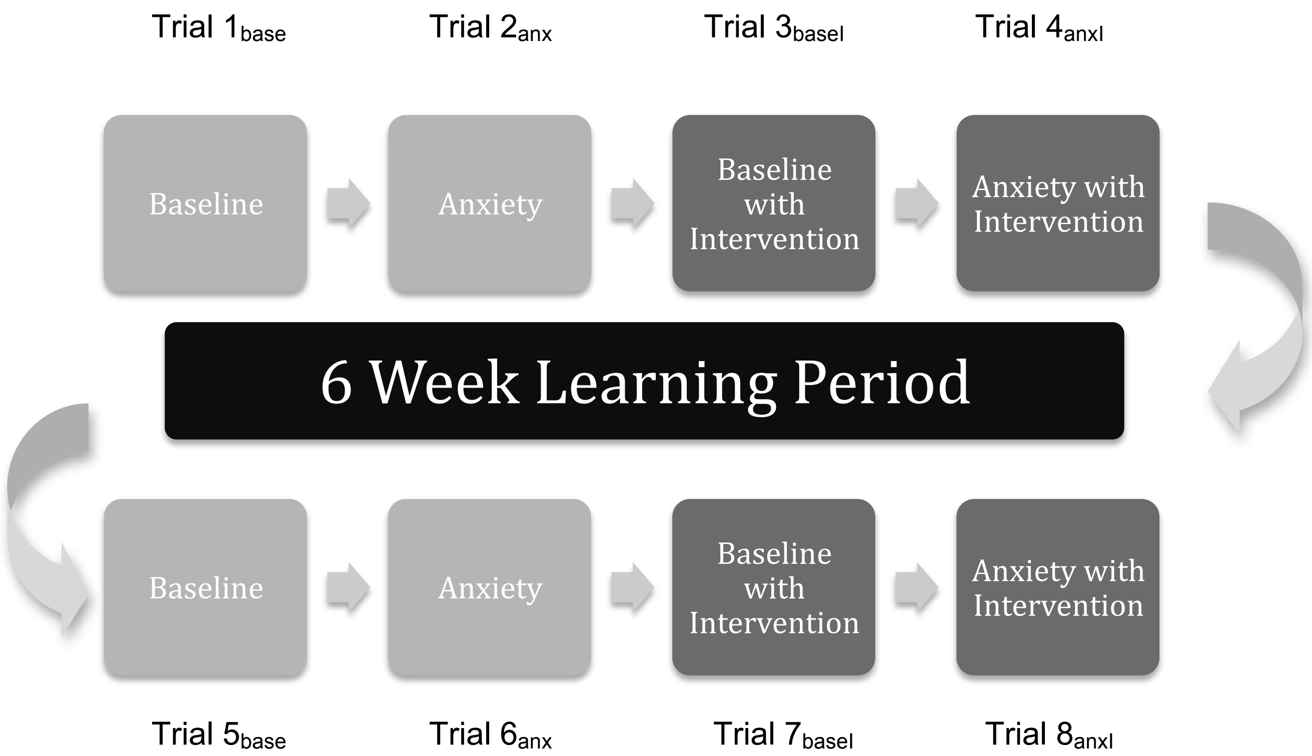

Figure 6.1. Experimental Conditions

Procedure

There were 6 weeks of practice time between the pre and post data collections. In this time all participants were instructed to practice with a 5 iron for 10 minutes in duration at a frequency of twice per week. This was to be in addition to their normal patterns of play and off course practice. In this period the test group practiced under the 5 second restriction while the control group were instructed to practice acting out their normal PPR. Regular email reminders were sent to during this period and compliance was assured before post-test commencement.

Instruments

The instruments used were as described in the general procedure (Chapter 3)

Data Analysis

The CSAI-2R and aMSRS scores were processed as outlined in the general procedure section (Chapter 3). In order to best test the performance effect of the 6 week learning period and reduce any effect of individual 'on the day' variance, performance in the baseline trials was calculated by comparing the change between each participant's trial 1_{base} and trial 3_{basel} scores. A comparison was then carried out between the pre and post-test score differential. The same procedure was followed to compare the anxiety scores. The change between trial 2_{anx} and trail 4_{anxl} were compared across pre and post-test blocks.

All comparisons were carried out using mixed factorial ANOVAs where the overall type I error rate for each analysis was set at $\alpha = .05$. Where Mauchly's test was violated, degrees of freedom were corrected using Greenhouse-

Geisser estimates of sphericity. Any post-hoc multiple comparisons were adjusted for using Bonferroni

Results

Questionnaire Reliability

Calculated Cronbach's alphas showed that all subscales of the aMSRS (α = 0.89) and the CASI-2R were internally reliable; somatic anxiety (α = 0.82), cognitive anxiety (α = 0.80) and self-confidence (α = 0.92).

Trial	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Overall**
Cognitive Anxiety	.68	.86	.83	.84	.80	.76	.83	.81	.80
Somatic Anxiety	.73	.76	.83	.73	.71	.78	.84	.87	.82
Self Confidence	.73	.83	.88	.80	.79	.82	.85	.89	.92
Reinvestment	.80	.86	.86	.89	.90	.93	.94	.94	.89

Table 6.1. Cronbach's alpha scores for the CSAI-2R and aMSRS across the 8 trials.

CSAI-2R Subscales

Cognitive Anxiety

There was a significant effect of the test on the cognitive anxiety subscale on for all 4 pairs of trails. Pair 1, $F(1, 26) = 9.60$, $p = .005$, pair 2, $F(1, 26) = 17.67$, $p = < .001$, pair 3, $F(1, 23) = 7.83$, $p = .010$ and pair 4 $F(1, 23) = 11.45$, $p = .003$.

Somatic Anxiety

There was a significant effect of the somatic anxiety subscale on test for pair 1, $F(1, 26) = 7.63$, $p = .010$, pair 2, $F(1, 26) = 13.80$, $p = < .001$, pair 3, $F(1, 23) = 5,09$, $p = .034$, and pair 4, $F(1, 23) = 13.8$, $p = .001$.

Self Confidence

There was no significant effect of the self-confidence subscale on test for pair 1, $F(1, 26) = .30$, $p = .863$, pair 2, $F(1, 26) = .83$ $p = .372$, or pair 3, $F(1, 23) = 3.03$, $p = .095$. There was a significant effect on pair 4, $F(1, 23) = 5.67$, $p = .026$.

CSAI-2R Direction

Table 6.2 shows a significant difference between high and low intensity in all trials with the high intensity scores all reporting a debilitative effect. This validates the effect of the intensity scores.

Mean Scores for CSAI-2R Direction and Intensity Scale

Pre Trials		**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**
Condition		**Base**	**Anx**	**Base**	**Anx**
Cognitive	High Intensity	-.64 ± .75	-.67 ± 1.62	-.60 ± 1.88	-.67 ± 1.57*
	Low Intensity	.37 ± 1.26	.19 ± 1.11	.92 ± 1.85	.73 ± 1.20^{S}
Somatic	High Intensity	-.89 ± 0.62*	-.98 ± .61*	-2.00 N/A	-.74 ± .63*
	Low Intensity	.67 ± 1.27^{S}	.25 ± 1.24^{S}	.52 ±.1.26	.64 ± 1.37^{S}

Post Trials		**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**
Condition		**Base**	**Anx**	**Base**	**Anx**
Cognitive	High Intensity	.67 ± 2.31	-.38 ± 1.60	2.10 ± 1.27	-.07 ± 1.70
	Low Intensity	.58 ± 1.39	.21 ± 1.23	.49 ± 1.56	.35 ± 1.19
Somatic	High Intensity	-.57 N/A	-.48 ± .44	-.29 ± 0.00	-1.36 ± 1.52
	Low Intensity	.53 ± 1.42	.23 ± 1.37	.72 ±.1.51	.65 ± 1.42

Table 6.2. CSAI-2R direction scale mean scores in the pre and post intervention trials.
$^{*,\$}$ indicates significant difference between pairs. Data are mean ± standard deviation.

Reinvestment

When analysed in their baseline/anxiety pairs, there was a significant main effect of trial on reinvestment scores for both pre $F(3,69) = 4.12$, $p = .01$ and post $F(3,69) = 3.02$, $p = .035$ scores.

Pre-Test Comparisons

Pairwise comparisons revealed a significant interaction effect between test and intervention group for reinvestment between pre-trials 1_{base} (baseline) and 3_{baseI} (baseline with intervention) ($p < .001$). The difference between trials 1 (baseline) and 2_{anx} (anxiety without intervention) was non-significant ($p = 1.000$) as was the difference between trials 2 (anxiety without intervention) and 4_{anxI} (anxiety with intervention) (p = .065) albeit marginal. The control group remained stable with no significant differences reported.

Post-Test Comparisons

The post-test comparisons also revealed a significant group interaction effect for reinvestment between post-trials 2_{anx} and 3_{basel} (p = .008) and trials 2_{anx} and 4_{anxl} (p = .020). The difference between trials 1_{base} and 2_{anx} (p = 1.000), 1_{base} and 3_{basel} (p = .413) and 1_{base} and 4_{anxl} (p = .773). showed non-significant change.

The control group remained stable with no significant differences detected.

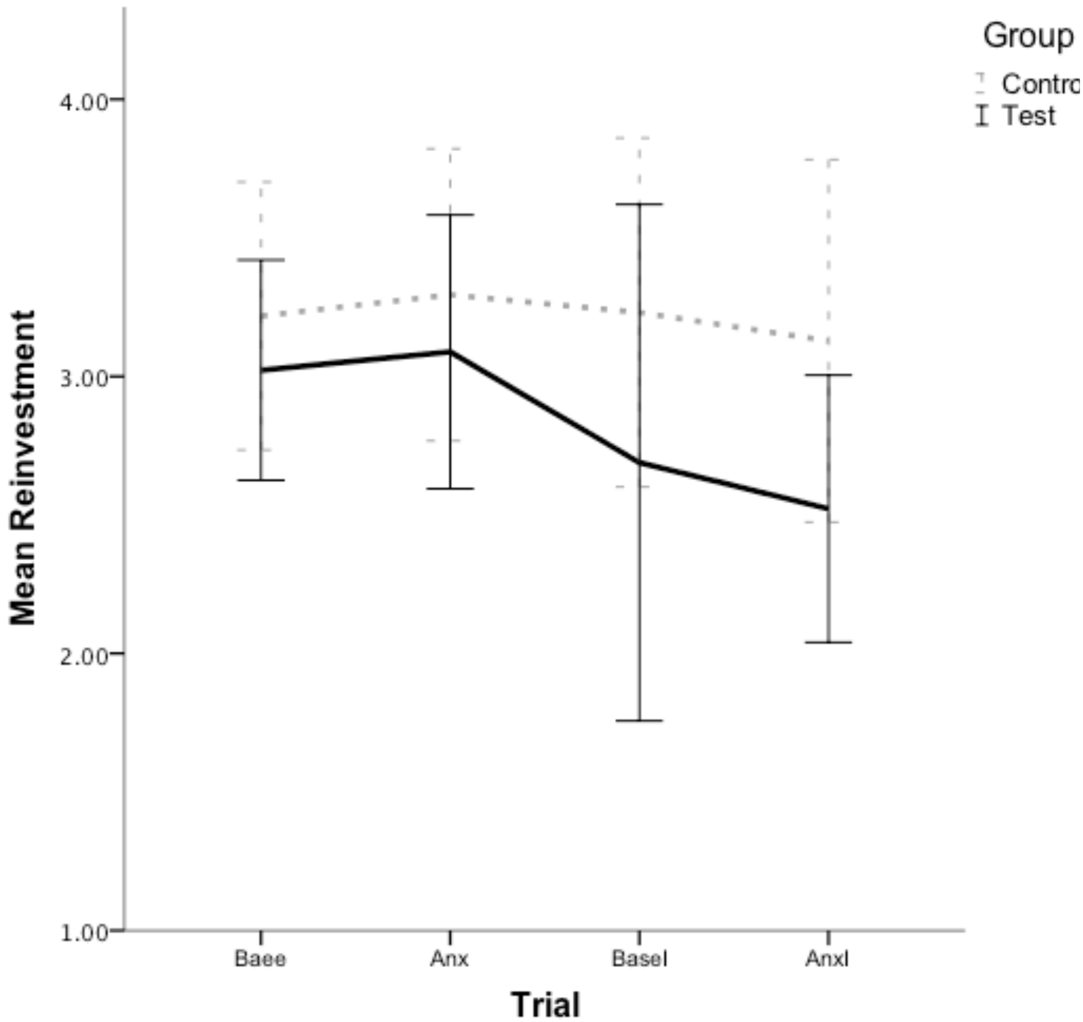

Figure 6.2. Error Bars: 95% CI. Reinvestment scores by group during pre-trials. Shows significant reduction in reinvestment during temporal restriction trials.

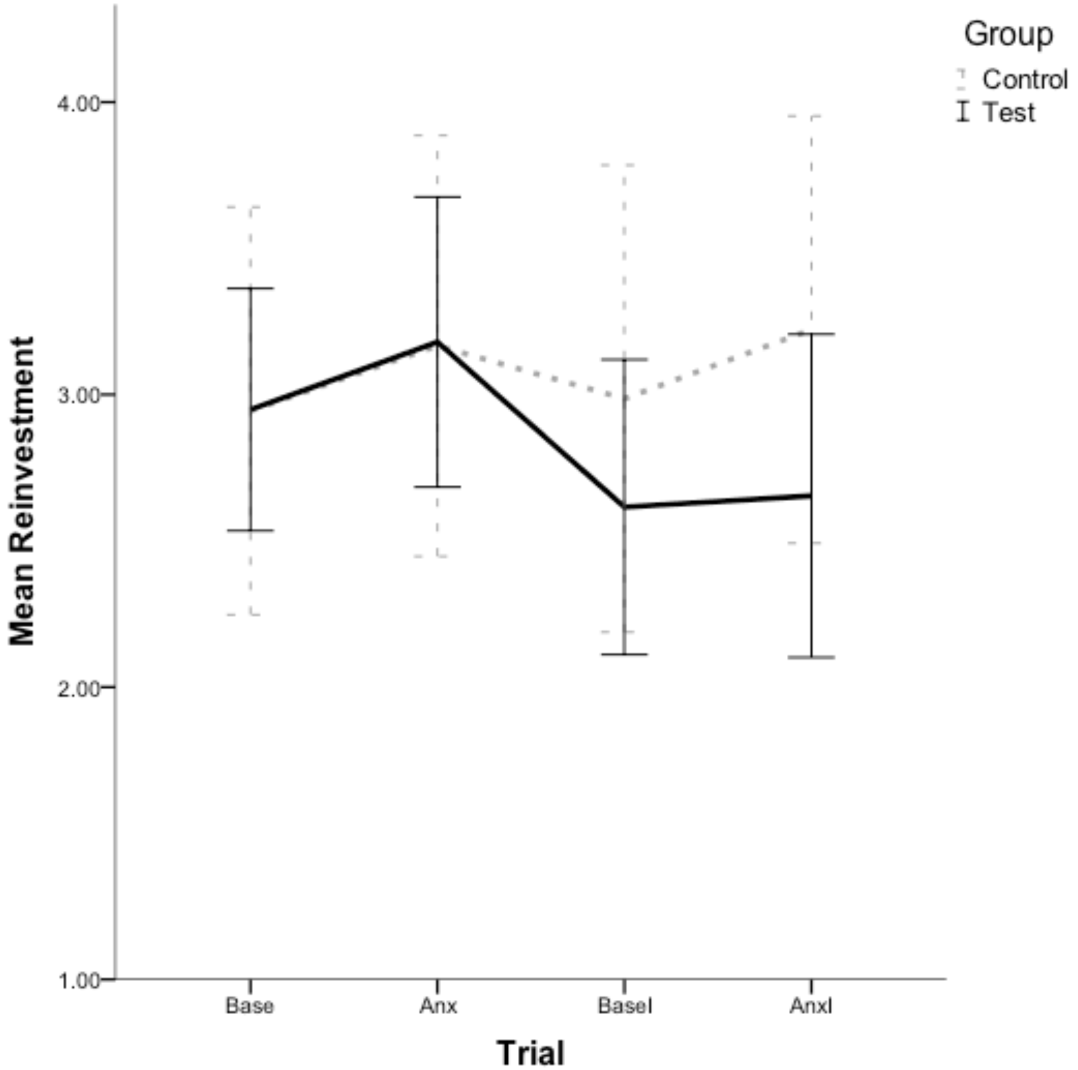

Figure 6.3. Error Bars: 95% CI. Reinvestment scores by group during post-trials. Shows significant reduction in reinvestment during temporal restriction trials.

Performance

No main effect was found for the repeated factor condition *F*(1,17) = .705, *p* =.41. Performance during the anxiety trials was calculated in the same manor. This time, by comparing the differences between anxiety trials in pre (blocks 2 and 4) and post (blocks 6 and 8). No main effect was found for the repeated factor condition *F*(1,22) = .161, *p* =.692

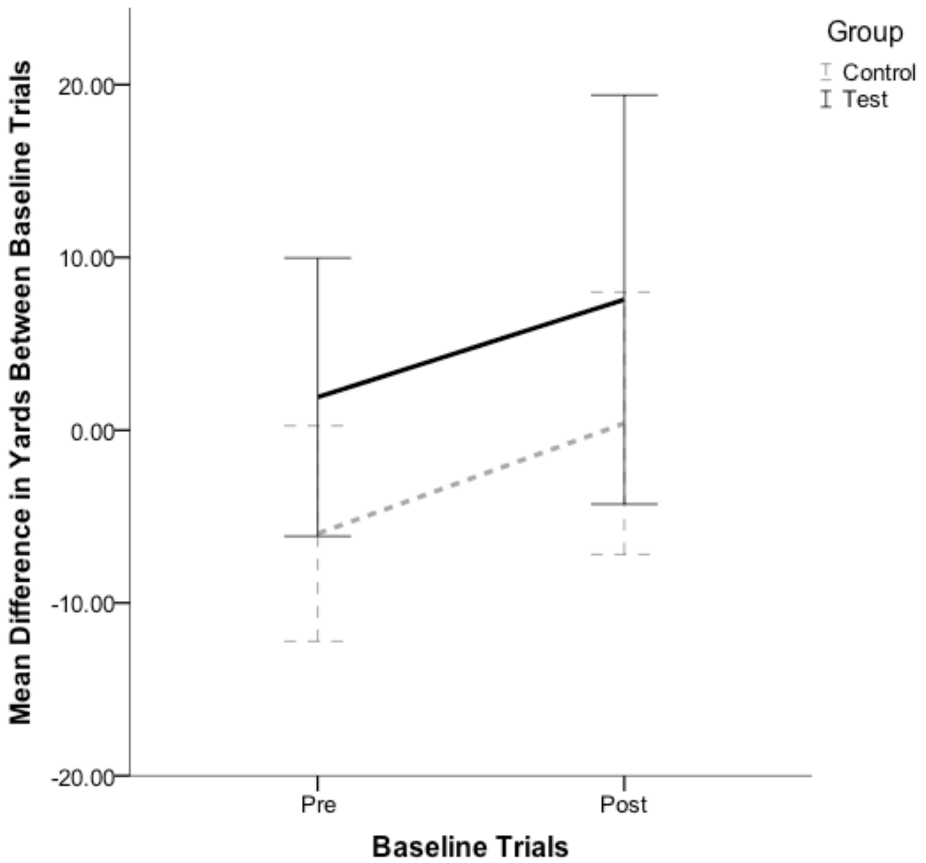

Figure 6.4. Error Bars: 95% CI. Mean difference in yards offline between baseline trials in pre and post-test trials. A positive score indicates less accuracy under temporal restriction.

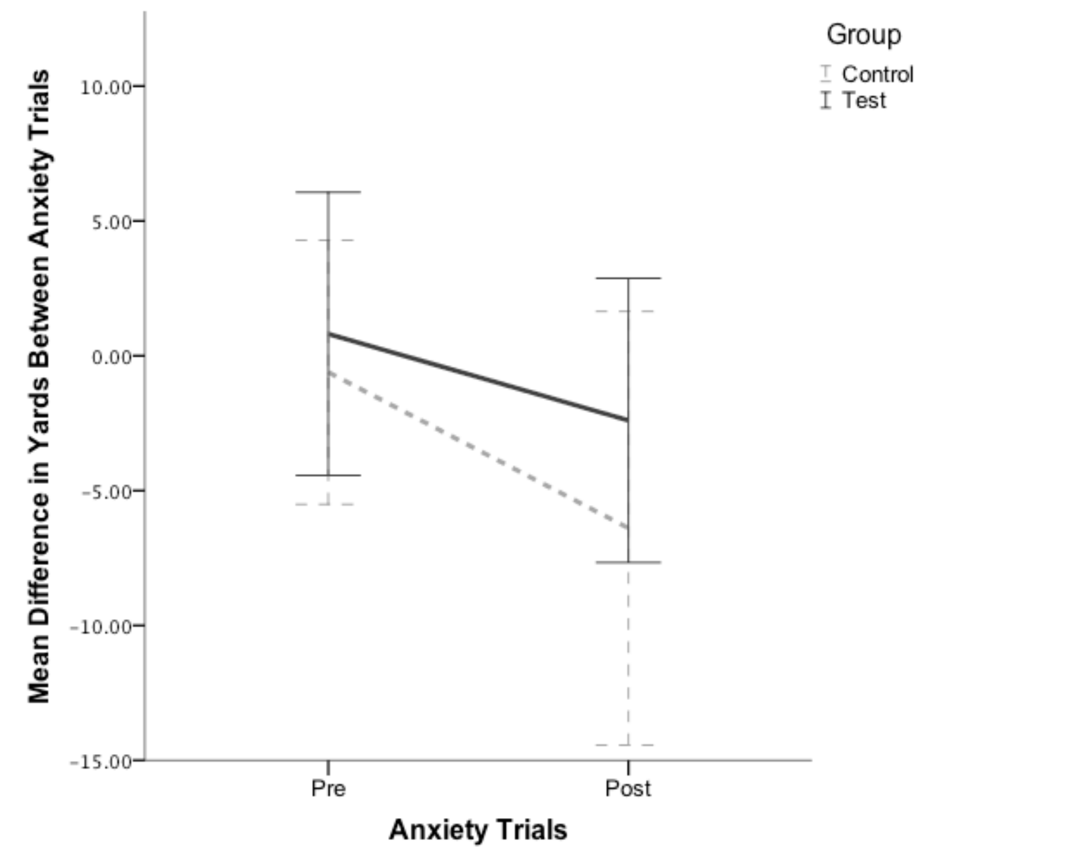

Figure 6.5. Error Bars: 95% CI. Mean difference in yards offline between anxiety trials in pre and post-test trials. A positive score indicates less accuracy under temporal restriction.

Discussion

The aim of this study was to examine the effects of a learning period in which participants practiced under a temporal restriction proven to limit conscious processing during shot execution. Central to the study was how the golfers reacted to this practice time in terms of both propensity for cognitive processing and performance measured by shot accuracy.

Reinvestment was measured with the use the aMSRS questionnaire (see Chapter 3) and performance was measured as shot accuracy of a full swing with a 5 iron.

There were a number of unique aspects to this study: the motor complexity of the full golf swing (Winter et al., 2014), the length of the learning period and the temporal restriction (Beilock et al., 2004b, Koedijker et al., 2011) all represent novel and challenging research facets.

The main findings support our first hypothesis by indicating a link between the temporal restriction and reduced state reinvestment. The reduced levels of reinvestment had no effect on performance in shot accuracy either from trial to trial or in pre and post learning period contrasts. This rejects our second hypothesis that the golfers would adapt to the intervention and perform better under pressure as a result of reduced reinvestment. This result also raises further questions around the efficacy of the CPH (Masters, 1992) and EMH (Beilock and Carr, 2001) theories in relation to complex motor skills.

The results from the CSAI-2R intensity scales indicate that the study successfully created the desired anxiety manipulation, although, this is not reflected in the performance results. The reaction to anxiety over the 8 trials was mixed with many of the sample actually improving in shot accuracy under anxiety conditions. This would be in line with the direction perception approach to anxiety (Mellalieu et al., 2006, Mellalieu et al., 2003, Robazza et al., 2008) which suggests that the player’s level of self-confidence can cause symptoms of anxiety to be perceived as being facilitative.

However, the traditional methods of analyzing the data from this scale have been found to be ineffective (Lundqvist et al., 2011) casting doubt over the direction perception approach. The results of the directions scale in this study are in line with this position. For both the cognitive and somatic scales there was a high level of correlation between intensity levels and a perceived debilitative effect of anxiety

Despite reporting anxiety as being debilitative the performance results in anxiety conditions were still varied indicating that many of the sample were able to perform in the presence of anxiety. This factor could be apportioned toward the null effect of the performance scores. With a large variance in performance relative to anxiety, inherent in the sample; it would be difficult to show any effect of the intervention. We suggest that future research may overcome this issue by taking a multiple case study approach with an extended baseline.

Although anxiety levels were successfully manipulated, the state reinvestment results show no meaningful change in reinvestment between base and anxiety conditions. This result questions a central pillar to the CPH, that under pressure there is greater propensity for reinvestment. It should be stated that, Masters et al. (1993a) does recognize individual trait factors as measured in the reinvestment scale questionnaire (Masters et al., 1993a). This instrument is recognised as an accurate predictor of one’s propensity to reinvest and centres largely on the trait of self-consciousness. Given this individualistic nature of reinvestment, it may be that not enough of our sample were high enough trait reinvestors to significantly affect the data under anxiety conditions. Alternatively, a higher level of cognitive anxiety may be required to see an overall effect on reinvestment,

The reinvestment data did show a significant reduction in swing related cognition during shot execution on the trials where the temporal restriction was in place. This however, was not affected by the learning period with similar levels of reinvestment being reported in pre and post trials. This negates any argument for a learning effect where the golfers may have become more accustomed to the restriction in such a way as to cognitively restructure, thus creating enough cognitive resource to focus more on their technique. Nor do the reinvestment results support any notion that the test participants may have become adept enough in their practice under the restriction that they switched to a reduced level of reinvestment in their normal pre performance routine. The lack of effect upon shot accuracy indicates that this method of forcing autonomous control on the group did not encourage automaticity in a way that is conducive to optimal movement control. Even given the 6-week learning period, the results show no significant improvement across the sample. This implies that practicing under restricted reinvestment conditions does not lead to improved performance in such conditions. Nor does it induce a more autonomous level of movement control. The performance results also raise further questions about the relationship between automaticity and complex skill performance (Ericsson, 2007, Toner and Moran, 2014).

Before reflecting further on this point, it is recognised that it could be the method of inducing automaticity that is the limiting factor in this design. The organic formation of automaticity via thousands of hours of practice (Ericsson et al., 1993b) may still require a certain level of focus on external cues (Toner et al., 2015), that may be prohibited by the temporal restriction (see chapter 9). It is also conceded that the 6-week learning period could have been ineffective due to either a lack of compliance in which case, the use of a practice diary is suggested for future studies of this nature. Alternatively, the amount of practice under the temporal restriction may not have been sufficient within the framework of the participant's regular golf activities.

In looking at this outcome from the perspective of Fitt's stage theory of motor learning (Fitts and Posner, 1967), the results would imply that a low number of our sample were not at an entirely autonomous stage of leaning (Ericsson, 2006b, Fitts and Posner, 1967) otherwise, we would have seen a more robust performance under the temporal restriction. This is consistent with case studies of professional golfers (Bernier et al., 2011) that found the vast majority to be employing cognitive cues to help control the swing. In line with this view, a recent paper (Carson and Collins, 2015) proposes a further 'motoric' element of the anxiety-performance relation to be 'skill establishment' defined as the level of automaticity of movement and trust in the process. Without knowing the participant's stage of development (skill establishment) at the start of the study, it is difficult to predict/measure their reaction to a reduction in conscious control in a way that would beget an applied intervention. Future research could utilize a measure of movement variability by way of three dimensional ‘local co-ordinate systems’ (Carson and Collins, 2014) to garner a baseline level of this ‘motoric’ concept.

Unlike simpler tasks (Masters, 1992), the full golf swing may actually benefit from some level of executive control. This may not be true for all elite golfers but most likely for some. As previously mentioned, an individualistic approach to the subject is not an entirely novel concept; Masters et al. (1993a). In addition to the self-consciousness, other individual trait factors may well have been an influence on this study by affecting each golfer’s ecological fit with the forced cognitive restriction. The individual’s learning style (Kollöffel, 2012, Pashler et al., 2008) may play a noteworthy role in how they best direct their attention during performance. If the cognitive style is more or less analytical in nature (Mumford and Honey, 1992) then the optimal level of executive control may be affected. Equally, given that verbal processing is understood to be more resource intensive (Antonietti and Giorgetti, 1998, Clark and Paivio, 1991, Kirby et al., 1988, Paivio, 1971, Richardson, 1977) than kinesthetic or visual modes, then a differential of the verbaliser/visualiser scale (Antonietti and Giorgetti, 1998, Richardson, 1977) could have affected the performance results within a forced autonomous state.

The capacity to hold information in temporary storage (Buszard et al., 2013) offers a further area that needs to be explored. In this study, the individual working memory capacity (WMC) may have been a fundamental variable that influenced the interaction between low reinvestment levels and performance. High levels of storage and processing power may simply mean a greater aptitude and reliance on some level of executive control.

When considering individual variance effects on task performance, a substantial omission in this and similar papers is the measure of the starting point in terms of automaticity. According to the ‘stages of learning’ model (Fitts and Posner, 1967), the use of ‘elite’ level golfers should guarantee an autonomous level of performance but this is not necessarily so. In the case of ‘expert’ performers automaticity is often rebuffed by a constant process of refining and enhancing physical and cognitive processes in the development of higher order skills (Ericsson et al., 2007). If a golfer is in a transitional/developmental stage, then according to Fitts and Posner’s (1967) own model, they will require some level of executive control and a forced automaticity condition would see a drop in performance.
The current study had other methodological challenges that need to be met on future research. Notably, the practice during the learning time needed tighter scrutiny with potential use of self-report practice diaries and qualitative questionnaires being required at each practice session.

Conclusion

The current study examined the effect of an automaticity intervention over a 6 week learning to period. There was a significant reduction in reinvestment levels during the intervention trials but there was no reported effect of the learning period on reinvestment. Nor was there any group wise effect on performance. While this supports our first hypothesis, it rejects our performance hypothesis and brings into question the efficacy of reinvestment theory and CPH in relation to complex motor skills.

It is recommended (Winter et al., 2014) that further studies into the nature of automaticity are to be carried out on complex skills, in applied settings and with a more individualistic approach.

The temporal restriction continues to be a valid research intervention and may prove to be a useful coaching tool for those performers that are reinvesting over their optimal level but for now, at least, we have to say that a blanket approach to automaticity is not valid. The question may be more of ‘what’ to think than ‘how much’ to think (Bernier et al., 2011, Mullen and Hardy, 2010). This is an increasing viewpoint within the literature (Carson and Collins, 2014) with distinctions being made between ‘part skill’ and ‘holistic’ (MacPherson et al., 2008) focus and positive effects of temporal cues (MacPherson et al., 2009) being reported (see chapter 9).

From a broader perspective, the results of this study, in relation to the novel complexity of the skill, lead us to question the efficacy of automaticity interventions in general. Automaticity appears to be present at moments of heightened performance (Csikszentmihalyi, 1997, Jackson and Csikszentmihalyi, 1999) but this doesn’t meant that forcing this state upon a performer will necessarily lead to the reverse causation. The nature of automaticity would seem to be more complex (Geeves et al., 2013, Toner and Moran, 2014) than this with possible extraneous factors including learning styles, trait reinvestment, modal preference, working memory capacity and stage of learning with numerous interactions of task restraints and environmental stimuli. With this in mind, future research needs to be less dichotic in nature and should take a more individualistic view of automaticity for expert performers.

CHAPTER 7

AUTOMATICITY OF THE GOLF SWING: ONE SIZE MAY NOT FIT ALL.

Abstract

We examined the full swing performance of highly skilled golfers (n=23) under baseline and anxiety conditions. Reinvestment theory predicts that when a performer thinks about their technique during shot execution it interferes with the more efficient unconscious processes and as a result, performance suffers. In this study we aimed to highlight individual trait factors that may influence this paradigm. In a repeat of an earlier design (see Chapter 3), in which conscious monitoring was severely restricted, we also examine any correlations of performance and state reinvestment with the personality traits of ‘broad learning style’ and ‘visual/verbal learning style’.

State reinvestment failed to show significant correlations with any of the learning style subscales.

The verbaliser group improved shot accuracy during the pre-intervention anxiety trial $r = .65$, $p = .006$, and showed a negative correlation coefficient with performance when pre and post intervention anxiety conditions were compared $r = -.65$, $p = .006$.

There was also a significant main effect of intervention between the verbaliser/visualiser groups performance on pre and post anxiety trials, $F(1,14) = 8.4$, $p <.012$. This led us to surmise a diverse processing type that contributes towards a differential in reinvestment effect.

This study raises further questions in to the design of Pre Performance Routines and encourages a less dichotic approach to automaticity research in the future.

Introduction

Of recent years the prevailing postulation in the field of automaticity research has taken the view that expert performance is best executed in the absence of conscious control. This conception is based on evidence taken from studies (Masters and Maxwell, 2008a, Winter et al., 2014, Wulf, 2007) of simple skills or of a contrived nature (Winter et al., 2014). A clear limitation within the literature is the lack of research into complex skills and individual factors affecting automaticity. With the aim of creating an optimum performance paradigm there seems to be ‘a one size fits all’ approach (Peh et al., 2010) that would suggest that all performers are better off discarding conscious control of their movements or at the very least, adopting an external focus of attention during motor skill execution (Wulf, 2007, Wulf, 2013). This was not found to be the case in the experimental Chapters 4-6. In our initial experiment (Chapter 4), participants were required to hit full golf shots under pressure and non-pressure conditions, combined with a temporal restriction manipulation to limit reinvestment. Under the forced ‘low reinvestment’ conditions the group analysis was insignificant but what was noteworthy, was the disparity of individual responses to the condition.

During the low reinvestment conditions some golfers greatly improved while the performance of others was either not affected or in some cases diminished. It would be easy to view individual differences as error variance as is often the case in sports psychology research (Furley and Memmert, 2010). In this case though, we pointed towards individual and personality differences that may contribute towards a paradigm that recognizes a differential in optimal levels of conscious processing between individuals. In this chapter we consider the notion that if personality differences affect our cognitive skills and (Roberts et al., 2013) decision making (Bell et al., 2013) then it could also be the case that the cognitive input during motor control is also dependent on individual trait factors. The set up outlined in the general methods (Chapter 3) is repeated with the addition of key personality measures.

Personality in Relation to Reinvestment

An emerging aspect within the literature is the personal differences and trait disposition to performing under an automatic processing paradigm. In Masters' 'reinvestment' (Masters and Maxwell, 2008a, Masters et al., 1993b) model (Masters and Maxwell, 2008a, Masters et al., 1993b) he sees the propensity to reinvest in online conscious control as being affected by a number of situational factors and significantly, by individual personality differences. Masters (1993) viewed the likelihood to reinvest linked to an inward focus of attention and compiled the 'reinvestment scale' (RS) in an aim to predict those participants that are most likely to revert to online conscious control of movement when under pressure. The 20 item scale was in the main, compiled of questions taken from the existing 'Self Consciousness Scale' (Fenigstein et al., 1975b) and the Emotional Control Questionnaire (Roger and Nesshoever, 1987). A single point was also taken from the Cognitive Failures Questionnaire (Broadbent et al., 1982). The study demonstrated a positive correlation between a high score on the RS and obvious performance decrements under pressure in a golf putting task. Masters (1993) also demonstrated a positive link between high reinvestment scores and those participants that were most likely to choke as reported by their coach. The RS was given further credence with similar experiments that followed (Chell et al., 2003, Jackson et al., 2006, Maxwell et al., 2006).

The scale has since been revisited (Masters et al., 2005) with the creation of a movement specific version. Other variations of the RS include questionnaires that predict decision making efficacy of sportsmen under pressure situations (Kinrade et al., 2010) and reinvestment in stroke victims (Kleynen et al., 2013).

Learning Style

With reinvestment considered to be affected by personality, we are examining personality factors that do not feature in the RS scale but may change the nature and efficacy of reinvestment between participants. A key area of consideration is the individual's cognitive patterns while learning, which may then influence their cognitive strategies during task performance (Buszard, 2014, ch. 4). There is a vast amount of literature on 'learning styles' (Cassidy, 2004, Clarke et al., 2010, Coffield et al., 2004a, Honey and Mumford, 1992, Howe et al., 2011, Kolb, 2005, Kolb, 1984) that suggests that one utilizes habitual cognitive patterns while learning; to an extent that we could class them as trait dispositions (Grigorenko and Sternberg, 1995, Zhang and Sternberg, 2002).

Throughout the learning styles literature the terms 'cognitive style' and 'learning style' are used interchangeably but more accurately, they have distinct meanings. A cognitive style has been defined as 'a person's typical or habitual mode of problem solving, thinking, perceiving and remembering' (Allport, 1937) (cited in Cassidy, 2004, p.420), while a learning style refers to the ways in which a person utilizes their cognitive style in a learning environment (Riding and Cheema, 1991). In this model the learning style is a sub-set of cognitive style.

In this individualistic approach, a learner would consistently adopt their strategy based on preferences that stem from physiological, psychological and sociological factors (Zhang and Sternberg, 2005, Zhang and Sternberg, 2006). The idea of a trait strategy to learning has become hugely popular with the creation of many different attempts to categorize learning habits and patterns. In a review that was not claimed to be exhaustive, Cassidy (2004) cited 24 different learning style inventories and classified them according their underlying approach. There were 7 dimensions of which, according to Curry's (1987) 'Onion model, the two most robust are 'information processing, which relates to a person's intellectual approach of processing information; and 'cognitive personality', seen as a 'relatively permanent personality dimension' (Riding and Cheema, 1991, p.195). It is partly for this reason that the instruments used in this study are viewed as two of the most popular and widely reviewed measures of learning styles (Duff and Duffy, 2002): The 'Learning Style Questionnaire' (LSQ) (Honey and Mumford, 1992) measures on the information processing dimension and the 'Verbaliser/Visualiser Questionnaire' (VVQ) (Richardson, 1977) relates to the cognitive personality categorization.

The LSQ is based on Kolb's 'Experiential Learning Model' (ELM) (Kolb, 2005, Kolb, 1984, Kolb et al., 2001) that proposes a 4 step cyclic model to learning that follows the process of concrete experience, observation and reflection, formation of abstract concepts and generalizations. The process returns to the first stage as the testing of the implications of these concepts in new situations leads to further concrete experiences (Sadler-Smith, 1997). Optimally, the learner would go through all 4 stages with equal intensity but Kolb (1984) suggests that most learners will have a preference for certain stages and favour these parts of the strategy. Honey and Mumford (1992) follow the same learner preference standpoint in their model. The LSQ (1992) is an 80 point questionnaire that scores the learner's preference on scales of; activist, theorist, pragmatist and reflector. The Activists like to be active, make decisions intuitively and dislike excessive structure. Theorists rely more on theory and logic, not trusting intuition and emotional input. Pragmatists are more likely to take risks and have a liking for practical methods and thinking. Pragmatists are unlikely to get involved in deep reflection or the theory of a topic. Reflectors like processes and would reflect on the deeper meaning, trying to understand how things work (Van Zwanenberg et al., 2000). Previous studies (Buszard, 2014) have shown how an individual's cognitive makeup can affect how they learn, which in turn determines their propensity to reinvest during performance. Consistent with this line of argument, our first hypothesis is that the participant's preference on this scale could affect their propensity for reinvestment, with the theorists and reflectors likely to be heavier reinvestors than pragmatists and activists. Secondly, we hypothesize that the groups will react differently to the restricted conscious control condition. We predict that the theorist and reflector groups will be familiar with processing declarative information via heavy input from working memory. This will be contrasted by the activist and pragmatist groups which will be more accustomed to procedural knowledge processes and less hypothesis testing

(Buszard, 2014, Furley and Memmert, 2010, Lewandowsky, 2011). In line with reinvestment theory (Masters and Maxwell, 2008a), it will be these second 2 groups that will perform better under pressure due to a lower propensity to reinvest. Meanwhile, the theorist/reflector groups will be heavy reinvestors and therefore benefit from the intervention.

Another key direction in the learning styles literature is the notion that learning is modality specific (Antonietti and Giorgetti, 1998, Campos et al., 2004, Fleming, 1995, Kirby et al., 1988, Massa and Mayer, 2006, Silver et al., 2000). All learning is directed through our primary senses of auditory, visual and kinaesthetic and individuals will develop and then rely on a preference for one of the modalities in a learning situation (Fleming and Mills, 2001, Fleming, 2006). The VVQ (Richardson, 1977) is the prominent instrument in this area and has been the centre of a number of studies and review papers (Antonietti and Giorgetti, 1998, Kollöffel, 2012, Massa and Mayer, 2006, Wang, 2007). The scale is a 15 item self administering questionnaire that is derived from a previous longer version (Paivio, 1971). The ‘modal specific’ nature of the VVQ affords this study a further perspective in relation to automaticity and cognitive processing. Cognitive Load Theory’ (Chandler and Sweller, 1991, Paas et al., 2003, Van Merrienboer and Sweller, 2005) suggests that afferent information is processed differently and places a separate load on working memory (Kirschner, 2002, Paas et al., 2004). Furthermore, if the sensory information is split between the two components then working memory capacity can be enhanced (Kirschner, 2002).

Having a trait preference for visual or verbal information when learning motor skills could make a qualitative difference to how the movement pattern is encoded and retrieved. A significant proportion of the motor learning literature sees the learning process as an accumulation of representations that form our internal code (motor program) for movement production (Adams, 1971, Schmidt, 2003)

Schema Theory (Deliens et al., 2013, Schmidt, 1975, Schmidt, 2003) in particular, has a highly representational component to movement production (Newell, 2003, Schmidt, 2003). In this model, schemas are formed through a process of taking prior learning information of movement outcome and internal representations from the environment. Through the process of 'composition' (Neves and Anderson, 1981), this information gets chunked into smaller units, the process of which not only serves to parameterize a general motor program but also deals with storage issues and contributes to the automaticity of a motor skill. As Schemas are made up of representations, we consider that a modal preference during schema formation could create a qualitative sensory difference in the schema (Tremblay and Proteau, 1998). In turn, this may lead to different performance requirements including levels of reinvestment and use of working memory. The use of the VVQ in this study could add valuable data to the effect of the modal influence on reinvestment. Since reinvestment is considered to be verbal processing domain (Masters and Maxwell, 2008a), we would expect a clear difference in reinvestment propensity between the groups with verbal processors scoring higher in the state reinvestment measures. We also consider the notion that verbal and visual information place different demands on working memory and therefore,

we would expect to see a difference in performance between the 2 groups. We hypothesize that verbal information weighs more than visual information on processing power during task performance and is therefore more debilitative during task performance under pressure. If this were to be the case then, in line with CPH, we would see the verbal group perform worse in the pre intervention anxiety trial and then when reinvestment is limited in the post anxiety trial, an improvement in performance should be evident.
In the LSQ and the VVQ we have solid practical measures of two of the most prominent concepts to have come out of the learning styles literature. Neither scale is infallible with both receiving heavy criticism over the level of suggested dichotomy of the concepts and the bipolar nature of the questions (Cockerton et al., 1990). More theoretically, the permanence (trait) of learning styles in general, is an ongoing debate with objections (Coffield et al., 2004b, Zhang and Sternberg, 2005) that an individual’s approach to learning is more transient and can be adjusted according to cognitive state and the task requirements (Kaufman, 2000, Kaufman, 2002, Zhang and Sternberg, 2005). Despite its lack of validity for certain sub-sets the LSQ is considered a reliable measure of the 4 behavioral dimensions (Cockerton et al., 1990) used in this study. Meanwhile the VVQ remains the primary instrument used to measure the verbaliser-visualiser dimension (Mayer and Massa, 2003).

Adding the 2 personality dimensions to the previous experimental design (Chapter 3) will provide valuable inter personal data that has so far not been covered in the existing motor performance literature.

Methods

Participants

Male (n = 20) and female (n = 3) golfers of handicap less than 6 participated in the study. Recruitment was from golfers studying at two universities in the United Kingdom.

Instruments

Learning Style Questionnaire

The LSQ (Honey and Mumford, 1992) is based on Kolb's 'Experiential Learning Model' (ELM) (Kolb, 2005, Kolb, 1984, Kolb et al., 2001) that proposes a 4 step cyclic model to learning. In the LSQ the styles classifications are: activist, theorist, pragmatist and reflector. The activists like to be active, make decisions intuitively and dislike excessive structure. An example question for the activist scale is, 'I enjoy fun loving spontaneous people'. Theorists would rely more on theory and logic, not trusting intuition and emotional input. A theorist example question is 'I am keen to reach answers via a logical approach'. Pragmatists are more likely to take risks and have a liking for practical methods and thinking. Pragmatists are unlikely to get involved in deep reflection or the theory of a topic. Example question; 'In meetings I put forward realistic practical ideas'. Reflectors like processes and would reflect on the deeper meaning, trying to understand how things work (Van Zwanenberg et al., 2000). An example of a question on the reflector scale is, 'I prefer to stand back from the situation and consider all perspectives. Optimally, the learner would go through all 4 stages with equal intensity but most learners will have a preference for certain stages and favor these parts of the strategy (Kolb, 1984). The LSQ is an 80 point questionnaire that requires the participant to mark whether they agree or disagree with the given statement for each item. This provides a score as to the learner's preferences on each of the 4 dimensions.

Verbaliser-Visualiser Questionnaire

The VVQ (Richardson, 1977) is a 15 item questionnaire that measures the verbaliser-visualiser dimension of cognitive style. The questionnaire contains items such as: 'I enjoy doing work that requires the use of words' and 'my daydreams are so vivid, I feel as though I actually experience them.' The 15 items were extracted from a previous questionnaire (Paivio, 1971) that provided evidence that people differ in their learning strategies. The VVQ requires a true or false answer to each item, which relates to the verbal-visual dimension. The results were organised to give a score on a continuum of visual to verbal style. This meant that some of the answers had to be reverse coded in order that a positive score is always a verbal value.

Both the LSQ and VVQ questionnaires were carried out online prior to the collection of the performance data.

Procedures

During this study the general procedure outlined in Chapter 3 was followed. In addition to this the Learning Style Questionnaire and the Verbaliser/Visualiser questionnaire were administered online before any performance data was collected.

Data Analysis

The data was analysed as per the general methods section (chapter x) with the addition of the VVQ and LSQ questionnaires. The VVQ scoring was organized so that the score represents a point on a continuum from visualiser to verbaliser. A high score represents a verbal processing trait. The learning style questionnaire scores were summed giving a score for each subscale. The subscales of personality for the VVQ and learning styles questionnaires were split into high and low groups by taking 1 standard deviation spread across the mean (Masters et al., 1993a). Any score that was ≤ 0.5 SD below the mean was appointed to the low group. Scores that were ≥ 0.5 SD above the mean were appointed to the high group. The resulting hi/low factors were correlated against the performance and state reinvestment data using Spearman’s Rho correlation analysis for non-parametric data.

Results

Questionnaire Reliability

Calculated Cronbach's alphas showed that all subscales of the CASI-2R; somatic anxiety (α = 0.76), cognitive anxiety (α = 0.76) and self-confidence (α = 0.82) were internally reliable. As was the aMSRS (α = 0.88), (Table 7.1).

Block	**1**	**2**	**3**	**4**	**Overall**
Cognitive Anxiety	.61	.86	.72	.85	.76
Somatic Anxiety	.79	.78	.72	.74	.76
Self Confidence	.78	.84	.85	.84	.82
Reinvestment	.82	.87	.91	.91	.88

Table 7.1. Cronbach's alpha scores for the CSAI-2R and aMSRS across the 4 trials.

The VVQ questionnaire has been shown in the past (Richardson, 1977) to have excellent test-re-test reliability, $r = 0.91$ $p = <.001$.

The calculated Chronbach's alpha values for the LSQ subscales showed marginal reliability; theorist (α = 0.57), reflector (α = 0..58), pragmatist (α = 0.52) with the exception of activist (α = 75).

	Cronbach's α
Theorist	.57
Reflector	.58
Pragmatist	.52
Activist	.75

Table 7.2. Cronbach's α scores for the Verbaliser/Visualiser and LSQ questionnaire subscales. The original Pragmatist Cronbach's α value was .39. Subsequent analysis of the inter-item correlations led to item 35 being removed to give a Cronbach's α of .52.

CSAI-2R Subscale Scores

There was a significant main effect across the 4 trials, of the CSAI-2R cognitive anxiety subscale scores of $F(3,72) = 6.29$, $p<.001$, (Figure 7.1.)

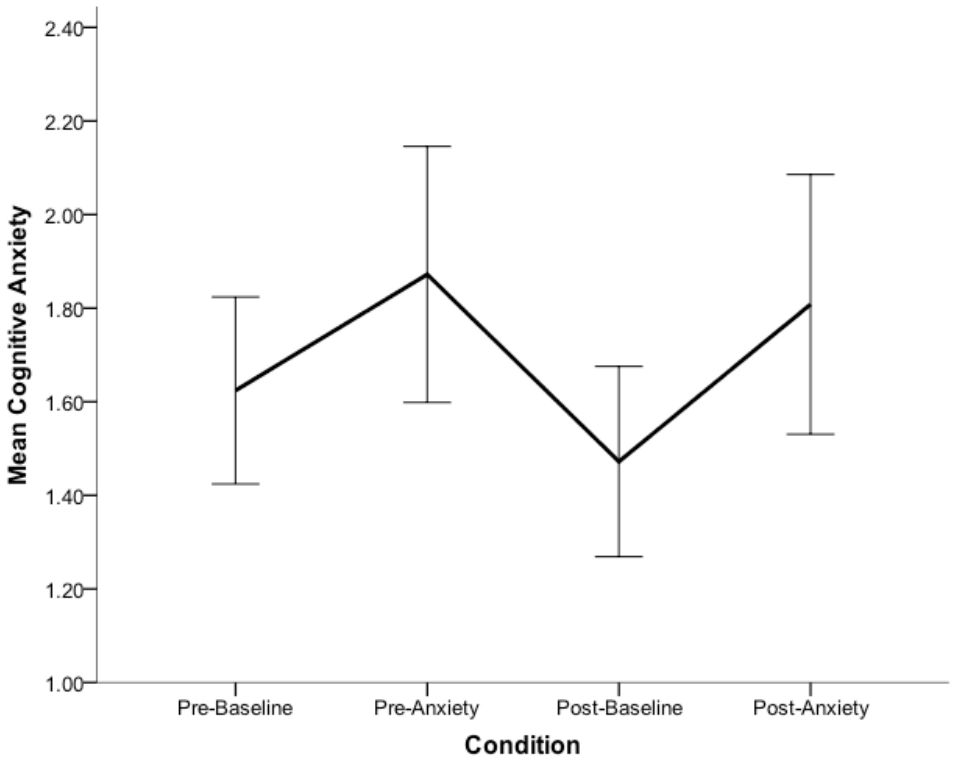

Figure 7.1. Error Bars: 95% CI. Cognitive anxiety scores across all 4 trials. Shows a desired and significant increase during both pre and post anxiety trials.

CSAI-2R Subscales

In line with the performance data, the CSAI-2R scores were analysed in 2 baseline/anxiety pairs. There was a significant effect of the cognitive anxiety subscale on test for both pairs of trails. Pair 1 $F(1, 24) = 4.95$, $p = .036$, pair 2 $F(1, 24) = 12.69$, $p = .002$. There was also a significant effect of the somatic anxiety subscale on test for both pair 1 $F(1, 24) = 5.35$, $p = .030$ and pair 2

F(1, 24) = 12.30, *p* = .002 but no significant effect was reported on the self-confidence subscale for either pair 1 *F*(1, 24) = 3.19, *p* = .087 or pair 2 *F*(1, 24) = 0.00, *p* = 1.000.

CSAI-2R Direction

Table 4 shows all high intensity scores reported as debilitative and all low intensity scores as facilitative. The difference between high and low intensity was significant on 3 trials of the cognitive scale. This validates the effect of the intensity scores.

		Pre		**Post**	
Condition		**Base**	**Anx**	**Base**	**Anx**
Cognitive	High Intensity	-0.30 ± 0.21*	-1.23 ± 0.94*	-1.35 ± 0.66*	-0.57 ± .098
	Low Intensity	0.72 ± 1.09^{S}	0.19 ± 1.33^{S}	0.38 ± 1.44^{S}	0.23 ± 1.50
Somatic	High Intensity	-0.07 ± 1.31	-0.46 ± 0.61	-0.71 N/A	-.055 ± 0.55
	Low Intensity	0.64 ± 1.09	0.59 ± 1.21	0.32 ±.1.34	0.56 ± 1.79

Table 7.3. CSAI-2R direction scale mean scores in the pre and post intervention anxiety conditions. $^{*,\$}$ indicates significant difference between pairs. Data are mean ± standard deviation.

State Reinvestment

Figure 7.2 shows the state reinvestment scores by condition. There was a significant main effect of trial on state reinvestment *F*(3,72) = 11.5, *p* <.001. Pairwise comparisons revealed a significant effect of intervention between pre and post conditions. This was evident on both baseline, ($p <$ .001) and anxiety (p = .004) trials. There was no effect of anxiety reported between trial 1_{base} and trial 2_{anx} (p = .84) or trial 3 $_{basel}$ and trial 4_{anxl} (p =.17).

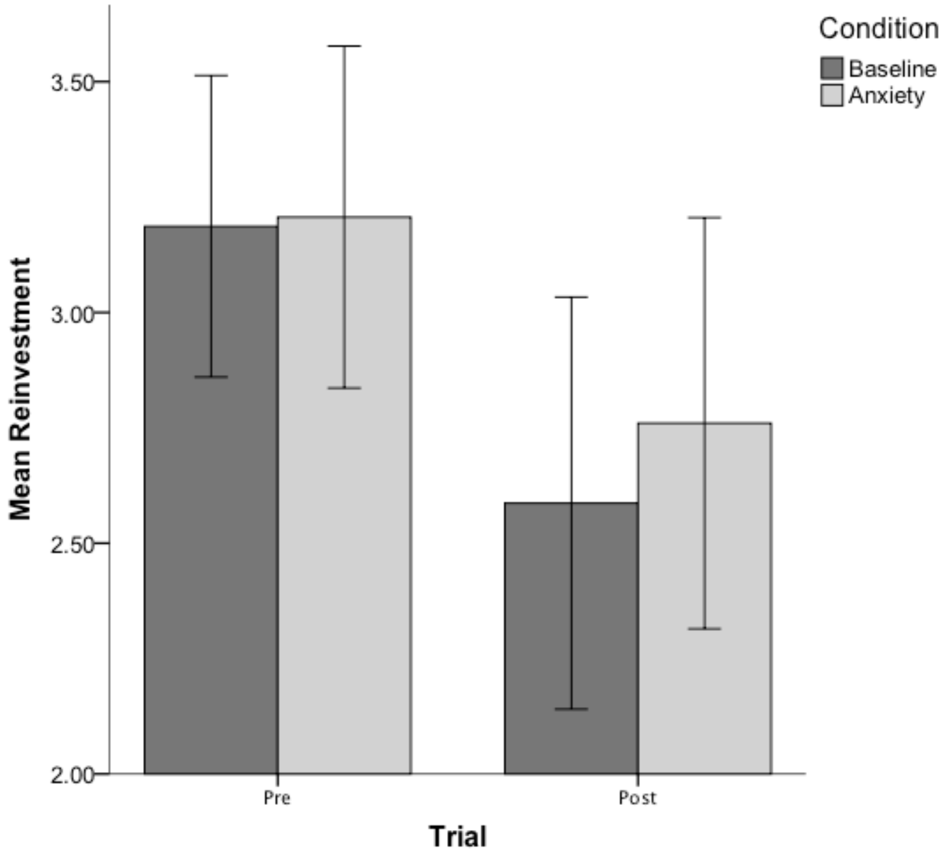

Figure 7.2. Error Bars: 95% CI. Reinvestment scores by condition. Shows significant reduction in reinvestment during post intervention trials.

State Reinvestment Correlations

There were no significant correlations reported between state reinvestment and any of the LSQ or VVQ subscales.

Performance

No main effect was found for the repeated factor condition *F*(2.1,45.3) = 1.6, *p* =.210. Performance during the anxiety trials was calculated by comparing the change between anxiety trials in pre and post to which no main effect was found *F*(1,22) = .392, *p* =.538. In testing the effect of the intervention on performance under pressure, the change between trial 1_{base} and trial 2_{anx} was compared with the change for the post trials 3_{basel} and $4_{anxl.}$ Again, no main effect was found *F*(1,22) = 1.48, *p* =.236.

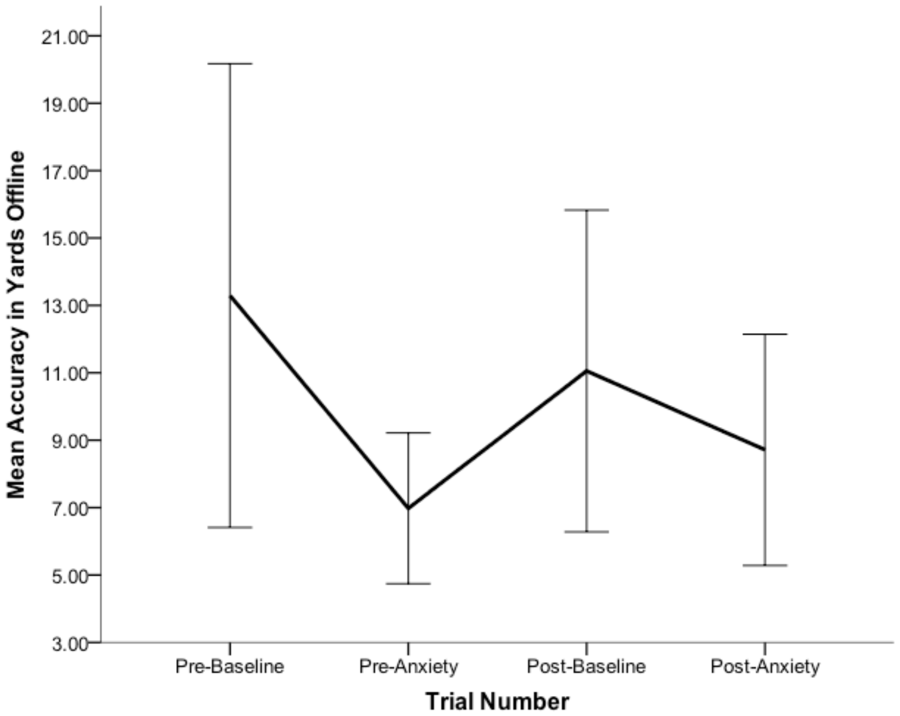

Figure 7.3. Error Bars: 95% CI. Accuracy means across the four trials. The pattern shows an improvement in post-baseline trials but no significant changes were detected.

Learning Style Questionnaire- Internal Correlation

The results from the LSQ showed a level of internal correlation with the theorist and reflector subscales showing a significant relationship to one another $r = -.84$, $p < .001$. The reflector and activist scales also show a significant negative correlation to one another $r = -.85$, $p = .001$.

Learning Style Questionnaire- Performance Correlation

There was a significant negative relationship between the theorist subscale and pre-intervention change in performance between baseline and anxiety conditions, $r = -.53$, $p = .034$. There was also a significant negative relationship between the reflector subscale and trial 4_{anxI} performance, $r = -.46$, $p = .05$.

The activist and pragmatist subscales showed no significant correlation.

Verbaliser-Visualiser

There was a significant positive relationship between the VVQ scale and performance in trial 2_{anx} $r = .65$, $p = .006$ and a significant negative relationship between the VVQ scale and performance changes between the anxiety trials $r = -.65$, $p = .006$.

There was also a significant effect of intervention between the group's performance on pre and post anxiety trials, $F(1,14) = 8.4$, $p <.012$ (Figure 7.4).

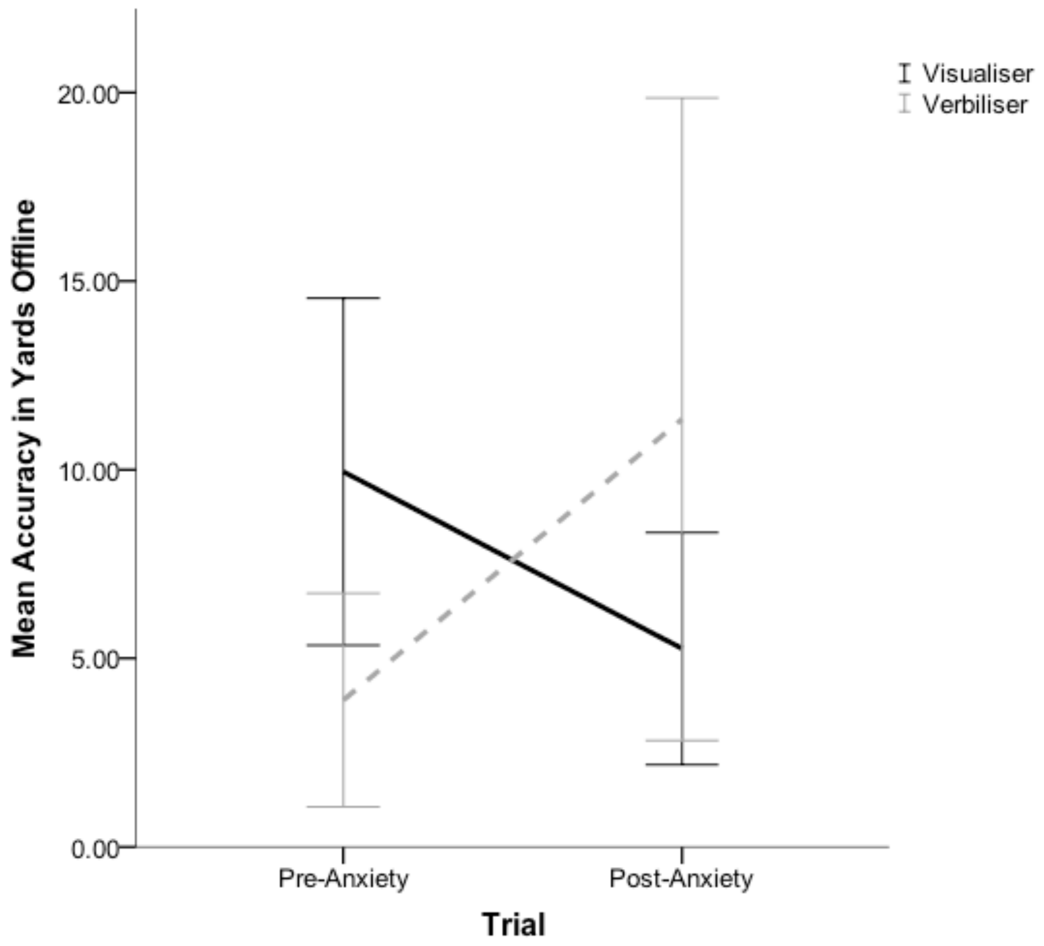

Figure 7.4. Error Bars: 95% CI. Accuracy means for pre and post anxiety trials. This indicates that the intervention is helpful to visualisers and harmful for verbalisers.

Discussion

Based on previous work (Masters et al., 2005, Masters and Maxwell, 2008a, Masters et al., 1993a, Maxwell et al., 2006) the aim of this study was to examine the relationship between learning styles and the verbaliser/visualiser separately, against full golf swing performance and state reinvestment under anxiety and baseline conditions. Unique to this study was the individualistic approach to automaticity, the motor complexity of the full golf swing and the temporal restriction intervention that was designed to limit state reinvestment.

The intervention was shown to be effective by reducing reinvestment in both baseline ($p < .001$) and anxiety ($p = .004$) pre-post comparisons. However, counter to the claims of the CPH, there was no significant change in state reinvestment between baseline and anxiety trials (see chapter 9).
As with the previous studies in this thesis (Chapters 4-6) the group performance results were not affected by the intervention. It was the individual disparity of performance effect in our initial experiment (Chapter 4) and the null performance effect in experiment two (Chapter 5) that directed us to look closer at the personality trait correlations for individual effects of limited reinvestment.

Learning Styles

We initially predicted that theorists and reflectors would show results in accordance with reinvestment theory on the basis that these two learning styles are more habitually pensive (Furnham, 1992, Kappe et al., 2009) and would likely be the higher reinvestors. Our hypotheses were that the high theorists and reflectors would show greater propensity to consciously control movement and as a result, would display performance decrements in the trial 2_{anx} and react more favorably to the intervention in trial 4_{anxI}. The initial hypothesis was not corroborated as the results failed to show any link between any of the learning styles and levels of state reinvestment. The performance results only lent partial support to our 2nd hypothesis by the way of the negative correlation coefficients between theorists and performance indicating that high-level theorists performed worse in trial 2_{anx} versus trial 1_{base}, $r = -.53$, $p = .034$. This would suggest that the theorist group, which is one of the more pensive of the learning styles (López et al., 2013), are less robust when anxious. According to the CPH and the second part of our performance hypothesis, this is caused by over reinvestment in declarative knowledge. Therefore, we also predicted that there would be a positive effect of intervention for this and the reflector group, given that the intervention was shown to successfully limit state reinvestment. This was not to be the case and in fact, the reflector group showed a negative correlation with performance in trial 4anxI, $r = -.46$, $p = .05$ indicating that the high reflectors performed sub-optimally when reinvestment was limited.

Furthermore, for our results to be in line with our hypotheses, the activist/pragmatists would have performed better that they did. These traits are considered to take a more practical, ‘give it a try’ approach to learning. We presumed from this that they will have engaged in less hypothesis testing (Buszard, 2014, Poletiek, 2013) and would have learned more implicitly than the theorist/reflectors. In keeping with the reinvestment theory, we had predicted that these two groups would be most resilient under pressure due to the lack of explicit knowledge build up (Masters and Maxwell, 2008a, Masters and Poolton, 2012) but this was not represented in any of the anxiety trial performance results.

On the face of it this null result would infer that there is no relationship between the subscales of the LSQ and either propensity to reinvest or performance in any of our conditions. Given the overall lack of correlation with the LSQ in this study, we have to consider the reliability of the measure to discriminate between the four subscales (Stellwagen, 2001). The internal correlation results from the LSQ showed the theorist and reflector subscales as being so strongly correlated to one another, $r = -.84$, $p < .001$, that could indicate that they are measuring the same thing. The reflector and activist scales show a significant negative correlation to one another to the magnitude, $r = -.85$, $p = .001$, that could suggest that they are measuring either end of the same bipolar dimension.

The internal reliability is also noteworthy with relatively low scores that are not dissimilar to scores reported in other studies (Kappe et al., 2009). We must also acknowledge the power of this study with respect to the level of noise in full golf shot data (See chapter 9).

Verbaliser-Visualiser Dimension

Our initial hypothesis was that reinvestment is a verbal domain and therefore there was likely to be a higher propensity for reinvestment in the verbal group. However, this was not the case as no significant correlations were identified between the VVQ scores and state reinvestment. Previous studies (Buszard, 2014) have pointed towards a link between verbal short-term memory and reinvestment propensity but it should be noted that the MSRS has two dimensions of reinvestment; conscious motor processing (CMP) which refers to the conscious control and monitoring of movement and movement self-consciousness (MS-C) which is a measure of 'concern about the impression given while moving' (Buszard, 2014, p.52). In a related study of adults (Buszard et al., 2013), the MS-C subscale of the MSRS showed a relationship with reinvestment propensity but not the CMP. This study was only concerned with the conscious control of movement and therefore, only the CMP dimension was used.

Our performance hypothesis was that the verbalisers would differ to visualisers in relation to the intervention. We expected verbal processing to have a debilitative effect on performance under pressure and therefore, show a performance drop off in trail 2_{anx} and an improvement in the post-intervention anxiety score facilitated by the limitation on reinvestment. Our hypothesis was not only rejected but the opposite effect was evident. The verbalisers were better than visualisers in the trial 2_{anx} but the visualisers had a significantly better performance in the anxiety conditions comparison. A possible explanation for this unexpected result is that visual information is in fact, more resource demanding under concurrent task performance. This would support the findings that show the visual group having a significantly better response to the intervention. Alternatively, the authors propose that the pre-post improvement of the visual group was due to visual cognition being unaffected by the intervention in trial 4_{anxI} where only the verbal reinvestment is limited. This would leave them with less 'noise' and the task performance governed by their more fluid and familiar visual type processing. This would be consistent with ‘meshing’ theories (Khanal et al., 2014, Pashler et al., 2008) of modality preference where one is encouraged to learn with and use our most dominant sense.

In parallel to this, it is also proposed that the verbaliser’s pre-post drop in performance is because this group is used to reinvestment under pressure and find it a necessary part of their task focus. In line with the processing efficiency theory (Eysenck and Calvo, 1992, Eysenck et al., 2007b) the verbaliser group responded well to the pressure during trial 2_{anx} due to an increase in attentional resources. When reinvestment was limited in trial 4_{anxl} this heightened focus was interrupted resulting in the drop in performance. This interpretation suggests that during a complex task, verbalisers require some level of reinvestment. For this interpretation to be fully upheld by the results, a trait propensity to consciously control movement would have been evident through a positive correlation between state reinvestment and the VVQ scale in the pre trials. The researchers acknowledge that this was not the case in this study.

The CSAI-2R intensity scales indicated that the study successfully created the desired anxiety manipulation, although, performance did not drop off with the rise in anxiety. This result is in line with the ‘direction perception’ approach to anxiety (Mellalieu et al., 2006, Mellalieu et al., 2003, Robazza et al., 2008) which suggests that the player’s level of self-confidence can cause symptoms of anxiety to be perceived as being facilitative and lead to enhanced results under anxiety conditions.

As stated in the data analysis, the traditional methods of analysing CSAI-2R direction data have been found to be ineffective (Lundqvist et al., 2011) casting doubt over the direction perception approach. In all intensity/direction parings during this study, there was a positive correlation between intensity levels and a perceived debilitative effect of anxiety. Therefore, the direction scale analysis from this study supports the Lundqvist et al. (2011) position by showing increases in anxiety to be perceived as debilitative. This does raise questions as to why we do not see the expected performance drop off during anxiety trials.

The same effect was evident in a recent study (Buszard, 2014) of a similar design. The authors noted that the anxiety trials always followed the baseline conditions and a lack of counterbalance was proposed as a potential limitation. We also consider the possibility that the baseline trials were perceived as unimportant and a lack of activation/motivation (Mellalieu et al., 2006, Swann et al., 2012) was a factor in 'below par' performance. Future studies may address this issue by replacing the baseline/anxiety set up with low anxiety/high anxiety conditions. This design limitation is discussed in more depth in Chapter 9 along with the potential non-linear relationship between pressure and reinvestment (Cooke et al., 2011).

Conclusion

The aim of the present study was to examine individualistic factors that may affect the reinvestment paradigm. It would appear from the results that further research is required for the application of the CPH to complex motor skills. Contrary to the reinvestment literature, our results indicate that conscious processing during task performance affects individuals differently. The high verbaliser group got worse when working memory input was constrained pointing toward a positive role for conscious processing in the full golf swing. Visualisers improved during the post intervention anxiety trial, which has been attributed to a processing refinement, not a complete absence of working memory input.

The effect and presence of automaticity is not a linear pattern and thus far, has been studied in an overly dichotic manner. Future research should consider further, the individual and qualitative factors of conscious processing. In particular, studies that evaluate ones capacity to hold and process information (Buszard, 2014, Winter et al., 2014) are much needed.

CHAPTER 8

THE RELATIONSHIP BETWEEN SHORT-TERM MEMORY, WORKING MEMORY AND REINVESTMENT DURING THE GOLF SWING.

Abstract

The dominant theories of motor learning view expert performance as largely automatic (Fitts and Posner, 1967, Luft and Buitrago, 2005). Moreover, 'reinvestment theory' (Masters and Maxwell, 2008a) suggests that the conscious application of declarative knowledge leads to a breakdown in skill through a decoupling effect of the movement pattern. Recent studies (Nyberg, 2014, Toner and Moran, 2014) have begun to dispute this position and its universal application, in search of a more flexible model that accounts for individual differences in cognitive traits (Winter et al., 2014) and a wider breadth of task constraints. By examining the relationship between cognitive resources and reinvestment this study is a substantial move away from the traditional 'one size fits all' approach to the subject.

Working memory is central to the ability to retain and process information while performing a motor skill (Baddeley, 2010, Ericsson and Kintsch, 1995); therefore, we predicted that the capacity of one's working memory would affect the optimum level of reinvestment during skill performance. This study tests for relationships between conscious processing during performance of a highly complex motor skill and individual resources of short-term memory and working memory capacity. Against these cognitive traits, performance is examined as accuracy of full swing shots in elite level golfers under baseline and anxiety conditions.

The results showed a significant relationship between short-term memory and performance under pressure, $r_s = .62$, $p = .018$, which was not replicated when reinvestment was limited. Working memory capacity (WMC) showed a significant relationship with performance under

pressure when reinvestment is limited $r_s = .54$, $p = .021$. This effect was down to the low WMC group getting worse when under a limited reinvestment trail, $F(1,16) = .382$, $p =.068$. Pre-anxiety 6.44 yards off line SD = 4.43. Post-anxiety 13.63 yards offline SD = 10.18.

There were also significant relationships between state reinvestment and short-term memory in trials 3_{anxl}, $r_s = -.48$, $p = .082$ and 4_{anxl} , $r_s = -.68$, $p = .007$.

This study is one of the first of its kind to test the effect of cognitive sub-traits relative to reinvestment and automaticity constructs. The results lend support for the long-term working memory model (Ericsson and Kintsch, 1995) and challenge the universal application of reinvestment theory. It is suggested that a more flexible model is required, that recognises the need for refined task focus and is flexible in respect to task and individual cognitive resources.

Introduction

Chapter 2 highlights a clear limitation within the automaticity literature as the lack of research into the inter-personal aspect of automaticity. Until recently (Buszard, 2014) there has been a ‘one size fits all’ approach (Peh et al., 2010) that would suggest that all performers are better off discarding conscious control of their movements (Beilock et al., 2004b, Beilock and Carr, 2001) or at the very least, adopting an external focus of attention during motor skill execution (Wulf, 2007, Wulf, 2013). This was addressed in Chapter 7 where learning styles (Antonietti and Giorgetti, 1998, Honey and Mumford, 1992) showed a clear differential in the effect of conscious movement control and pointed toward a more individualistic account of reinvestment.

In this chapter we are considering the notion that if personality differences (Bell et al., 2013, Roberts et al., 2013) affect our level/type of conscious control during task execution then it could also be the case that the cognitive input during motor control is also dependent on individual cognitive trait factors. The previous experiment (Chapter 7) is repeated with the substituted measures of short-term memory and working memory capacity.

The literature on reinvestment, choking under pressure and attentional focus are largely dominated by information processing theories (Hill et al., 2010, Masters and Maxwell, 2008a, Wulf, 2007). Masters (1993) brought many of these hypotheses together with the formation of his reinvestment theory. In this model Masters (2003) distinguishes between two different types of motor learning information that are stored in memory and contribute toward motor skill performance. Masters’ (1993) approach to learning describes the transformation of information from declarative memory to procedural memory

(Fitts and Posner, 1967). In the outset, the learner engages in a process of hypothesis testing (Neves and Anderson, 1981) which creates a mass of explicit rule based information that is held in declarative memory. Over time and repetition this declarative information is transformed into procedural knowledge which is characterised by a nonentity of rules and an inability to verbalize the information due to its abstract nature (Beilock, 2011). At this advanced stage of learning, according to reinvestment theory, the action is best performed in the absence of declarative knowledge and conscious input. In fact, undesired conscious input will cause the movement pattern to break down due to the uncoupling of coded information back into its step by step form of earlier hypothesis testing. Both declarative and procedural knowledge are held in long term memory but in distinct parts of the brain (Beilock, 2011) and are accessed differently. Procedural information is applied automatically and in the absence of conscious control while declarative information is a more conscious process.

All the information processing models have at their core, the control of attention and the capacity to hold and process information. Stemming from early work by Baddeley and Hitch (1974) this role is attributed to working memory (WM, Baddeley, 1992, Baddeley, 2007, Baddeley and Hitch, 1994) which is a prerequisite utility in the application of decelerate knowledge.

The biological components of WM are not thought to be located in absolute proximity to each other but are rooted in the prefrontal cortex (Beilock, 2011, Knudsen, 2007, Miller and Cohen, 2001). The system is comprised of four constructs: the central executive, which has control over the system as a whole; the phonological loop and visio-spatial sketchpad, which deal with verbal and visual information respectively. More (Baddeley, 2000) recently, came the addition of the episodic buffer, which is tasked with directing attention and focus as well as provided further storage. There is a consistency in the literature that WM is of fixed capacity, therefore limiting the information that can be held and processed at any one time (Alloway et al., 2008, Conway et al., 2003).

Opposing the limited capacity view, Ericsson and Kintsch (1995) introduced a revised version of WM that takes into account individual capacity differences as a function of skill. In the long term working memory (LT-WM) model the skilled performer can gain access to information stored in long-term memory (LTM). This can only be accessed via retrieval cues in what they term short-term working memory (ST-WM). This significant change to the capacity models allows for domain specific retrieval of information from LTM and thus extends the capacity of WM considerably. The amount of retrievable information is not fixed but a more transient concept based on one's skill in efficiently accessing task relevant information in LTM (Sohn and Doane, 2003). In the capacity model, individual performance differences are limited by the amount of 'domain general information' that can be held in an active state in Short-term memory (STM, Sohn and Doane, 2003). The LT-WM hypothesis views individual performance difference as a matter of retrieval skill of domain specific information from LTM. This makes WM capacity more dynamic and skill based.

Despite WMC and LT-WM being opposing theories, there is evidence (Sohn and Doane, 2003) of their co-existence based on the requirement for trait and domain based working memory constructs. The interaction between the two would be skill dependent with the less developed skills requiring more input from WM, the reliance of which diminishes with skill development.

Given the centrality of WM in high level cognitive skills relating to concentration and ‘cognitive power’ (Beilock, 2011), the relevance of WMC could be considerable in explaining individual performance differences in a wide number of sporting demands. Any domain that requires a refined allocation of attention (Capizzi et al., 2013) and a level of mindfulness (Birrer et al., 2012) could be influenced by WMC. There are a growing number of studies of the effect of WMC in academic tasks (Beilock, 2011, Beilock and Carr, 2005, Beilock and DeCaro, 2007, Conway et al., 2003, DeCaro et al., 2009, DeCaro et al., 2011) but as highlighted by Furley and Memmert (2010), there are very limited studies (Buszard et al., 2013) of the individual difference in WMC within the sports psychology literature. This is despite recognizing WMC plays a key role in attention focus, performance under pressure, reinvestment theory, imagery, skill acquisition and concentration in general (Mayers et al., 2011, Moreau, 2013, Unsworth and Spillers, 2010, Voss et al., 2010).

Since the processing of declarative knowledge occurs in WM then WMC would appear to be a key differential in understanding the inter-personal factors in the reinvestment paradigm. This relationship was recently examined in a study of motor performance, reinvestment and WMC (Buszard et al., 2013, study 1). As with the academic value of high WMC reported above, WMC was found to have a positive relationship with motor performance. To this point, the authors cited ‘superior hypothesis testing and problem solving abilities' (Buszard et al., 2013, pg.82) of high WMC individuals as a possible factor.

It was also shown that for children, a positive correlation exists between WMC and both movement self-consciousness (MS-C) and conscious motor processing (CMP) forms of reinvestment. In a follow up study of adults (Buszard et al., 2013, study 2) only MS-C correlated with WMC but notably, there was also a performance differential which indicated a negative relationship between WMC and performance under pressure. A growing hypothesis (Beilock and Carr, 2005, DeCaro et al., 2009) is that those with high WMC would be heavily reliant on conscious processing which in turn would lead them to be high reinvestors, ultimately leading to performance decrements under pressure. This was the explanation favoured by Buszard et al. (2013). Other studies (Laborde et al., 2015, Wood et al., 2015) provide a positive link between WMC and performance under pressure conditions, citing the 'controlled attention perspective' of WMC. In this account of WMC it is not the qualities of WM to hold information that is most relevant but it's function of maintaining top-down attentional control, suppressing interference (Engle, 2002, Engle and Kane, 2004) and directing task focus (Wood et al., 2015). This is somewhat in line with the more simplistic capacity concept to be trialed in this study; that high WMC affords more scope for reinvestment before any choking effect is apparent. In this paradigm the amount of reinvestment that is optimal may be directly proportionate to the capacity of WM.

High WMC individuals may perform at their best with a low level of well-allocated swing thoughts. These could range from temporal cues

(MacPherson et al., 2009), a holistic focus (MacPherson et al., 2008), key effecters to other ‘high order’ elements of the skill (Toner et al., 2015).

The quantity of swing thoughts and level of cognitive load would be relative to WMC so there would still be a need to keep this regulated so as not to solely rely on WM control of movement. This would overload WM and lead back to the reinvestment effect. In this capacity related model, low WMC golfers may perform at their best when keeping reinvestment to a minimum and thus stay within their more inhibited WM threshold.

There is little known about the direct role of STM in the online conscious control of complex skills. In its traditionally understood role (Atkinson and Shiffrin, 1968), STM acts only as a temporary storage mechanism that would play a very limited role in the online monitoring or control on motor skills. If this is the case, then we wouldn’t expect to see any meaningful relationship between STM and performance. Any significant relationship between these two factors would be more consistent with the LT-WM model where ST-WM generates retrieval cues that access context based information in LT-WM.

It is our initial hypothesis that both STM and WM will have a positive correlation with reinvestment propensity. This is based on the notion that these individuals will be accustomed to explicit information processing (Beilock, 2011) and will have engaged in higher levels of hypothesis testing during learning (Buszard et al., 2013). Secondly, we hypothesize that consistent with the LT-WM model, STM and WMC will have a positive relationship with performance.

Methods

During this study the general procedure outlined in Chapter 3 was followed, with the additional measures of verbal short-term memory and verbal working memory.

Participants

24 elite level golfers (handicap ≤ 5) participated in the study. Recruitment was from golfers studying at two universities in the United Kingdom.

Additional Instruments

The Automated Working Memory Assessment (AWMA) (Alloway, 2007) is a monitored computer assessment that measures the separate components of STM and WM. The AWMA was chosen on the basis of its widespread use and validity (Alloway et al., 2008, Buszard et al., 2013).

Using dual tasks of simultaneous storage and processing, the assessment includes 2 measures each of the visio-spacial and verbal aspects of WM. An example of this is the listening recall task where a sequence of sentences is read out via the computer program. After each sentence the participant is required to say if the statement is true or false. Meanwhile they must remember the last word of all the sentences to be recalled in the correct order at the end of the task. As with all the AWMC items, the task starts off with only one sentence and progresses through multiple sentences until a predetermined failure rate is reached.

Verbal and visio-spacial short term memory is also measured by using only storage tasks such as a simple digit span tasks where the participant simply needs to remember as many numbers as possible from a spoken list. The participants were first offered a 4 digit task which progressed to 9 digits on successful completion of each level. Based on the movement encoding literature (Helstrup, 2000, Moreau, 2013) and the verbal nature of reinvestment (Buszard et al., 2013, Masters and Maxwell, 2008a), only the verbal subscales were used.

Data Analysis

All data was analysed as per the general procedure in Chapter 3. The results of the AWMC test were correlated against performance and state reinvestment data using Spearman's Rho correlation analysis for non-parametric data. The subscales of the AWMC were split into high and low groups by taking 1 standard deviation spread across the mean (Masters et al., 1993b). Any score that was ≤ 0.5 SD below the mean was appointed to the low group. Scores that were ≥ 0.5 SD above the mean appointed to the high group.

Results

Internal Reliability

Calculated Cronbach's alphas showed that all subscales of the CASI-2R; somatic anxiety (α = 0.76), cognitive anxiety (α = 0.76) and self-confidence (α = 0.82) and the aMSRS (α = 0.88) were internally reliable.

Block	**1**	**2**	**3**	**4**	**Overall**
Cognitive Anxiety	.61	.86	.72	.85	.76
Somatic Anxiety	.79	.78	.72	.74	.76
Self Confidence	.78	.84	.85	.84	.82
Reinvestment	.82	.87	.91	.91	.88

Table 8.1. Cronbach's alpha scores for the CSAI-2R and aMSRS across the 4 trials.

CSAI-2R Scores

There was a significant main effect across the 4 trials, of the CSAI-2R cognitive anxiety subscale scores of $F(3,72) = 6.29$, $p<.001$.

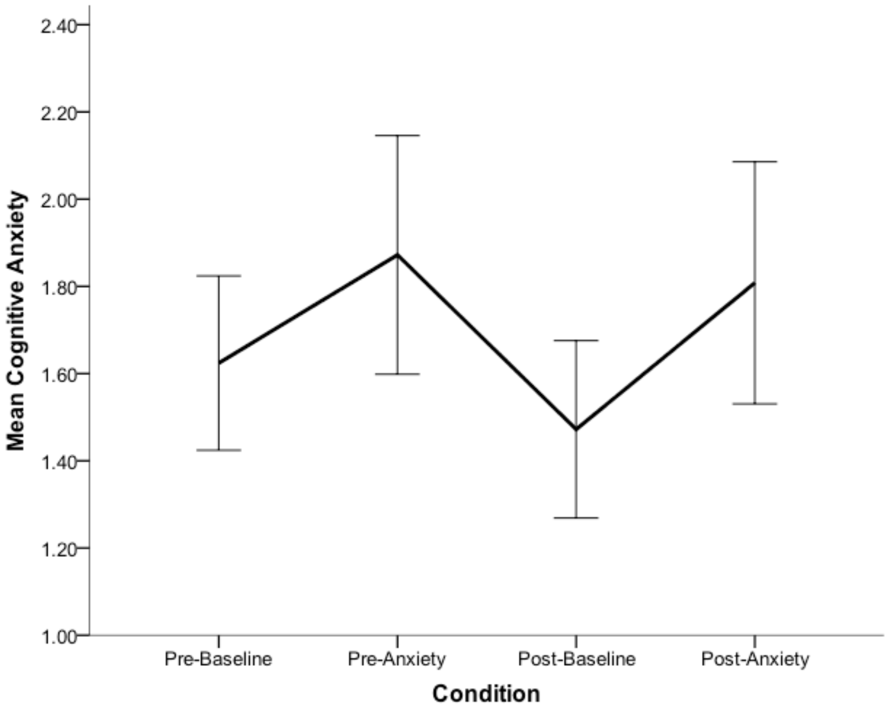

Figure 8.1. Error Bars: 95% CI. Cognitive anxiety scores across all 4 trials. Shows a desired and significant increase during both pre and post anxiety trials.

CSAI-2R Subscales

In line with the performance data, the CSAI-2R scores were analyzed in 2 baseline/anxiety pairs. There was a significant effect of the cognitive anxiety subscale on test for both pairs of trails. Pair 1 $F(1, 24) = 4.95$, $p = .036$), pair 2 $F(1, 24) = 12.69$, $p=.002$). There was also a significant effect of the somatic anxiety subscale on test for both pair 1 $F(1, 24) = 5.35$, $p = .03$) and pair 2 $F(1, 24) = 12.3$, $p= <.002$) but was no significant effect was reported on the self confidence subscale for either pair 1 $F(1, 24) = 3.19$, $p = 0.87$) or pair 2 $F(1, 24) = 0$, $p = 1$).

CSAI-2R Direction

Table 4 shows all high intensity scores reported as debilitative and all low intensity scores as facilitative. The difference between high and low intensity was significant on 3 trials of the cognitive scale. This validates the effect of the intensity scores.

		Pre		**Post**	
Condition		**Base**	**Anx**	**Base**	**Anx**
Cognitive	High Intensity	-.30 ± .21*	-1.23 ± .94*	-1.35 ± .66*	-.57 ± .98
	Low Intensity	.716 ± 1.09^{S}	.19 ± 1.33^{S}	.38 ± 1.44^{S}	.23 ± 1.5
Somatic	High Intensity	-.07 ± 1.31	-.46 ± .61	-.71 N/A	-.55 ± .55
	Low Intensity	.64 ± 1.09	.59 ± 1.21	.32 ±.1.34	.56 ± 1.79

Table 8.2. CSAI-2R direction scale mean scores in the pre and post intervention trials. $^{*,\$}$ indicates significant difference between pairs. Data are mean ± standard deviation.

Reinvestment

There was a significant main effect of trial on reinvestment $F(3,72) = 11.5$, $p < .001$. Pairwise comparisons revealed a significant effect of intervention between pre and post conditions. This was evident on both baseline, ($p < .001$) and anxiety ($p = .004$) trials. There was no effect of anxiety reported between trial 1_{base} and 2_{anx} ($p = .84$) or 3_{basel} and 4_{anxl} ($p = .17$)

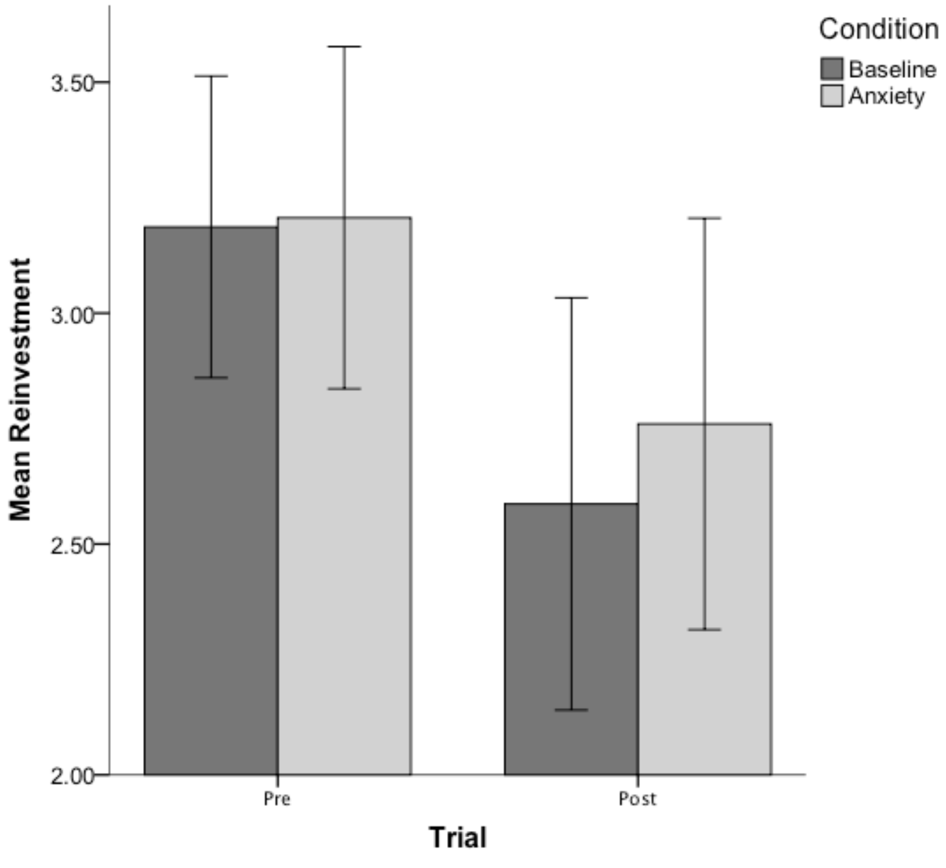

Figure 8.2. Error Bars: 95% CI. Reinvestment scores by condition. Shows significant reduction in reinvestment during post intervention trial.

Overall Performance

No main effect on performance was found for the repeated factor condition $F(2.1, 45.3) = 1.6$, $p = .210$. Performance during the anxiety trials was calculated by comparing the differences between anxiety trials in pre and post. No main effect was found for the repeated factor condition $F(1,22) = .392$, $p = .538$. In testing the effect of the intervention on performance under pressure, the change between (Δ) trial 1_{base} and trial 2_{anx} was compared with the same Δ for the post trials 3_{basel} and $4_{anxl.}$ No main effect was found $F(1,22) = 1.48$, $p = .236$

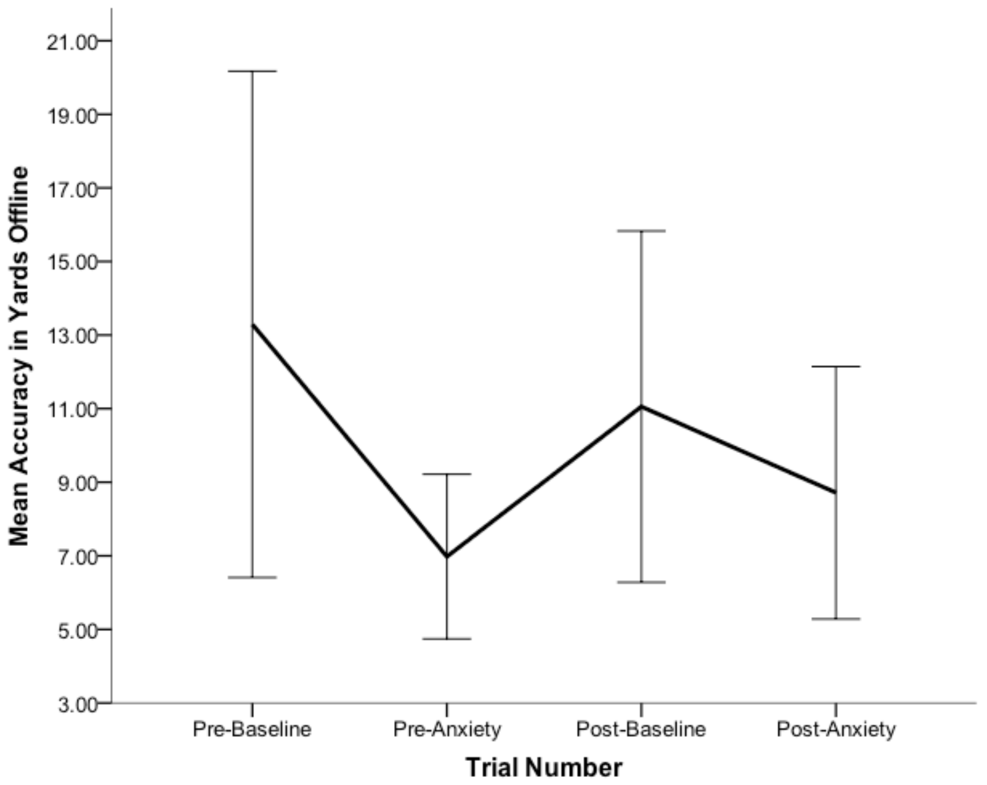

Figure 8.3. Error Bars: 95% CI. Accuracy means across the four trials. No significant changes are reported.

Correlations

Short-Term Memory - Reinvestment

There were negative relationships between STM and levels of reinvestment in trials 3_{anxI}, *r* = -.48, *p* = .082 and 4_{anxI}, *r* = -.68, *p* = .007. Follow up analysis revealed a significant overall effect of group, F(3, 36) = 5.53, *p* = .003 on reinvestment across the 4 trials.

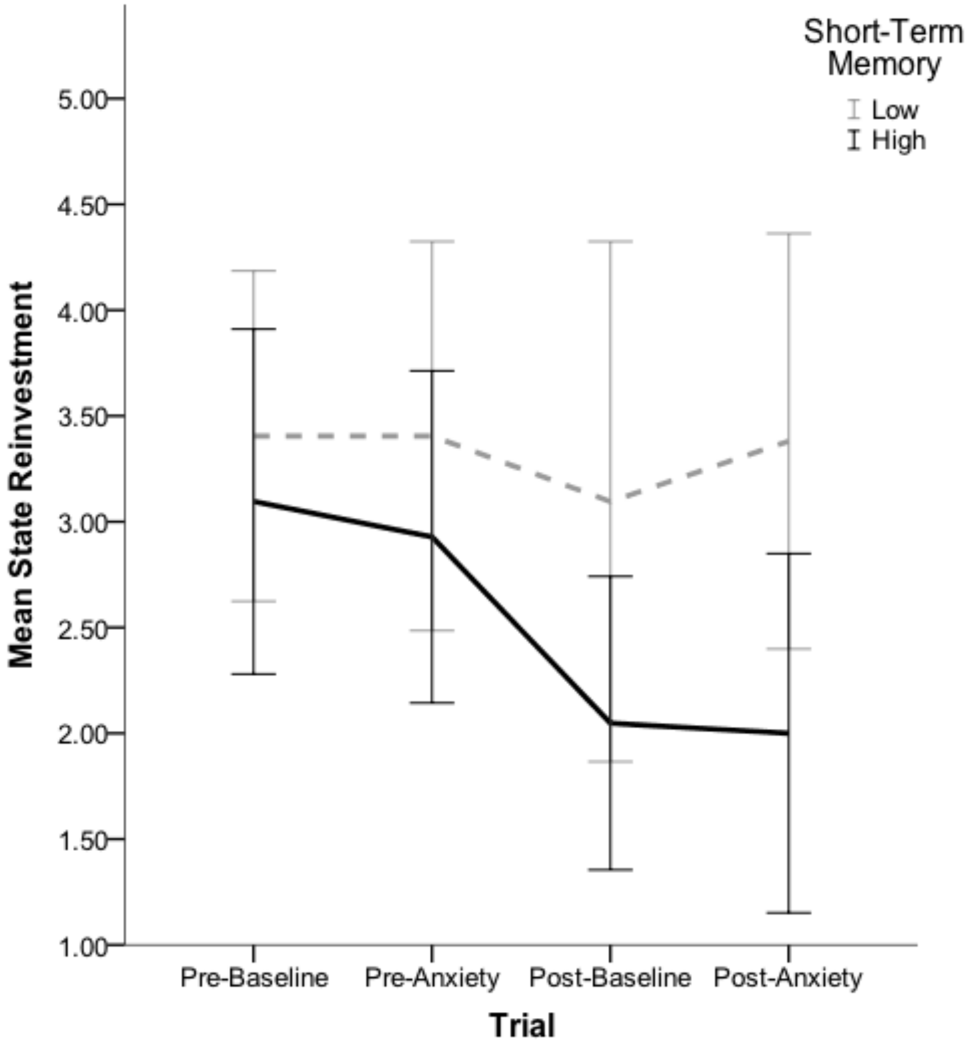

Figure 8.4. Error Bars: 95% CI. Reinvestment means across the four trials for high and low short term memory groups.

There was also a significant effect of group on reinvestment between pre and post anxiety trial state reinvestment, F(1,12) = 10.44, *p* =.007 and a meaningful effect between pre and post baseline trials, F(1, 12) = .953 *p* = .063.

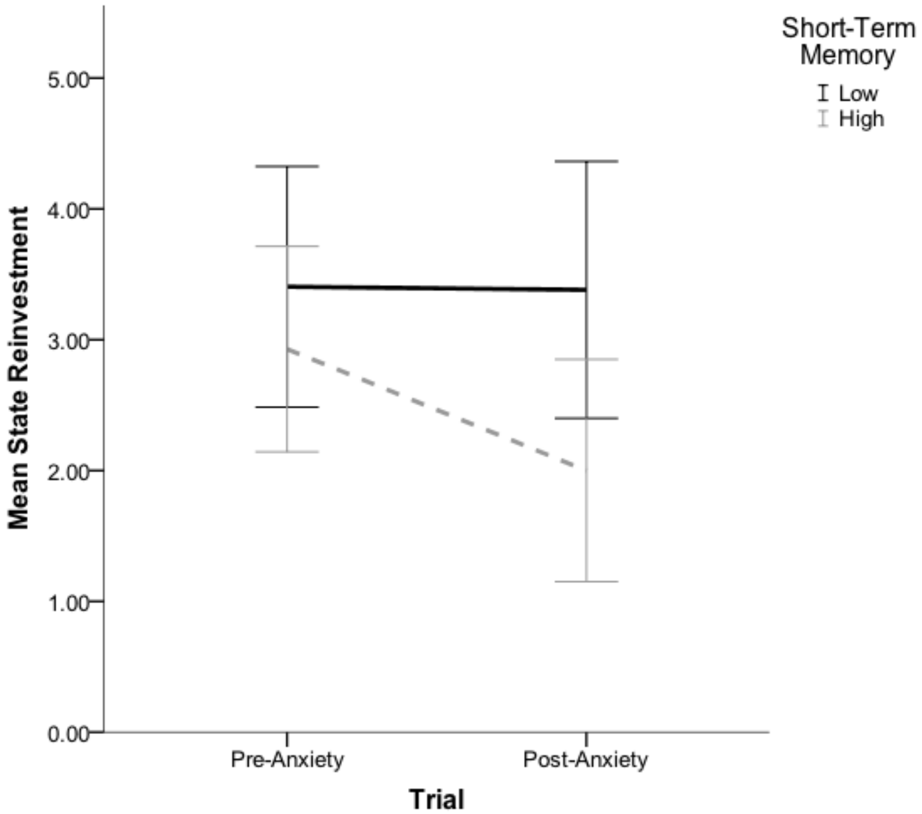

Figure 8.5. Error Bars: 95% CI. Reinvestment means across the pre and post anxiety trials for high and low verbal short-term memory groups. The pattern shows a significant effect of the intervention between groups.

Short-Term Memory – Performance

There was a significant relationship between STM and performance in trial 2_{anx} $r = .62$, $p = .018$. Figure 5 below shows this being the result of only the high STM group improving under the trial 2_{anx} while the low STM group remains stable. It is worth noting that although not significant, we see a similar effect in trial 4_{anxl} $r = .44$, $p = .12$.

Follow up analysis reported no significant between groups results F(13, 36) = .846, $p = .478$.

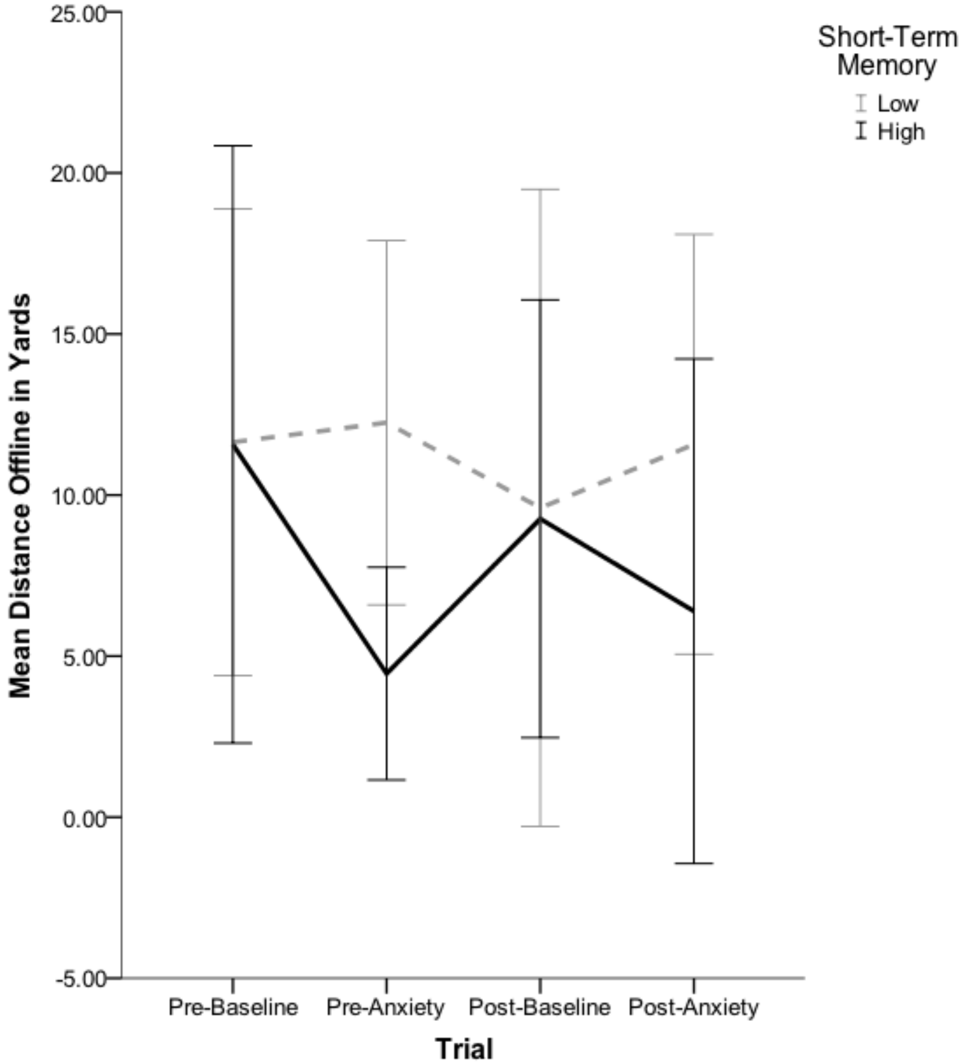

Figure 8.6. Error Bars: 95% CI. Performance across all 4 trials by high and low short-term memory groups. The high STM group improved under pressure while the low group did not.

Working Memory - Reinvestment

Through the use of the AWMC test working memory was split into recall (WM_{recall}) and processing ($WM_{process}$) subscales. Neither scale showed any relationship with the propensity for state reinvestment in any of the 4 trials.

Working Memory - Performance

Both scales showed a significant relationship with post Δ scores and a high correlation coefficient with the anxiety Δ value. This suggests that the higher your WM capacity, the better you perform under pressure when reinvestment is limited. It also points toward a positive effect for high WM groups and the intervention.

		WM_{recall}	$WM_{process}$
Post Δ Score	Correlation coefficient	.53*	.49*
	Sig. (2 tailed	.02	.037
Anxiety Δ Score	Correlation coefficient	.43	.54*
	Sig. (2 tailed	.075	.021

Table 8.3. * = Significant ($p < .05$). Coefficients between working memory and performance.

Follow up analysis showed a noteworthy effect of $WM_{process}$ group on performance between pre and post anxiety trials $F(1,16) = .382$, $p = .068$.

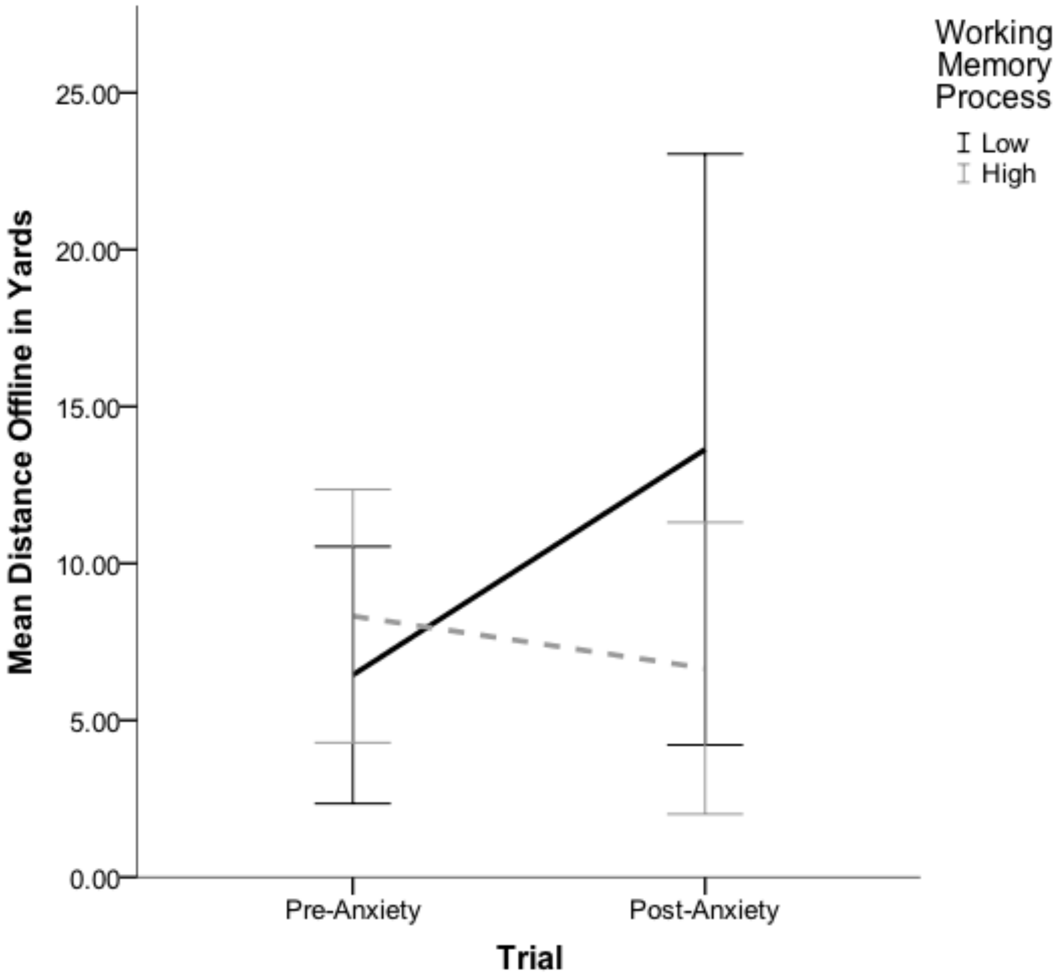

Figure 8.7. Error Bars: 95% CI. Performance by high and low $WM_{process}$ groups in pre and post anxiety trials. The graph shows the low $WM_{process}$ group having a negative reaction to the intervention while the high $WM_{process}$ group improve in shot accuracy.

Working Memory – Reinvestment

There were no significant relationships between the working memory scales and trait reinvestment.

Reinvestment - Performance

There was a negative relationship between reinvestment and performance in trial 2_{anx}, r = 40 , p = .056. This was notably, not the case in trial 4_{anx}, r = .18 , p = .42.

There was also a negative relationship between reinvestment levels in both pre trails and the performance difference between baseline and anxiety trials in the pre conditions, trial 1_{base}, r = -.40, p = .059, trial 2_{anx}, r = -.49 , p = .018.

Discussion

The aim of this study was to examine the relationship between the cognitive traits of short-term memory and working memory capacity with conscious processing and full golf swing performance. Taking such an individualistic approach to automaticity is unique in itself but the introduction of short-term and working memory measures, as a possible factor in conscious processing, is a novel and long overdue angle. As with Chapters 4-7 the complex nature of the golf swing also presents new territory for studies in reinvestment and automaticity.

The main findings indicate that neither STM nor WM showed any relationship with the propensity for reinvestment in baseline conditions. However, true to our initial hypothesis, there is an effect differential of reinvestment that is dependent upon an individual’s short-term memory and working memory capacity.

A positive correlation was reported between short-term memory and performance during in trial 2_{anx}, where overall state reinvestment was raised. However, this was not repeated in the post-intervention anxiety trial (trial 4_{anxI}) due to the reduction in conscious processing. This leads us to suggest that STM plays a role in conscious processing and that, counter to reinvestment theory, some conscious processing is helpful in coping with anxiety within the limitation of STM capacity.

Meanwhile working memory seems to be a dividing factor when reinvestment is limited as in the post intervention trials. The difference between anxiety trials for WMC indicated that performance in low WMC group declined when reinvestment was limited. We interpret from this that conscious control has a major contribution from STM. When this is limited via a temporal restriction, working memory takes a more prominent role. In essence, the temporal restriction devolves control from STM to WM.

Short-Term Memory

There was a positive relationship reported between STM and performance under pressure. It is noteworthy that this is due to an improvement in shot accuracy of the high STM group in the anxiety trials. Critically, this effect was less so when reinvestment was limited in trial 4. This points towards a positive role of STM in movement production under pressure. The role of STM in the capacity models of WM (Baddeley, 2007) is as a temporary storage mechanism only and therefore should not affect conscious processing during the golf swing. We predicted that any reported relationship between STM and performance would point more toward the LT-WM theory where STM also functions in accessing information from LT-WM.

This is further corroborated by the negative relationship reported between reinvestment and STM in post trials. This indicates that the temporal restriction has more impact on high STM individuals than the low STM group, implying a difference in processing type between the two groups.

An alternative hypothesis is that STM plays an active part of reinvestment. In which case, these results also could shed a new light on the reinvestment theory. According to which, during pressure conditions, conscious processing is typically increased to a detrimental effect on performance. This is based on the conscious control of movement causing a breakdown in the previously higher level processing of movement stored in proceduralized memory. However, the correlation between STM and performance reported in this study, could point towards a positive effect of conscious processing with capacity being a contributing factor. This is more in line with Attentional Threshold Hypothesis (Gucciardi and Dimmock, 2008, Mullen and Hardy, 2000b) and Attentional Control Theory (ACT, Eysenck et al., 2007a) explanations for performance effects under pressure (discussed in chapter 9). In these models, conscious processing is a capacity issue that leaves a degraded attention on task relevant stimuli. In which case, the high STM group will simply have more available capacity to deal with the extra cognitive load created in the anxiety condition.

Working Memory

In keeping with the findings of Buszard et al. (2013, Study 2), no correlation between WMC and propensity for reinvestment (CMP) was reported. The positive relationship between WM and performance changes between pre and post-intervention anxiety trials could be explained as the effect of the high working memory capacity group becoming too reliant on declarative knowledge processing and being prone to reinvestment (Beilock, 2011, Beilock and Carr, 2005). In this model, the improvement in trial 4_{anxI} would be explained by the restriction of such processing to a more workable level. This however, cannot be the case in the current study, as the high WM group did not actually improve in trial 4_{anxI}. It was the low WM group that got worse in this condition that led to the positive correlation. This would imply a more positive role for WM that is supportive of the attention perspective account of WMC (Engle, 2002, Wood et al., 2015). Since reinvestment across the sample was limited post intervention, we have to surmise that WM is potentially less affected by the temporal restriction and therefore still able to play a role in consciously controlling the movement. This hypothesis is consistent with a study by Laborde et al. (2015) that showed a debilitative effect of pressure on WM processes linked to performance. Another possibility is that when reinvestment is limited in the post trials, conscious control of the movement is reduced but working memory still plays a role in movement production. Access to domain specific information in LTM or motor regions of the brain could be mediated through WM. This would be somewhat consistent with LT-WM theory where a distinction between LT-WM and ST-WM is made. A third explanation, as put forward by Buszard et al. (2013), is that WM is linked to the ability to inhibit conscious control during shot execution. Related to this study, the low WMC group are still ineffectively trying to consciously control their actions during the temporal restriction. The high WMC group are able to inhibit conscious control and allow a more implicit mode of movement control.

Overall Reinvestment - Performance

The overall effect of reinvestment was consistent with the CPH. We observed a negative relationship between reinvestment and performance under pressure in the pre trials. This however, wasn’t alleviated by simply reducing reinvestment, as evidenced in the post trials. There were no overall intervention effects on performance. The implications of these results could be viewed that in general, reinvestment is debilitating but simply limiting it is not an effective solution.

It is notable that, had we viewed reinvestment across the group then we would have seen results that support the CPH. However, when more individual factors were measured, conscious processing appeared to affect people in different ways.

Task focus needs to be refined in a way that is harmonious with the individual's cognitive make up.

We recognise two main limitations of this study. Firstly, the WM capacity model views WM as a domain general construct that can be measured accurately with instruments such as the AWMC. However, LT-WM explains WM as domain specific, in which case, the accuracy of the AWMC would be affected by reading and numeracy skills. Future research needs to take into account the application of domain general instruments and aim to measure the more domain specific sub-skills. Secondly, there is some doubt in the absolute distinction between measures of STM and WMC. Previous studies (Colom et al., 2008, Unsworth and Engle, 2007, Unsworth and Spillers, 2010) have highlighted the difficulty distinguishing accurately between STM (as measured by simple spans) and WMC (as measured by complex spans). Unsworth and Spillers (2010) state that the two tests essentially measure the same thing. Future work needs to be careful in making clear definitions based on these tests and could consider using only the WMC sub-scale. In this study we recognize this limitation and offer an alternative hypothesis based on the two sub-scales being a broad measure of WMC only. In which case, we see WMC having a positive effect on performance under anxiety trials and during post trials. This suggests a positive role of WMC during the golf swing. This role is either in aiding conscious control, which would be consistent with the literature but create a problem for the reinvestment theory. Alternatively, the role of WM could be to access procedural memory out of our awareness. This is linked to LT-WM theory with the ability to inhibit conscious control as a function of WM (Buszard et al., 2013). Thirdly, the positive effects of WMC are consistent with the controlled attention perspective where WM is attributed to maintaining task focus and suppressing interference. This account is in-line with the ACT (Eysenck et al., 2007b) where effects of pressure are related to attentional resources.

Although the alternatives are not to be ruled out and may not be entirely exclusive to each other, we favour our first interpretation. WMC facilitates conscious control of movement via well-allocated attentional cues, as per our second hypothesis earlier in this chapter. This is represented in our results where high WMC correlated with performance in both anxiety trials. Under these conditions, attentional resources would have been challenged (Eysenck et al., 2007a) placing a premium on high WMC. During the temporal restriction, the performance of the low WMC group deteriorated through the dual effect of anxiety, consuming attentional resources, and the intervention not affording enough time to focus on conscious control strategies.

Conclusion

This study looked for correlation factors of performance, state reinvestment and the cognitive sub-skills of STM and WMC. The combined STM and WMC results point towards the co-existence of WMC and LT-WM. Under pressure, when reinvestment is most likely, ST-WM plays a key role in motor control by affording access to procedural memory and motor systems. When this function of ST-WM is limited then access to LT-WM is also interrupted, thus a heightened importance is placed on WMC.

This study also provides additional evidence of individual differences in cognitive processes and strategies underlying working memory and motor performance. This is likely to be heavily influenced by brain plasticity (Boyden et al., 2004, Dayan and Cohen, 2011, Walker and Stickgold, 2006) and is in line with the Embodied Approach of Cognition (Moreau, 2012, 2013) where an interrelated dependence exists between conceptual and sensorimotor processes.

While this study has provided new insights into the role of STM and WM in skilled performance, we recognize that this is only the second study of its type (Buszard et al., 2013) and that future research is required to better understand the cognitive processes underlying movement production. Further research is also required in relating the reinvestment theory to complex skills. We note that a negative relationship between reinvestment and performance was reported when a direct correlation was taken between the two factors across the whole group. However, when a more individualistic approach was taken, the utility of conscious control was not so clear-cut. It would seem that a multifarious account of reinvestment would be more appropriate if it is to be applied to complex skill.

CHAPTER 9

GENERAL DISCUSSION

Aims

The fundamental aim of this work was to add insight into the effect of reinvestment by elite level golfers executing the full swing. To this end, 3 key areas were explored: Firstly, the effect of limiting reinvestment on performance. Secondly, the performance effect of practice under reduced reinvestment conditions and finally, the individual trait factors that may interact with the propensity to and the value of conscious control during the golf swing.

The Experimental Progression

Phase 1: The effect of limiting reinvestment on full golf swing performance.

The experiments carried out in Chapters 4-6 examined the effect that limiting reinvestment has on full golf swing performance. Conscious control of movement was restricted in both baseline and anxiety conditions via the use of a temporal restriction (Chapter 4). In Chapter 5 we further investigated the effect that time taken in the execution stage has on reinvestment levels; and Chapter 6 looked at the reinvestment and performance effects of a learning period of practice under a reduced reinvestment condition.

In all 3 of these experiments, the effect of a temporal restriction on full golf swing performance was unclear as neither shot distance nor accuracy were affected in either baseline or anxiety conditions. We suggest that the null result was due to high individual variance in reaction to the intervention.

Before looking deeper at other factors that may have interacted with our intervention, it was of key importance to investigate any relationship between time taken in shot execution and levels of reinvestment. Chapter 5 explored 3 different temporal restrictions in line with this aim and also examined any performance effect. The results showed a relationship between the time taken in shot execution and the amount of reinvestment reported. This pattern was non-linear with the shortest time corridor showing significantly less conscious input than the middle or long time conditions. It was extrapolated from these results that reinvestment is limited under a certain time threshold but above this threshold (5 seconds), additional time taken does not necessarily mean more reinvestment. Given that reinvestment was successfully restricted in the short time condition, in accordance with the CPH, we would have expected some level of performance enhancement in these trials. This proved not to be the case with no performance effect being reported on either a straight trial-wise comparison or the difference between baseline and anxiety conditions. Having now shown that the temporal restriction effectively limits reinvestment, the performance results of this study cast doubt over the efficacy of the CPH in relation to complex motor skills and begged the question; do complex skills require some level of executive control?

Chapter 6 explored the reinvestment and performance effects of practicing under a temporal restriction. This design also aimed to equalize any possible interference in the previous studies, caused by the harsh nature of being forced into a temporal restriction. To this end, the general procedure (Chapter 3) was repeated twice over with a 6-week learning period between testing. Once again, reinvestment was significantly limited during all temporally restricted trials. No performance results were shown either within testing blocks or across the 6-week intervention. This suggests that practicing under restricted conscious control conditions does not necessarily lead to increased automaticity.

The implication from chapters 1-3 is that a temporal restriction is effective in limiting reinvestment but that performance is not affected, somewhat contradicting the CPH and making this an ineffective intervention for resilience under pressure.

We further questioned the automaticity of complex skills and suggested that for some people, a certain level of conscious control is required. Therefore, we utilized a more individualistic approach going forward.

Phase 2: The relationship between individual trait factors and the propensity to, and the effect of, conscious control during the golf swing.

Chapters 7 and 8 examined the relationship between the trait factors of general learning style, verbaliser-visualiser learning style, (Chapter 7) and the capacity of short-term memory and working memory (Chapter 8) on the propensity for reinvestment and the performance effect of conscious control.

In Chapter 7 the Learning Style Questionnaire showed a negative relationship between theorists and performance in the anxiety trial but no other correlations were reported.

The Verbaliser-Visualiser scale showed superior performance under pressure for high verbalisers, which was then negated when conscious control was restricted. Visualisers reported improved results in the post anxiety condition in comparison to the pre anxiety trail, indicating a positive reaction to the intervention.

This was a key differential in the effect of the temporal restriction. From this, we suggested that verbalisers require some level of executive control while visualisers benefitted from a reduced amount of verbal processing, allowing them a more fluid visual processing type. Notably, in this model the modality of processing is a key differential and thus moves us away from a blanket approach to whether one should or should not think about technique during execution.

In Chapter 8 additional trait factors that may influence reinvestment and task performance were examined with further measures of short-term memory (STM) and working memory (WM). There was a significant positive relationship reported between STM and performance during the pre-anxiety condition but significantly, this was negated in the post trials. The WM results showed a positive correlation with shot accuracy in the post versus pre anxiety trial comparison. This was interpreted to imply that the intervention was more suited to the high WM group who remained stable in the post trials while the low WM group deteriorated. From these results, we deduced that STM and WM may play a key role in movement production. This may be to facilitate conscious processing via information storage and processing or possibly as part of an underlying process such as the allocation of attention (Engle, 2002) or retrieval of information from LTM (Ericsson and Kintsch, 1995). Together, the findings of chapters 7 and 8 point toward individual trait factors that influence the role of reinvestment in relation to a complex motor skill. We surmise from this that it is of limited use to approach the subject of automaticity as a 'one size fits all' construct. The evidence from experimental chapters 4-8 implies that a more fluid account of attentional focus is required.

Theoretical Implications

Three key theoretical positions were evident through this thesis; (1) the utility of conscious control in complex motor skills, (2) related individual trait factors and (3) the efficacy of temporal restriction as an optimal performance intervention. These three concepts are discussed separately in the following section.

The Utility of Conscious Control in Complex Motor Skills

The prevalent body of research into conscious processing during motor skills has come from the ‘self-focus’ theories (L. Beilock, 2002, Masters, 1992) which were brought together by Masters (1992) under the umbrella term ‘reinvestment’. Consistent with Master’s (1992) conscious processing hypothesis, reinvestment states that the conscious control of a movement causes a breakdown in the procedural/unconscious processes that better serve movement production. Prior to this dissertation, reinvestment research has been criticized for being limited to simple or contrived tasks (Winter et al., 2014) and has rarely been carried out on a skill as complex as the full golf swing. Throughout this thesis we have viewed our results against the theoretical position of reinvestment and have found little evidence to suggest its universal relevance to a task as complex and varied as the golf swing. All 5 experiments (Chapters 4-8) involved the testing of elite golfers under baseline and pressure conditions and with a temporal restriction that successfully reduced reinvestment. Within the whole thesis there was little evidence of a negative reinvestment effect on performance or that reducing reinvestment would aid performance. This leads us to propose alternative hypotheses. Firstly, we take into account the potential effect differential between individuals (discussed later in this chapter) In addition, we consider the notion that for skills which are self paced and as complex as the golf swing, a certain level of executive control is required for optimal performance. This is disparate to reinvestment theory that states that “reinvestment is more disruptive to complex tasks with many components that must be coordinated, than simple tasks that are easily proceduralised” (Masters and Maxwell, 2008a, p.164). Our explanation has backing from a number of recent studies (Ericsson et al., 2007, Geeves et al., 2013, Jenkins, 2007, Mullen and Hardy, 2010, Sutton et al., 2011, Winter et al., 2014) that support some level of ‘facilitative reinvestment’. This progression of thought has gained enough support to inspire an ‘emerging inter-disciplinary movement known as ‘somaesthetics’ (Toner and Moran, 2015, p.111) which is ‘to investigate the role of consciousness in body awareness and skill learning’ (Shusterman, 2009, 2011).

Within this field, Toner and Moran (2015) see a transient yet positive role for conscious control and like Ericsson’s model of experience and deliberate practice (Ericsson, 2006a, Williams and Ericsson, 2005), advocate that somatic awareness is required in the process of technical refinement. Moreover, Toner and Moran (2015) also highlight the potential fragility of habits and offer conscious control as an effective means to control a movement when the habitual pattern is somewhat dysfunctional. The challenge being to appropriately switch between reflective (internal foci) and

unreflective (external foci) in such a way as to refine and best perform our procedural movement patterns. This stems from work by Shusterman (2009, 2011) in which the concept of someasthetic reflection is introduced as being ‘conscious of our own (body) consciousness’ (Shusterman, 2009, p.134)
More directly relating to golf, the concept of useful reinvestment or ‘mindedness’ (Sutton et al., 2011) is lent further support by studies of elite golfers that found evidence of conscious control (Bernier et al., 2011, Jenkins, 2007, Toner and Moran, 2011). Toner and Moran (2011) found elite level golfers to have between 1 and 2 technique related thoughts during the stroke. Furthermore, they also reported no detrimental performance effects when the putting stroke was consciously altered during execution. In naturalistic studies of elite golfers, Jenkins (2007) interviewed professionals playing on the European Tour (1989-1991) and found that all 113 golfers that were interviewed, reported using swing keys on the course and in practice. Meanwhile, Bernier et al. (2011) showed elite level golfer’s focus to be transient in nature and adapted to the task and context.
The naturalistic studies are not, in themselves definitive evidence of the efficacy of conscious control over automatic processing, not least since we don’t know the qualitative nature of the ‘swing keys’, but for such large numbers of elite golfers to report the use of conscious control, something is drawing them to reinvest. Add this to the results of recent experimental research (Carson et al., 2013, MacPherson et al., 2008, Toner and Moran, 2011) and the efficacy of the reinvestment theory becomes less convincing.
In summary of our position on constructive reinvestment, we fully recognize the debilitating effects of ‘over reinvestment’ but are less dichotic in our

stance, especially when it refers to skills with the complexity of the full golf swing. Our position is more in line with that of Toner and Moran (2011, 2014, 2015) in recognizing the central challenge of knowing when and what to focus our conscious attention on. In view of the body of evidence above we align our thinking with Ericsson (2007) who claims complete automaticity is only likely for simple and ‘everyday’ actions where the refinement of which serves no greater purpose. For competitive and complex skills such as the golf swing, where continued improvement is of a premium, the current conception of automaticity may be misleading. In a recent paper (Toner et al., 2015) a model of skill development is presented that doesn’t ever realize complete automaticity but a switch of attention occurs from lower order (mechanics of movement) to higher order (strategic) elements. When this model is viewed alongside the notion that expert performers benefit from focusing on key ‘effectors’ of the movement (Carson and Collins, 2015) a more hierarchical (Schack and Mechsner, 2006) account of automaticity seems appropriate. This would certainly best serve practitioners in selecting the most appropriate interventions where, currently, the prevailing advice from the literature (don’t think about your movement) is too simplistic to serve performance as a whole.

Individual Trait Factors

In accordance with this position, we also advocate that the utility of reinvestment is a much more individualistic concept than has previously been proposed. A key feature of reinvestment theory is that the propensity to consciously control movement is personality related, as predicated with the use of the reinvestment scale (Masters et al., 1993a). The results from

Chapter 7 showed no correlation between the subscales of the LSQ and VVQ questionnaires with the propensity to reinvest.

A recent study Buszard (2014) did add to the personality dependent position by indicating a positive relationship between WM in children and the propensity for conscious control during task execution. This result was not repeated in our study of elite golfers, as there was no relationship between WM and levels of reinvestment. STM however, did correlate with reinvestment propensity. There was no relationship between STM and reinvestment in the pre trials but we did observe a negative relationship in the temporally restricted trials. This led us to surmise that the propensity to reinvest procedural knowledge is not necessarily influenced by verbal short-term memory capacity but the qualitative make up of reinvestment is affected by this trait; as indicated by the difference in the effect of the temporal restriction on the high and low STM groups.

While reinvestment theory describes a trait based propensity for conscious control, the effect of reinvestment described within the CPH is invariable. The results from this thesis would indicate that the utility of conscious control may also be trait dependent. The traits of verbal/visual processing preference (Chapter 7), STM and WMC (Chapter 8) all reported significant performance differentials that may indicate a trait based effect of conscious control. In Chapter 7 high verbaliser's performance deteriorated when reinvestment was limited, while visualisers performed better in the post trials. As this is the first study of its kind with a number of unique aspects, I am cautious about extrapolating too much from these results. It is however, tentatively hypothesized that given that reinvestment is verbal in nature (Buszard, 2014), the verbalisers require some level of conscious control but the visualisers, that performed better when reinvestment was limited, did so due to a lack of verbal interference to their more fluid visual processes.

In the cognitive science field there is yet a framework that would comfortably describe the findings of this thesis but a more philosophical approach does have an accord. In the theory of Applying Intelligence to Reflexes (AIR, Sutton et al., 2011) there is room for individual differences in motor control. AIR recognizes that some people will adopt a more ‘top down’ (cognitive processing) method, whilst others may utilize a ‘bottom up’ (embodied control). There is also a less dichotic view on conscious control that better allows for task perturbations. To this end, experts ‘counteract automaticity’ (Ericsson, 2003, 2007) (cited in Toner and Moran, 2011) that would otherwise limit the capability to make situational adjustments.

Whilst more research is required of an individualistic nature, we can draw from this study that it is not only the propensity to reinvest that is personality related but the utility of reinvestment is also affected by trait characteristics.

3. The Efficacy of Temporal Restriction as an Optimal Performance Intervention

Throughout all 5 experimental chapters (Chapters 4-8), there was no collective improvement in performance when reinvestment was limited. Most notably, chapter 3 featured a 6-week practice interval for the accustomisation to low reinvestment and the nuances of a temporal restriction. Even so, no performance effects were observed. This leads us to believe that some individuals require a level conscious control to perform optimally. Alternatively, if reinvestment is indeed universally debilitating then simply restricting working memory input in this manner is not the answer. Although temporal restrictions have shown to be effective in putting (Beilock et al., 2004a, Bell et al., 2013), the complexities of the full swing require a more subtle intervention to focus the mind. We suggest that future work in this area incorporates the 'expert-performance approach' (Ericsson et al., 2007) that recognizes the explicit nature of golf's pedagogy (Kelly, 1969) and an expert's on-going quest for refinement (Carson et al., 2013). Intervention based approaches to automaticity and debilitating effects of conscious control should look toward attentional focus strategies (McKay and Wulf, 2012, Wulf, 2007) and mindfulness based approaches to the subject (Gardner and Moore, 2004, 2012).

That said, we did see a favorable reaction to the intervention from high visualisers, indicating the temporal restriction was successful at reducing interference from verbal cognitive input. It seems that the efficacy of the intervention will be affected by a number of key factors, notably, the stage of learning/refinement that the player is presently at and their personal cognitive control architecture. Once again, a multitude of factors must mean that one size dos not fit all.

Methodological implications

It is common in reinvestment research to utilize either a dual task scenario or use false explicit focus conditions (Lam et al., 2010a, Maddox et al., 1999b, Masters, 1992, McKay and Wulf, 2012, Mullen and Hardy, 2010, Mullen et al., 2007). The dual task procedure (see Chapter 2) forcibly overloads working memory and has been criticized for its lack of ‘real world’ application (Winter et al., 2014). The false explicit condition involves a prescribed mechanical thought being imposed for the purpose of attaining an overly dichotic (Peh et al., 2010) comparison to the implicit conditions that these designs test against. Both of these prevalent methods are misrepresentative of the performer’s organic cognitive strategy. The current study has overcome this gap in the research-performance spectrum by allowing the performers to control movement in their normal manner before a measure of state reinvestment was taken after each trial (Chapters 5-8). While this method is less invasive and has afforded us a more ecological measure of conscious control, it doesn’t provide any qualitative data. Future research is needed to understand the qualitative nature of conscious control.

It is also noted that the state reinvestment instrument used was adapted from the movement specific reinvestment scale and only represents what Masters termed ‘conscious motor processing’ (CMP). This form of reinvestment is characterized by the conscious monitoring of mechanical movements. The full MSRS also includes a separate measure of ‘movement self-consciousness’ (M-SC), which relates to self-referential thinking around one’s movement. Had we used both measures of the MSRS, we may have seen some results that were more in-line with reinvestment theory. Furthermore, administering the MSRS before trials may have given us further insights into trait reinvestment and the possibly of supporting the MSRS as a predictor of choking under pressure.

In Chapter 7, the VVQ was used as a measure of visual or verbal trait disposition. Like any 'trait' measure, the scale is criticized for its permanence (Antonietti and Giorgetti, 1998). It has also been highlighted that the VVQ is a very broad measure that lacks internal validly and that the results of the scale do not differentiate between different types of visual processing (Blazhenkova and Kozhevnikov, 2009, Kollöffel, 2012, Kozhevnikov et al., 2002, Kozhevnikov et al., 2005) or the further diversification of cognitive ability, style and preference (Mayer and Massa, 2003).

Since it is a bipolar scale, we were unable to show internal reliability in Chapter 7. The VVQ has previously been reported as having very high test re-test reliability, r = 0.91 (Richardson, 1977), and has been shown to be an accurate measure of verbal processing (Green and Schroeder, 1990). Given that CMP reinvestment is regarded as a verbal process (Buszard, 2014) and that the VVQ is considered to be the primary instrument used (Kozhevnikov et al., 2002, Kozhevnikov et al., 2005, Mayer and Massa, 2003) for testing the verbaliser/visualiser dimension, we are confident that the VVQ fits the requirements of this study. It is however, recommended that future research in this area use the revised version of the VVQ (Kirby et al., 1988) which no longer uses a uni-dimension of verbalizer-visualizer but recognizes three separate dimensions of verbal, visual and dream cognition. For research in this domain, it is recommended that as with other studies (Mendelson and Thorson, 2004), the dream scale is omitted leaving the separate measures of verbal and visual learning styles.

In Chapter 8 the Automated Working Memory Assessment (AWMA, Alloway, 2007) was used to measure verbal short-term memory and working memory. We are confident in our choice of instrument, as used in similar studies (Buszard et al., 2013) but recognize the difficulty in distinguishing between short-term memory and working memory. The AWMA uses simple span tasks to measure STM and complex span tasks for WM. The tasks are distinguishable by the additional processing requirements present in the complex span test. Unsworth and Spillers (2010) contest that the simple span task is not effective at measuring STM exclusively. If this is indeed the case then the STM scale used in Chapter 8 actually provides a further measure of WM. This is recognized in the chapter and an alternative hypothesis is given. A pertinent feature of this thesis is the mixed levels of somatic anxiety reported throughout. In interpretation of this facet we conclude that to consistently induce significant levels of somatic anxiety would require a greater degree of mediators than the combination of social evaluation, competition and rewards (Baumeister and Showers, 1986, cited in Cooke et al, 2014) used in this study. That said, on the basis that this is a study of cognitive effects (conscious processing) we are satisfied that the anxiety manipulation was sufficient. This is evidenced by the presence of significant levels of cognitive anxiety throughout the experimental chapters.

This did not however, lead to performance decrements. In fact, we observed improved shot accuracy during some of the anxiety trials (Chapters 7 and 8). This could be attributed to a number of factors, not least that elite level golfers are frequently exposed to pressure, which may lead to a level of resilience. We must also consider that the antecedents of pressure are likely to be very individualistic with the effects of audience, significant other, consequence and monetary rewards creating an effect differential within a group (Markman et al., 2006, Tanaka and Sekiya, 2010, Tanaka and Sekiya, 2011).
Performance gains under pressure were also reported in a similar design by Buszard (2014) who questioned the efficacy of a monetary incentive. We know from the CSAI-2R directional scale that all anxiety was perceived to be debilitative and previous studies have shown monetary incentive to be effective (Gucciardi and Dimmock, 2008, Mullen et al., 2005) so we therefore, remain confident in this aspect of the design. Buszard (2014) also cited a 'lack of counterbalancing' in the way the anxiety condition always followed the baseline trials, to be a possible design flaw. We view this to be a likely cause of the null performance results due to a disparity in activation and motivation (Mellalieu et al., 2006, Swann et al., 2012). If this were to be the case then participants would have been less than optimally aroused (Jackson et al., 2001) in the baseline trials and only concentrated fully during anxiety conditions. We propose that future designs involve low and high anxiety conditions and avoid the obvious 'no consequence' baseline condition.
In the light of a recent study of the performance effects of pressure (Cooke et al., 2011), the null effect witnessed throughout this study should not be entirely unexpected. In a study of elite golfers the authors found a quadratic

effect of pressure on performance whereby putting accuracy improved on the baseline measure during a moderate pressure condition and only declined in the high pressure trials. Cooke et al. (2011) cited the processing efficiency theory (Eysenck and Calvo, 1992) to describe the non-linear effects of pressure on performance but notably, called for studies that measure attentional resources to be able to corroborate this position. The PET (Eysenck and Calvo, 1992) views the effects of pressure as potentially facilitative through the process of recruiting further attentional resources. The Cooke et al. (2011) study was the first to demonstrate this effect by showing increased effort and anxiety to be in-line with positive performance effects. Only when attentional resources reach threshold in the high anxiety trials did the pressure prove to be debilitative on performance. In addition to anxiety, effort and performance, the Cooke et al. (2011) study also measured conscious motor processing with an adapted subscale taken from the MSRS. This too formed a quadratic relationship with pressure. Contrary to reinvestment theory, conscious processing decreased under moderate pressure and only retuned to baseline levels during high pressure trials.

The findings from the Cooke et al. (2011) study show a level of consistency with the anxiety, state reinvestment and performance results witnessed throughout the experimental chapters (Chapters 4-8).

Although this thesis is not specifically aimed at comparing the ‘choking’ accounts of the PET and reinvestment theory, the results do clearly favour the PET and related Attentional Control Theory (Eysenck et al., 2007b).

Finally, it is important that we acknowledge the difficulty in showing meaningful performance results from full golf swing data. The inherent variance of full 5 iron shots, even with elite level golfers, makes for an imperfect and noisy environment to collect data. Future research utilizing a full swing should consider using a pitching wedge in the aim of reducing shot variance from the well-struck shots. Separately, substantial miss-hits are uncommon with highly skilled golfers but they do happen and the effect of such outliers would negate any overall patterns that may otherwise emerge. For this reason, in this study mis-hit shots were controlled by discounting any ball that did not carry 120 yards for men and 90 yards for women. The authors concede that this is not an ideal experimental design and that mis-hits are a part of the game. Moreover, the qualifying distance controlled for is fairly arbitrary and leads to an undesirably dichotic condition.

Practical Applications

Coaching practice takes a lead from empirical research (Carson and Collins, 2011) and as such, the standard advice from psychologists working in the game is that golfers should ‘not think about their swing’ during game play (Gallwey, 1979, Rotella, 1995). From the evidence in this thesis and concurrent with AIR (Sutton et al., 2011) and MESH (Christensen et al., 2015) theories , it seems likely that people control movement production in different ways and that forcibly restricting reinvestment is too blunt an approach when viewed against more organic interventions (Aherne et al., 2011, Gardner and Moore, 2004, 2012).

Firstly, we recognize the special demands of individual skills. For example, putting studies for skilled golfers have repeatedly shown optimal performance to occur in the absence of conscious control (Beilock et al., 2004a). While we would hesitate to label putting as ‘simple’, the mechanical demands are outweighed by perceptual/cognitive skills. As such, lower order elements of stroke control need to take a lesser priority of focus than the higher order elements of environment and strategy (Toner et al., 2015). In this instance, we are in accordance with the extant literature. However, more complex skills such as the full swing may require a level of cognitive control that guides other, more automatic elements of the movement (Sutton, 2015). It should be noted at this stage that not all types of conscious processing have been shown to lead to the de-automization of skill. Somatic awareness has been viewed as facilitative to performance (Nyberg, 2014) and coaches should be encouraged to develop the phenomenon through constraints led approaches and parameterization (Davids et al., 2008). With regard to other forms of facilitative conscious processing, Carson and Collins (2015) question the literature for not portraying a movement that is being effectively and explicitly controlled in practice. The rationale being that if an ‘internal’ focus of attention is familiar then it will not necessarily lead to the breakdown of a proceduralized skill back into smaller units (Maurer and Munzert, 2013). The message for practitioners in this instance would seem to be that it if a movement is effectively being controlled via conscious processing then there may not be any benefit in forcing a change to more a more automatic process. This is corroborated by the results of our intervention throughout this thesis.

That said, in a sport that has a high reliance on explicit coaching methods (Carson et al., 2013) there remains a premium on avoiding cognitive overload during performance and enhancing the automization of skill through practice. The most direct approach to this objective, is to completely restrict the explicit rules built up during acquisition (Rendell et al., 2011). Although implicit learning has been shown to have benefits in empirical testing (Mullen et al., 2007), the application of such an approach in a coaching setting is almost impossible over the long-term development of a golfer (Carson and Collins, 2014, 2015, Winter et al., 2014). That leaves the question of best practice for coaches with regard to skill refinement and automaticity (Rendell et al., 2011). Analogy learning has been recommended (Lam et al., 2009) as an effective approach in which the intervention conveys a rich volume of task related information while avoiding cognitive overload. I recognize that analogy learning may not contain enough depth of information to facilitate all facets of long term refinement (Koedijker et al., 2007, Lam et al., 2009), and thus would never rule out a more explicit approach if required. That said, efforts need to be made to reduce cognitive load and organize movement so that there are less individual procedural parts (Masters et al., 1993b) to the encoding of the pattern.

The mechanisms underlying analogy learning are firstly, the relatedness of the new intended movement to an already learned and familiar pattern (Liao and Masters, 2001), and secondly, the holistic nature of the instruction that avoids focus on ‘skill parts’. This second mechanism does not necessarily need to form an analogy but it should be the intention of the coach to, where possible, keep instruction away from ‘skill parts’ and have the performer focus on holistic cues (MacPherson et al., 2008).

In the event of technique change requiring explicit instruction (Carson et al., 2013) then the practitioner needs to first of all understand the relatedness of this change to the system as a whole (Kelso, 1997), and make such long-term interventions during ‘off season’ periods. Through a competitive season, skill refinement should be crafted via holistic and temporal cues (MacPherson et al., 2009), key movement effectors (Carson and Collins, 2015) and higher order elements of movement control (Toner et al., 2015). The latter two of which, are likely to induce an external focus of attention (Wulf, 2013).

Where there has been a build up of explicit information and performance decrements are observed, the temporal restriction could prove to be a useful intervention as a coaching tool to moderate conscious control. Used on a regular basis, the temporal restriction would deepen the players’ awareness of their own parameters for executive control and improve their somatic awareness (Toner and Moran, 2015). In this manner, the effects of explicit learning could be moderated. The intervention could also be effective in aiding extreme reinvestors that show obvious negative performance effects from over thinking. In this scenario, the intervention would be the first step before more subtle adjustments/discoveries are made to bring the level of conscious control to an optimal level (Toner and Moran, 2011).

Future Directions

It is clear that the dichotic approach to automaticity that has dominated the literature thus far is not robust enough to describe the results found in this thesis. We propose several key aspects to be considered in future study. Further research into automaticity should distinguish between simple and complex tasks on the basis that the results from previous putting studies (Beilock and Gray, 2012, Mullen and Hardy, 2010, Toner and Moran, 2011), that support the reinvestment theory, were not replicated in these studies. We also contend that future research into automaticity needs to be less dichotic. To this end, more qualitative and individualistic designs are required. Previous studies (Bell and Hardy, 2009a, MacPherson et al., 2008, Wulf, 2007) provide strong evidence that reinvestment effects differ across an array of attentional foci. Factors of cognitive load (de Jong, 2010, Paas et al., 2004, Van Merrienboer and Ayres, 2005) and processing type (Bernier et al., 2011) may lead to new understandings.

The use of ‘think aloud’ (Schack, 2012, Toner and Moran, 2011) protocols would give a more phenomenological account of task focus and a potentially, deeper understanding of the effects of attention loci. In addition to this, the use of this methodology would also provide a more detailed quantitative measure of swing thoughts and the relationship between them. i.e the level of congruency and hierarchy of representations (Schack, 2004, Schack and Mechsner, 2006).

Just as recent studies have shown WM to be a factor in the way motor skills are learned (Buszard, 2014), the results of this thesis have indicated that people also control motor sequences differently. More studies that measure cognitive traits of personality, STM and WM are called for. It is likely that an interaction between qualitative trait factors will be observed and lead to a deeper understanding of conscious processing.

It has been highlighted that a key facet of expert performance is the process of constant refinement (Sutton et al., 2011). Furthermore, true automaticity leads to a state of ‘arrested development’ (Ericsson, 2007, Ericsson et al., 1993b, Ericsson et al., 2007). To this end, we recommend that future research into conscious control, differentiate the stage of the performer in relation to the learning cycle (Carson and Collins, 2015, Ericsson, 2006b, Fitts and Posner, 1967).

General Discussion/Concluding Remarks

The fundamental aims of this thesis were to examine the effect of conscious processing during full golf swing performance and in particular, the performance effects of reducing working memory input.

Over the course of the 5 experiments (Chapters 4-8) we have demonstrated mixed effects in relation to reinvestment theory. From this we deduce that the reinvestment effect for highly skilled golfers is based on a number of factors that make up an individual’s cognitive composition while executing the full swing. The performance area of automaticity needs further research based on a broader outlook. To this end, we point toward the conceptual positions of the ACT (Eysenck et al., 2007b), Mesh approach (Christensen et al., 2015) and LT-WM (Ericsson and Kintsch, 1995).

It would seem that a multifarious account of reinvestment would be more appropriate if it is to be applied to complex skills. Such a model would need to take into consideration the transient developmental phase of the skill (Carson and Collins, 2015, Fitts and Posner, 1967). A golfer undergoing swing enhancements will need to consciously control the pattern until such a time the new movement has been proceduralised. For such a diverse model to be accurate, a multitude of individual cognitive factors also needs to be taken into account. These would include neuro-plasticity, WMC, LT-WM, and various learning styles. Since this would seemingly create a convoluted and problematical approach to the problem, a more fluid account of task focus needs to be applied to complex motor skill performance.

LIST OF REFERENCES

Adams, J.A. (1971) A closed-loop theory of motor learning. **Journal of motor behavior**.

Aherne, C., Moran, A.P. and Lonsdale, C. (2011) The effect of mindfulness training on athletes' flow: an initial investigation. **Sport Psychologist***,* 25: (2): 177.

Akella, D. (2010) Learning together: Kolb's experiential theory and its application.

Alloway, T.P. (2007) "Automated Working Memory Assessment". Harcourt Assessment.

Alloway, T.P., Gathercole, S.E., Adams, A.M., et al. (2005) Working memory and phonological awareness as predictors of progress towards early learning goals at school entry. **British Journal of Developmental Psychology***,* 23: (3): 417-426.

Alloway, T.P., Gathercole, S.E., Kirkwood, H., et al. (2008) Evaluating the validity of the automated working memory assessment. **Educational Psychology***,* 28: (7): 725-734.

Allport, D.A. (1980) Attention and performance. **Cognitive psychology: New directions**, 112–153.

Allport, G. (1937) Personality: A psychological interpretation. **New York: Henry Holt**.

An, J., Wulf, G. and Kim, S. (2013) Increased carry distance and X-factor stretch in golf through an external focus of attention. **Journal of Motor Learning and Development**, 1: 2-11.

Anderson, J.R. (1982) Acquisition of cognitive skill. **Psychological review**, 89: (4): 369.

Anderson, J.R. (1992) Automaticity and the ACT* theory. **American Journal of Psychology**, 105: (2): 165-180.

Anderson, J.R. (1995) **Learning and memory: An integrated approach 1995**. New York: Wiley.

Anson, G., Elliott, D. and Davids, K. (2005) Information processing and constraints-based views of skill acquisition: divergent or complementary? **Motor control**, 9: (3).

Antonietti, A. and Giorgetti, M. (1998) The verbalizer-visualizer questionnaire: A review. **Perceptual and motor skills**, 86: (1): 227-239.

Atkinson, R.C. and Shiffrin, R.M. (1968) Human memory: A proposed system and its control processes. **Psychology of learning and motivation**, 2: 89-195.

Babiloni, C., Del Percio, C., Iacoboni, M., et al. (2008) Golf putt outcomes are predicted by sensorimotor cerebral EEG rhythms. **The Journal of physiology**, 586: (1): 131-139.

Baddeley, A. (1992) Working memory. **Science**, 255: (5044): 556-559.

Baddeley, A. (2000) The episodic buffer: a new component of working memory? **Trends Cogn Sci**, 4: (11): 417-423.

Baddeley, A. (2007) **Working memory, thought, and action**. Oxford University Press.

Baddeley, A. (2010) Working memory. **Current Biology**, 20: (4): R136-R140.

Baddeley, A. and Hitch, G. (1974) "Working memory: Advances in research and theory. The Psychology of learning and motivation (Vol. 8, pp. 47–49)". Academic Press.

Baddeley, A.D. (1966) The capacity for generating information by randomization. **The Quarterly journal of experimental psychology**, 18: (2): 119-129.

Baddeley, A.D. (1996) Exploring the central executive. **Quarterly Journal of Experimental Psychology**, 49: (A): 23.

Baddeley, A.D. and Hitch, G.J. (1994) Developments in the concept of working memory. **Neuropsychology**, 8: (4): 485.

Bargh, J.A. and Chartrand, T.L. (1999) The unbearable automaticity of being. **American psychologist**, 54: (7): 462.

Bargh, J.A., Chen, M. and Burrows, L. (1996) Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. **Journal of personality and social psychology**, 71: (2): 230.

Baumeister, J., Reinecke, K., Liesen, H., et al. (2008a) Cortical activity of skilled performance in a complex sports related motor task. **European journal of applied physiology**, 104: (4): 625-631.

Baumeister, J., Reinecke, K. and Weiss, M. (2008b) Changed cortical activity after anterior cruciate ligament reconstruction in a joint position paradigm: an EEG study. **Scandinavian journal of medicine & science in sports**, 18: (4): 473-484.

Baumeister, R. (1984) Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance. **Journal of personality and social psychology**, 46: (3): 610-620.

Baumeister, R.F. and Showers, C.J. (1986) A review of paradoxical performance effects: Choking under pressure in sports and mental tests. **European Journal of Social Psychology**, 16: (4): 361-383.

Beilock, S. (2011) **Choke: What the secrets of the brain reveal about getting it right when you have to**. Simon and Schuster.

Beilock, S., Bertenthal, B., McCoy, A., et al. (2004a) Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. **Psychon Bull Rev**, 11: (2): 373.

Beilock, S.L., Bertenthal, B.I., Hoerger, M., et al. (2008) When does haste make waste? Speed-accuracy tradeoff, skill level, and the tools of the trade. **Journal of Experimental Psychology: Applied**, 14: (4): 340.

Beilock, S.L., Bertenthal, B.I., McCoy, A.M., et al. (2004b) Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. **Psychon Bull Rev**, 11: (2): 373-379.

Beilock, S.L. and Carr, T.H. (2001) On the fragility of skilled performance: what governs choking under pressure? **J Exp Psychol Gen**, 130: (4): 701-725.

Beilock, S.L. and Carr, T.H. (2005) When High-Powered People Fail Working Memory and ‚ÄúChoking Under Pressure‚Äù in Math. **Psychological Science**, 16: (2): 101-105.

Beilock, S.L. and DeCaro, M.S. (2007) From poor performance to success under stress: working memory, strategy selection, and mathematical problem solving under pressure. **Journal of Experimental Psychology: Learning, Memory, and Cognition**, 33: (6): 983.

Beilock, S.L. and Gonso, S. (2008) Putting in the mind versus putting on the green: Expertise, performance time, and the linking of imagery and action. **The Quarterly journal of experimental psychology**, 61: (6): 920-932.

Beilock, S.L. and Gray, R. (2007) Why do athletes choke under pressure?

Beilock, S.L. and Gray, R. (2012) From attentional control to attentional spillover: A skill-level investigation of attention, movement, and performance outcomes. **Human Movement Science**.

Beilock, S.L. and Lyons, I.M. (2008) Expertise and the Mental Simulation of Action. **Handbook of Imagination and Mental Simulation***,* 21.

Beilock, S.L., Wierenga, S.A. and Carr, T.H. (2002) Expertise, attention, and memory in sensorimotor skill execution: Impact of novel task constraints on dual-task performance and episodic memory. **The Quarterly Journal of Experimental Psychology: Section A***,* 55: (4): 1211-1240.

Bell, J. and Hardy, J. (2009a) Effects of Attentional Focus on Skilled Performance in Golf. **Journal of Applied Sport Psychology***,* 21: (2): 163-177.

Bell, J.J. and Hardy, J. (2009b) Effects of attentional focus on skilled performance in golf. **Journal of Applied Sport Psychology***,* 21: (2): 163-177.

Bell, J.J., Mawn, L. and Poynor, R. (2013) Haste makes waste, but not for all: The speed-accuracy trade-off does not apply to neurotics. **Psychology of Sport and Exercise***,* 14: (6): 860-864.

Bennett, M., Plummer, A. and Morrice, P. (2009) **The Stack and Tilt Swing**. Gotham Books.

Bergsteiner, H. and Avery, G.C. (2014) The twin-cycle experiential learning model: reconceptualising Kolb's theory. **Studies in Continuing Education**, 36: (3): 257-274.

Bernardi, G., Ricciardi, E., Sani, L., et al. (2013) How Skill Expertise Shapes the Brain Functional Architecture: An fMRI Study of Visuo-Spatial and Motor Processing in Professional Racing-Car and Naïve Drivers. **PLoS One**, 8: (10): e77764.

Bernier, M., Codron, R., Thienot, E., et al. (2011) The Attentional Focus of Expert Golfers in Training and Competition: A Naturalistic Investigation. **Journal of Applied Sport Psychology**, 23: (3): 326-341.

Birrer, D., Röthlin, P. and Morgan, G. (2012) Mindfulness to enhance athletic performance: Theoretical considerations and possible impact mechanisms. **Mindfulness (N Y)**, 3: (3): 235-246.

Bläsing, B., Tenenbaum, G. and Schack, T. (2009) The cognitive structure of movements in classical dance. **Psychology of Sport and Exercise**, 10: (3): 350-360.

Blazhenkova, O. and Kozhevnikov, M. (2009) The new object‐spatial‐verbal cognitive style model: Theory and measurement. **Applied cognitive psychology**, 23: (5): 638-663.

Boutcher, S.H. (1990) The role of performance routines in sport. **Stress and performance in sport**, 231-245.

Boutcher, S.H. and Crews, D.J. (1987) The effect of a preshot attentional routine on a well-learned skill. **International Journal of Sport Psychology**.

Boutcher, S.H. and Rotella, R.J. (1987) A psychological skills educational program for closed-skill performance enhancement. **Sport Psychologist***,* 1.

Boyden, E.S., Katoh, A. and Raymond, J.L. (2004) Cerebellum-dependent learning: the role of multiple plasticity mechanisms. **Neuroscience***,* 27.

Broadbent, D.E., Cooper, P.F., FitzGerald, P., et al. (1982) The cognitive failures questionnaire (CFQ) and its correlates. **British Journal of Clinical Psychology***,* 21: (1): 1-16.

Buszard, T. (2014) Motor skill acquisition in childhood: Exploring the links between working memory, implicit learning and equipment modification. **PhD Thesis, Victoria University**.

Buszard, T., Farrow, D., Zhu, F.F., et al. (2013) Examining movement specific reinvestment and working memory capacity in adults and children. **International Journal of Sport Psychology***,* 44: (4): 351-366.

Campos, A., Lopez, A., Gonzalez, M.A., et al. (2004) Imagery factors in the Spanish version of the Verbalizer-Visualizer Questionnaire. **Psychol Rep***,* 94: (3 Pt 2): 1149-1154.

Cannonieri, G.C., Bonilha, L., Fernandes, P.T., et al. (2007) Practice and perfect: length of training and structural brain changes in experienced typists. **Neuroreport***,* 18: (10): 1063-1066.

Capizzi, M., Correa, Á. and Sanabria, D. (2013) Temporal orienting of attention is interfered by concurrent working memory updating. **Neuropsychologia**, 51: (2): 326-339.

Cappuccio, M.L. (2015) Introduction: when embodied cognition and sport psychology team-up. **Phenomenology and the Cognitive Sciences**, 1-13.

Carson, H.J. and Collins, D. (2011) Refining and regaining skills in fixation/diversification stage performers: The Five-A Model. **International Review of Sport and Exercise Psychology**, 4: (2): 146-167.

Carson, H.J. and Collins, D. (2014) Effective skill refinement: focusing on process to ensure outcome. **Central European Journal of Sport Sciences and Medicine**, 7: (3): 5-21.

Carson, H.J. and Collins, D. (2015) The fourth dimension: A motoric perspective on the anxiety–performance relationship. **International Review of Sport and Exercise Psychology**, 1-21.

Carson, H.J., Collins, D. and MacNamara, Á. (2013) Systems for technical refinement in experienced performers: The case from expert-level golf. **International Journal of Golf Science**.

Cassidy, S. (2004) Learning styles: An overview of theories, models, and measures. **Educational Psychology**, 24: (4): 419-444.

Cellini, N. and McDevitt, E.A. (2015) The Temporal Dynamics of Motor Memory across Wake and Sleep. **The Journal of Neuroscience**, 35: (35): 12085-12087.

Chandler, P. and Sweller, J. (1991) Cognitive load theory and the format of instruction. **Cognition and instruction***,* 8: (4): 293-332.

Chell (2005) Conscious Processing, Stress and Focus of Attention in Skilled Golfers. **Centre for Sport and Exercise Science**.

Chell, B.J., Graydon, J.K., Crowley, P.L., et al. (2003) Manipulated stress and dispositional reinvestment in a wall-volley task: an investigation into controlled processing. **Perceptual and motor skills***,* 97: (2): 435-448.

Cheng, W.-N.K., Hardy, L. and Markland, D. (2009) Toward a three-dimensional conceptualization of performance anxiety: Rationale and initial measurement development. **Psychology of Sport and Exercise***,* 10: (2): 271-278.

Chow, J.Y., Woo, M.T. and Koh, M. (2014) Effects of External and Internal Attention Focus Training on Foot-Strike Patterns in Running. **International Journal of Sports Science and Coaching***,* 9: (2): 307-320.

Christensen, W., Sutton, J. and McIlwain, D. (2015) Cognition in skilled action: Meshed
control and the varieties of skill experience. Mind and Language. **Mind and Language (in press)**.

Clark, J.M. and Paivio, A. (1991) Dual coding theory and education. **Educational psychology review***,* 3: (3): 149-210.

Clarke, T.A., Lesh, J.J., Trocchio, J.S., et al. (2010) Thinking styles: teaching and learning styles in graduate education students. **Educational Psychology**, 30: (7): 837-848.

Cockerton, T., Naz, R. and Sheppard, S. (1990) Factoral Validity and Internal Reliablilty of Honey and Mumford's Learning Styles Questionnaire. **Psychol Rep**, 67: (3): 859-866.

Coffield, F., Moseley, D., Hall, E., et al. (2004a) Learning styles and pedagogy in post-16 learning: A systematic and critical review.

Coffield, F., Moseley, D., Hall, E., et al. (2004b) Should we be using learning styles?: What research has to say to practice.

Collins, D., Jones, B., Fairweather, M., et al. (2001) Examining anxiety associated changes in movement patterns. **International Journal of Sport Psychology**.

Colom, R., Abad, F.J., Quiroga, M., et al. (2008) Working memory and intelligence are highly related constructs, but why? **Intelligence**, 36: (6): 584-606.

Conway, A.R., Kane, M.J. and Engle, R.W. (2003) Working memory capacity and its relation to general intelligence. **Trends Cogn Sci**, 7: (12): 547-552.

Cooke, A. (2013) Readying the head and steadying the heart: a review of cortical and cardiac studies of preparation for action in sport. **International Review of Sport and Exercise Psychology**, 6: (1): 122-138.

Cooke, A., Kavussanu, M., Gallicchio, G., et al. (2014) Preparation for action: Psychophysiological activity preceding a motor skill as a function of expertise, performance outcome, and psychological pressure. **Psychophysiology***,* 51: (4): 374-384.

Cooke, A., Kavussanu, M., McIntyre, D., et al. (2011) Effects of competitive pressure on expert performance: Underlying psychological, physiological, and kinematic mechanisms. **Psychophysiology***,* 48: (8): 1146-1156.

Cooper, N.R., Croft, R.J., Dominey, S.J., et al. (2003) Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypotheses. **International Journal of Psychophysiology***,* 47: (1): 65-74.

Cotterill, S. (2010) Pre-performance routines in sport: Current understanding and future directions. **International Review of Sport and Exercise Psychology***,* 3: (2): 132-153.

Cotterill, S.T., Sanders, R. and Collins, D. (2010) Developing effective pre-performance routines in golf: Why don't we ask the golfer? **Journal of Applied Sport Psychology***,* 22: (1): 51-64.

Crews, D.J. and Boutcher, S.H. (1986) An exploratory observational behavior analysis of professional golfers during competition. **Journal of Sport Behavior***,* 9: (2): 51-58.

Csikszentmihalyi, M. (1997) **Finding flow: The psychology of engagement with everyday life**. Basic Books.

Curry, L. (1987) **Integrating concepts of cognitive or learning style: A review with attention to psychometric standards**. Canadian College of Health Service Executives.

Czech, D., Ploszay, A. and Burke, K.L. (2004) An examination of the maintenance of preshot routines in basketball free throw shooting. **Journal of Sport Behavior***,* 27: (4): 323-329.

Davids, K.W. (2010) The constraints-based approach to motor learning: Implications for a non-linear pedagogy in sport and physical education. **Motor learning in practice: A constraints-led approach***,* 3-16.

Davids, K.W., Button, C. and Bennett, S.J. (2008) **Dynamics of skill acquisition: A constraints-led approach**. Human Kinetics.

Davidson, R.J. (2004) What does the prefrontal cortex "do" in affect: perspectives on frontal EEG asymmetry research. **Biological psychology***,* 67: (1): 219-234.

Dayan, E. and Cohen, L.G. (2011) Neuroplasticity subserving motor skill learning. **Neuron***,* 72: (3): 443-454.

de Jong, T. (2010) Cognitive load theory, educational research, and instructional design: some food for thought. **Instructional science***,* 38: (2): 105-134.

DeCaro, M.S., Carlson, K.D., Thomas, R.D., et al. (2009) When and how less is more: Reply to Tharp and Pickering. **Cognition***,* 111: (3): 415-421.

DeCaro, M.S., Thomas, R.D., Albert, N.B., et al. (2011) Choking under pressure: Multiple routes to skill failure. **Journal of Experimental Psychology: General***,* 140: (3): 390.

Deeny, S.P., Haufler, A.J., Saffer, M., et al. (2009) Electroencephalographic coherence during visuomotor performance: a comparison of cortico-cortical communication in experts and novices. **Journal of motor behavior***,* 41: (2): 106-116.

Deliens, G., Schmitz, R., Caudron, I., et al. (2013) Does recall after sleep-dependent memory consolidation reinstate sensitivity to retroactive interference? **PLoS One***,* 8: (7): e68727.

Dreyfus, H. and Dreyfus, S.E. (2000) **Mind over machine**. Simon and Schuster.

Duff, A. and Duffy, T. (2002) Psychometric properties of Honey & Mumford's Learning Styles Questionnaire (LSQ). **Personality and individual differences***,* 33: (1): 147-163.

Engle, R.W. (2002) Working memory capacity as executive attention. **Current directions in psychological science***,* 11: (1): 19-23.

Engle, R.W. and Kane, M.J. (2004) Executive attention, working memory capacity, and a two-factor theory of cognitive control. **Psychology of learning and motivation***,* 44: 145-200.

Ericsson, K.A. (1998) The Scientific Study of Expert Levels of Performance: general implications for optimal learning and creativity 1. **High Ability Studies**, 9: (1): 75-100.

Ericsson, K.A. (2003) Development of elite performance and deliberate practice: An update from the perspective of the expert performance approach. **Expert performance in sports: Advances in research on sport expertise**, 49-84.

Ericsson, K.A. (2006a) The influence of experience and deliberate practice on the development of superior expert performance. **The Cambridge handbook of expertise and expert performance**, 10: (3): 683-703.

Ericsson, K.A. (2006b) The influence of experience and deliberate practice on the development of superior expert performance. **The Cambridge handbook of expertise and expert performance**, 683-703.

Ericsson, K.A. (2007) Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. **International Journal of Sport Psychology**, 38: (1): 4.

Ericsson, K.A. and Kintsch, W. (1995) Long-term working memory. **Psychological review**, 102: (2): 211.

Ericsson, K.A., Krampe, R.T. and Tesch-Römer, C. (1993a) The role of deliberate practice in the acquisition of expert performance. **Psychological review**, 100: (3): 363.

Ericsson, K.A., Krampe, R.T. and Tesch-Römer, C. (1993b) The role of deliberate practice in the acquisition of expert performance. **PSYCHOLOGICAL REVIEW-NEW YORK-**, 100: 363-363.

Ericsson, K.A., Prietula, M.J. and Cokely, E.T. (2007) The making of an expert. **Harvard Business Review**, 85: (7/8): 114.

Eysenck, M., Derakshan, N., Santos, R., et al. (2007a) Anxiety and cognitive performance: Attentional control theory. **Emotion**, 7: (2): 336-353.

Eysenck, M.W. and Calvo, M.G. (1992) Anxiety and performance: The processing efficiency theory. **Cognition & Emotion**, 6: (6): 409-434.

Eysenck, M.W., Derakshan, N., Santos, R., et al. (2007b) Anxiety and cognitive performance: Attentional control theory. **Emotion**, 7: (2): 336-353.

Fenigstein, A., Scheier, M.F. and Buss, A.H. (1975a) Public and private self-consciousness: Assessment and theory. **Journal of Consulting and Clinical Psychology; Journal of Consulting and Clinical Psychology**, 43: (4): 522.

Fenigstein, A., Scheier, M.F. and Buss, A.H. (1975b) Public and private self-consciousness: Assessment and theory. **Journal of consulting and clinical psychology**, 43: (4): 522.

Fischer, M.H. (1997) Attention allocation during manual movement preparation and execution. **European Journal of Cognitive Psychology**, 9: (1): 17-51.

Fischer, S., Hallschmid, S.M., Elsner, A.L., et al. (2002) Sleep forms memory for finger skills. **PNAS** 99: (18): 11987-11991

Fitts, P.M. and Posner, M.I. (1967) **Human performance**. Brooks/Cole.

Fleming, N. and Mills, C. (2001) VARK: A guide to learning styles. **online at http://www. vark-learn. com,(accessed September 2001).• The majority of students in this sample is multimodal. This implies the potential for**.

(1995) **Research and Development in Higher Education, Proceedings of the 1995 Annual Conference of the Higher Education and Research Development Society of Australasia (HERDSA), HERDSA** 18

Fleming, N.D. (2006) **Teaching and learning styles: VARK strategies**. ND Fleming.

Furley, P.A. and Memmert, D. (2010) The role of working memory in sport. **International Review of Sport and Exercise Psychology**, 3: (2): 171-194.

Furnham, A. (1992) Personality and learning style: A study of three instruments. **Personality and individual differences**, 13: (4): 429-438.

Gabbett, T.J. and Abernethy, B. (2012) Dual-task assessment of a sporting skill: influence of task complexity and relationship with competitive performances. **Journal of Sports Sciences**, 30: (16): 1735-1745.

Gallwey, T. (1979) **The Inner Game of Golf**. Pan.

Gardner, F.L. and Moore, Z.E. (2004) A mindfulness-acceptance-commitment-based approach to athletic performance enhancement: Theoretical considerations. **Behavior Therapy**, 35: (4): 707-723.

Gardner, F.L. and Moore, Z.E. (2012) Mindfulness and acceptance models in sport psychology: A decade of basic and applied scientific advancements. **Canadian Psychology/Psychologie Canadienne***,* 53: (4): 309.

Gaudreau, P., Nicholls, A. and Levy, A.R. (2010) The ups and downs of coping and sport achievement: An episodic process analysis of within-person associations. **Journal of Sport & Exercise Psychology***,* 32: (3): 298.

Geeves, A., McIlwain, D.J., Sutton, J., et al. (2013) To Think or Not To Think: The apparent paradox of expert skill in music performance. **Educational Philosophy and Theory***,* (ahead-of-print): 1-18.

Gevins, A., Smith, M.E., McEvoy, L., et al. (1997) High-resolution EEG mapping of cortical activation related to working memory: effects of task difficulty, type of processing, and practice. **Cerebral Cortex***,* 7: (4): 374-385.

Gimmig, D., Huguet, P., Caverni, J.P., et al. (2006) Choking under pressure and working memory capacity: When performance pressure reduces fluid intelligence. **Psychon Bull Rev***,* 13: (6): 1005-1010.

Glazebrook, C.M., Kiernan, D., Welsh, T.N., et al. (2015) How one breaks Fitts's Law and gets away with it: Moving further and faster involves more efficient online control. **Human Movement Science***,* 39: 163-176.

Glazier, P. (2011) Movement variability in the golf swing: Theoretical, methodological, and practical issues. **Research quarterly for exercise and sport***,* 82: (2): 157-161.

Gordon, T. and Burch, N. (1975) **T.E.T. Teacher Effectiveness Training**. Crown.

Gorman, A. (2008) Skill Automaticity in Sport: Coaching Strategies to Minimise'Paralysis by Analysis'. **Australian Institue of Sport***,* 29: (2).

Green, K.E. and Schroeder, D.H. (1990) PSYCHOMETRIC QUALITY OF THE VERBALIZER-VISUALIZERQUESTIONNAIRE AS A MEASURE OF COGNITIVE STYLE. **Psychol Rep***,* 66: (3): 939-945.

Grigorenko, E.L. and Sternberg, R.J. (1995) "Thinking styles". **International handbook of personality and intelligence***.* Springer 205-229.

Gucciardi, D.F. and Dimmock, J.A. (2008) Choking under pressure in sensorimotor skills: Conscious processing or depleted attentional resources? **Psychology of Sport & Exercise***,* 9: (1): 45-59.

Han, Y., Yang, H., Lv, Y.-T., et al. (2009) Gray matter density and white matter integrity in pianists' brain: a combined structural and diffusion tensor MRI study. **Neuroscience letters***,* 459: (1): 3-6.

Harmon-Jones, E. and Peterson, C. (2009) Electroencephalographic methods in social and personality psychology. **Methods in social neuroscience***,* 170-197.

Hatfield, B.D., Haufler, A.J., Hung, T.-M., et al. (2004) Electroencephalographic studies of skilled psychomotor performance. **Journal of Clinical Neurophysiology***,* 21: (3): 144-156.

Hatfield, B.D. and Hillman, C.H. (2001) The psychophysiology of sport: A mechanistic understanding of the psychology of superior performance. **Handbook of sport psychology**, 2: 362-386.

Haufler, A.J., Spalding, T.W., Santa Maria, D., et al. (2000) Neuro-cognitive activity during a self-paced visuospatial task: comparative EEG profiles in marksmen and novice shooters. **Biological psychology**, 53: (2): 131-160.

Helstrup, T. (2000) The effect of strategies and contexts on memory for movement patterns. **Scandinavian journal of psychology**, 41: (3): 209-215.

Hill, D.M., Hanton, S., Matthews, N., et al. (2010) Choking in sport: a review. **International Review of Sport and Exercise Psychology**, 3: (1): 24-39.

Holder, T., Greenlees, I. and Moran, A. (2003) Concentration training for closed skills. Pre-performance routine. **Concentration skills training in sport**, 67-75.

Holroyd, C.B., Yeung, N., Coles, M.G., et al. (2005) A mechanism for error detection in speeded response time tasks. **Journal of Experimental Psychology: General**, 134: (2): 163.

Honey, P. and Mumford, A. (1992) The manual of learning styles.

Howe, M.W., Atallah, H.E., McCool, A., et al. (2011) Habit learning is associated with major shifts in frequencies of oscillatory activity and synchronized spike firing in striatum. **Proc Natl Acad Sci U S A**, 108: (40): 16801-16806.

Jackson, R., Ashford, K. and Norsworthy, G. (2006) Attentional focus, dispositional reinvestment, and skilled motor performance under pressure. **Journal of Sport and Exercise Psychology***,* 28: (1): 49.

(1999)

Jackson, R.C. (2003) Pre-performance routine consistency: temporal analysis of goal kicking in the Rugby Union World Cup. **Journal of Sports Sciences***,* 21: (10): 803-814.

Jackson, R.C. and Baker, J.S. (2001) Routines, rituals, and rugby: case study of a world class goal kicker. **Sport Psychologist***,* 15: (1): 48-65.

Jackson, S.A. and Csikszentmihalyi, M. (1999) **Flow in sports**. Human Kinetics.

Jackson, S.A. and Roberts, G.C. (1992) Positive performance states of athletes: Toward a conceptual understanding of peak performance. **The Sport Psychologist***,* 6: (2): 156-171.

Jackson, S.A., Thomas, P.R., Marsh, H.W., et al. (2001) Relationships between flow, self-concept, psychological skills, and performance. **Journal of Applied Sport Psychology***,* 13: (2): 129-153.

Jäncke, L., Koeneke, S., Hoppe, A., et al. (2009) The architecture of the golfer's brain. **PLoS One***,* 4: (3): e4785.

Jenkins, S. (2007) The use of swing keys by elite tournament professional golfers. **International Journal of Sports Science and Coaching***,* 2: 199-229.

Jordan, M.I. (1990) Motor learning and the degrees of freedom problem.

Jordet, G., Hartman, E. and Sigmundstad, E. (2009) Temporal links to performing under pressure in international soccer penalty shootouts. **Psychology of Sport and Exercise***,* 10: (6): 621-627.

Kahneman, D. (1973) **Attention and Effort**. Englewood Cliffs, NJ: Prentice-Hall.

Kal, E., van der Kamp, J. and Houdijk, H. (2013) External attentional focus enhances movement automatization: A comprehensive test of the constrained action hypothesis. **Human Movement Science***,* 32: (4): 527-539.

Kappe, F., Boekholt, L., Den Rooyen, C., et al. (2009) A predictive validity study of the Learning Style Questionnaire (LSQ) using multiple, specific learning criteria. **Learning and Individual Differences***,* 19: (4): 464-467.

Kaufman, J.C. (2000) **Thinking styles in creative writers and journalists**. Yale University.

Kaufman, J.C. (2002) Narrative and paradigmatic thinking styles in creative writing and journalism students. **The Journal of Creative Behavior***,* 36: (3): 201-219.

Keefe, R. (2003) **On The Sweet Spot**. Simon and Schuster.

Kelly, H. (1969) **The Golfing Machine**. The Golfing Machine LLC.

Kelso, J.S. (1997) **Dynamic patterns: The self-organization of brain and behavior**. MIT press.

Kerick, S.E., Douglass, L.W. and Hatfield, B.D. (2004) Cerebral cortical adaptations associated with visuomotor practice. **Medicine and Science in Sports and Exercise***,* 36: (1): 118-129.

Kerick, S.E., McDowell, K., Hung, T.-M., et al. (2001) The role of the left temporal region under the cognitive motor demands of shooting in skilled marksmen. **Biological psychology***,* 58: (3): 263-277.

Kerr, J.H. (2014) **Motivation and emotion in sport: Reversal theory**. Psychology Press.

Khanal, L., Shah, S. and Koirala, S. (2014) Exploration of preferred learning styles in medical education using VARK modal.

Kingston, K., Hardy, L. and Thomas, P. (2001) Pre-performance routine training using holistic process goals. **Optimising performance in golf***,* 264-278.

Kinrade, N.P., Jackson, R.C., Ashford, K.J., et al. (2010) Development and validation of the decision-specific reinvestment scale. **J Sports Sci***,* 28: (10): 1127-1135.

Kirby, J.R., Moore, P.J. and Schofield, N.J. (1988) Verbal and visual learning styles. **Contemporary educational psychology***,* 13: (2): 169-184.

Kirschner, P.A. (2002) Cognitive load theory: Implications of cognitive load theory on the design of learning. **Learning and instruction***,* 12: (1): 1-10.

Kleynen, M., Braun, S.M., Beurskens, A.J., et al. (2013) Investigating the Dutch Movement-Specific Reinvestment Scale in people with stroke. **Clinical Rehabilitation***,* 27: (2): 160-165.

Knudsen, E.I. (2007) Fundamental components of attention. **Annu. Rev. Neurosci.***,* 30: 57-78.

Koedijker, J.M., Oudejans, R.R. and Beek, P.J. (2007) Explicit rules and direction of attention in learning and performing the table tennis forehand. **International Journal of Sport Psychology***,* 38: (2): 227-244.

Koedijker, J.M., Poolton, J.M., Maxwell, J.P., et al. (2011) Attention and time constraints in perceptual-motor learning and performance: Instruction, analogy, and skill level. **Consciousness and cognition***,* 20: (2): 245-256.

Koehn, S., Morris, T. and Watt, A.P. (2013a) Flow State in Self-Paced and Externally-Paced Performance Contexts: An Examination of the Flow Model. **Psychology of Sport and Exercise**.

Koehn, S., Morris, T. and Watt, A.P. (2013b) Flow state in self-paced and externally-paced performance contexts: An examination of the flow model. **Psychology of Sport and Exercise***,* 14: (6): 787-795.

Kolb, A.Y. (2005) The Kolb learning style inventory–version 3.1 2005 technical specifications. **Boston, MA: Hay Resource Direct**.

Kolb, D.A. (1984) **Experiential learning: Experience as the source of learning and development**. Prentice-Hall Englewood Cliffs, NJ.

Kolb, D.A., Boyatzis, R.E. and Mainemelis, C. (2001) Experiential learning theory: Previous research and new directions. **Perspectives on thinking, learning, and cognitive styles**, 1: 227-247.

Kollöffel, B. (2012) Exploring the relation between visualizer–verbalizer cognitive styles and performance with visual or verbal learning material. **Computers & Education**, 58: (2): 697-706.

Kozhevnikov, M., Hegarty, M. and Mayer, R.E. (2002) Revising the Visualizer-Verbalizer Dimension: Evidence for Two Types of Visualizers. **Cognition and instruction**, 20: (1): 47-77.

Kozhevnikov, M., Kosslyn, S. and Shephard, J. (2005) Spatial versus object visualizers: A new characterization of visual cognitive style. **Memory & cognition**, 33: (4): 710-726.

L. Beilock, H.C., C MacMahon,J Starkes (2002) When Paying Attention Becomes Counterproductive: Impact of Divided Versus Skill-Focused Attention on Novice and Experienced Performance of Sensorimotor Skills . **Journal of Experimental Psychology: Applied** , 8: (1): 6-16.

Laborde, S., Furley, P. and Schempp, C. (2015) The relationship between working memory, reinvestment, and heart rate variability. **Physiology & behavior**, 139: 430-436.

Lally, P. and Gardner, B. (2013) Promoting habit formation. **Health Psychology Review**, 7: (sup1): S137-S158.

Lam, W., Maxwell, J. and Masters, R. (2010a) Probing the allocation of attention in implicit (motor) learning. **J Sports Sci**, 28: (14): 1543-1554.

Lam, W.K., Masters, R.S. and Maxwell, J.P. (2010b) Cognitive demands of error processing associated with preparation and execution of a motor skill. **Consciousness and cognition**, 19: (4): 1058-1061.

Lam, W.K., Maxwell, J.P. and Masters, R. (2009) Analogy Learning and the Performance Motor Skills Under Pressure. **Journal of Sport & Exercise Psychology**, 31: (3).

Land, W. and Tenenbaum, G. (2012) An Outcome-and Process-Oriented Examination of a Golf-Specific Secondary Task Strategy to Prevent Choking Under Pressure. **Journal of Applied Sport Psychology**, 24: (3): 303-322.

Land, W.M., Frank, C. and Schack, T. (2014) The influence of attentional focus on the development of skill representation in a complex action. **Psychology of Sport and Exercise**, 15: (1): 30-38.

Lewandowsky, S. (2011) Working memory capacity and categorization: individual differences and modeling. **Journal of Experimental Psychology: Learning, Memory, and Cognition**, 37: (3): 720.

Liao, C.M. and Masters, R.S.W. (2001) Analogy learning: A means to implicit motor learning. **J Sports Sci**, 19: (5): 307-319.

Logan, G.D. (1985) Skill and automaticity: Relations, implications, and future directions. **Canadian Journal of Psychology**, 39: (2): 367-386.

Logan, G.D. (1988) Toward an instance theory of automatization. **Psychological review**, 95: (4): 492.

Logan, G.D. (2002) An instance theory of attention and memory. **Psychological review**, 109: (2): 376.

Logan, G.D. and Cowan, W.B. (1984) On the ability to inhibit thought and action: A theory of an act of control. **Psychological review**, 91: (3): 295.

Lonsdale, C. and Tam, J.T. (2008) On the temporal and behavioural consistency of pre-performance routines: An intra-individual analysis of elite basketball players' free throw shooting accuracy. **J Sports Sci**, 26: (3): 259-266.

López, B.G., Cerveró, G.A., Rodríguez, J.M.S., et al. (2013) Learning styles and approaches to learning in excellent and average first-year university students. **European journal of psychology of education**, 28: (4): 1361-1379.

Luft, A.R. and Buitrago, M.M. (2005) Stages of motor skill learning. **Molecular neurobiology**, 32: (3): 205-216.

Lundqvist, C. (2006) Competing under pressure: State anxiety, sports performance and assessment.

Lundqvist, C., Znttä, G. and Raglin, J.S. (2011) Directional anxiety responses in elite and sub‐elite young athletes: intensity of anxiety symptoms matters. **Scandinavian journal of medicine & science in sports**, 21: (6): 853-862.

Mack, M.G. (2001) Effects of time and movements of the preshot routine on free throw shooting. **Perceptual and Motor Skills**, 93: (2): 567-573.

MacKay, D.G. (1982) The problems of flexibility, fluency, and speed–accuracy trade-off in skilled behavior. **Psychological review**, 89: (5): 483.

MacPherson, A., Collins, D. and Morriss, C. (2008) Is what you think what you get? Optimizing mental focus for technical performance. **The Sport Psychologist**, 22: (3): 288-303.

MacPherson, A.C., Collins, D. and Obhi, S.S. (2009) The importance of temporal structure and rhythm for the optimum performance of motor skills: a new focus for practitioners of sport psychology. **Journal of Applied Sport Psychology**, 21: (S1): S48-S61.

Maddox, M., Wulf, G. and Wright, D. (1999a) The effect of an internal vs. external focus of attention on the learning of a tennis stroke. **Journal of Exercise Psychology**, 21.

Maddox, M., Wulf, G. and Wright, D. (1999b) The effect of an internal vs. external focus of attention on the learning of a tennis stroke. **Journal of Exercise Psychology**, 21: S78.

Markman, A.B., Maddox, W.T. and Worthy, D.A. (2006) Choking and excelling under pressure. **PSYCHOLOGICAL SCIENCE-CAMBRIDGE-**, 17: (11): 944.

Martens, R., Burton, D., Vealey, R.S., et al. (1990) Development and validation of the competitive state anxiety inventory-2. **Competitive anxiety in sport**, 117-190.

Massa, L.J. and Mayer, R.E. (2006) Testing the ATI hypothesis: Should multimedia instruction accommodate verbalizer-visualizer cognitive style? **Learning and Individual Differences***,* 16: (4): 321-335.

(2005) **Proceedings of the ISSP 11th World Congress of Sport Psychology, Sydney, Australia**

Masters, R. and Maxwell, J. (2008a) The theory of reinvestment. **International Review of Sport and Exercise Psychology***,* 1: (2): 160-183.

Masters, R., Polman, R.C. and Hammond, N. (1993a) 'Reinvestment': A dimension of personality implicated in skill breakdown under pressure. **Personality and individual differences***,* 14: (5): 655-666.

Masters, R.S. and Poolton, J.M. (2012) 4 Advances in implicit motor learning. **Skill acquisition in sport: Research, theory and practice***,* 59.

Masters, R.S.W. (1992) Knowledge, nerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. **British Journal of Psychology**
, 83: 343-358.

Masters, R.S.W. and Maxwell, J. (2008b) The theory of reinvestment. **International Review of Sport and Exercise Psychology***,* 1: (2): 160-183.

Masters, R.S.W. and Maxwell, J.P. (2004) Implicit motor learning, reinvestment and movement disruption: What you donít know wonít hurt you. **Skill acquisition in sport: Research, theory and practice***,* 207-228.

Masters, R.S.W., Polman, R.C.J. and Hammond, N.V. (1993b) Reinvestment': A dimension of personality implicated in skill breakdown under pressure. **Personality and individual differences***,* 14: (5): 655-666.

Masters, R.S.W., Poolton, J.M. and Maxwell, J.P. (2008) Stable implicit motor processes despite aerobic locomotor fatigue. **Consciousness and Cognition***,* 17: (1): 335-338.

Maurer, H. and Munzert, J. (2013) Influence of attentional focus on skilled motor performance: Performance decrement under unfamiliar focus conditions. **Human Movement Science***,* 32: (4): 730-740.

Maxwell, J., Masters, R. and Poolton, J. (2006) Performance breakdown in sport: the roles of reinvestment and verbal knowledge. **Research quarterly for exercise and sport***,* 77: (2): 271-276.

Maxwell, J.P., Masters, R.S.W. and Eves, F.F. (2000) From novice to no know-how: A longitudinal study of implicit motor learning. **J Sports Sci***,* 18: (2): 111-120.

Maxwell, J.P., Masters, R.S.W. and Eves, F.F. (2003) The role of working memory in motor learning and performance. **Consciousness and Cognition***,* 12: (3): 376-402.

Mayer, R.E. and Massa, L.J. (2003) Three Facets of Visual and Verbal Learners: Cognitive Ability, Cognitive Style, and Learning Preference. **Journal of educational psychology***,* 95: (4): 833.

Mayers, L.B., Redick, T.S., Chiffriller, S.H., et al. (2011) Working memory capacity among collegiate student athletes: Effects of sport-related head contacts, concussions, and working memory demands. **Journal of clinical and experimental neuropsychology**, 33: (5): 532-537.

McKay, B. and Wulf, G. (2012) A distal external focus enhances novice dart throwing performance. **International Journal of Sport and Exercise Psychology**, 10: (2): 149-156.

McLeod, P. (1977) A dual task response modality effect: Support for multiprocessor models of attention. **Quarterly Journal of Experimental Psychology**, 29: 651-667.

Mellalieu, S.D., Hanton, S., Fletcher, D., et al. (2006) A competitive anxiety review: Recent directions in sport psychology research. **Literature reviews in sport psychology**, 1-45.

Mellalieu, S.D., Hanton, S. and Jones, G. (2003) Emotional labeling and competitive anxiety in preparation and competition. **Sport Psychologist**, 17: (2): 157-174.

Mendelson, A.L. and Thorson, E. (2004) How verbalizers and visualizers process the newspaper environment. **Journal of Communication**, 54: (3): 474-491.

Mesagno, C., Marchant, D. and Morris, T. (2009) Alleviating choking: The sounds of distraction. **Journal of Applied Sport Psychology**, 21: (2): 131-147.

Mesagno, C. and Mullane-Grant, T. (2010) A comparison of different pre-performance routines as possible choking interventions. **Journal of Applied Sport Psychology**, 22: (3): 343-360.

Miller, B.L. and Cummings, J.L. (2007) **The human frontal lobes: Functions and disorders**. Guilford press.

Miller, E.K. and Cohen, J.D. (2001) An integrative theory of prefrontal cortex function. **Annual review of neuroscience**, 24: (1): 167-202.

Milton, J., Solodkin, A., Hluštík, P., et al. (2007) The mind of expert motor performance is cool and focused. **Neuroimage**, 35: (2): 804-813.

Moore, L.J., Vine, S.J., Cooke, A., et al. (2012) Quiet eye training expedites motor learning and aids performance under heightened anxiety: The roles of response programming and external attention. **Psychophysiology**, 49: (7): 1005-1015.

Moran, A.P. (1996) **The psychology of concentration in sport performers: a cognitive analysis**. Psychology Press.

Moran, T.a. (2014) Considering the role of cognitive control in expert performance.

Moreau, D. (2012) The role of motor processes in three-dimensional mental rotation: Shaping cognitive processing via sensorimotor experience. **Learning and Individual Differences**, 22: (3): 354-359.

Moreau, D. (2013) Motor expertise modulates movement processing in working memory. **Acta Psychologica**, 142: (3): 356-361.

Mrazek, M.D., Franklin, M.S., Phillips, D.T., et al. (2013) Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. **Psychological Science**, 24: (5): 776-781.

Mullen, R. and Hardy, L. (2000a) State anxiety and motor performance: Testing the conscious processing hypothesis. **J Sports Sci**, 18: (10): 785-799.

Mullen, R. and Hardy, L. (2000b) State anxiety and motor performance: Testing the conscious processing hypothesis.

. **Journal of Sports Sciences, 18, 785–799.**

, 18: 785-799.

Mullen, R. and Hardy, L. (2010) Conscious processing and the process goal paradox. **Journal of Sport & Exercise Psychology**, 32: (3): 275-297.

Mullen, R., Hardy, L. and Oldham, A. (2007) Implicit and explicit control of motor actions: Revisiting some early evidence. **British Journal of Psychology**, 98: (1): 141-156.

Mullen, R., Hardy, L. and Tattersall, A. (2005) The effects of anxiety on motor performance: A test of the conscious processing hypothesis. **Journal of Sport and Exercise Psychology**, 27: 212–225.

Mumford, A. and Honey, P. (1992) Questions and answers on learning styles questionnaire. **Industrial and Commercial Training**, 24: (7).

(1994) **Science and golf II: Proceedings of the world scientific congress of golf** E and FN Spon London.

Nakamura, J. and Csikszentmihalyi, M. (2009) Flow theory and research. **Handbook of positive psychology***,* 195-206.

Nettersheim, A., Hallschmid, M., Born, J., et al. (2015) The Role of Sleep in Motor Sequence Consolidation: Stabilization Rather Than Enhancement. **The Journal of Neuroscience***,* 35: (17): 6696-6702.

Neves, D.M. and Anderson, J.R. (1981) Knowledge compilation: Mechanisms for the automatization of cognitive skills. **Cognitive skills and their acquisition***,* 57-84.

Newell, A. and Rosenbloom, P.S. (1981) Mechanisms of skill acquisition and the law of practice. **Cognitive skills and their acquisition***,* 1.

Newell, K.M. (1986) Constraints on the development of coordination. **Motor development in children: Aspects of coordination and control***,* 34: 341-360.

Newell, K.M. (2003) Schema theory (1975): Retrospectives and prospectives. **Research quarterly for exercise and sport***,* 74: (4): 383-388.

Nicholls, A.R. and Polman, R.C. (2008) Think aloud: Acute stress and coping strategies during golf performances. **Anxiety, Stress, & Coping***,* 21: (3): 283-294.

Nieuwenhuys, A. and Oudejans, R.R. (2012) Anxiety and perceptual-motor performance: toward an integrated model of concepts, mechanisms, and processes. **Psychological research***,* 76: (6): 747-759.

Nieuwenhuys, A., Pijpers, J.R., Oudejans, R.R., et al. (2008) The influence of anxiety on visual attention in climbing. **Journal of Sport & Exercise Psychology**, 30: (2): 171.

Nunnally, J. (1962) The analysis of profile data. **Psychological bulletin**, 59: (4): 311.

Nyberg, G. (2014) Developing a 'somatic velocimeter'–the practical knowledge of freeskiers. **Qualitative Research in Sport, Exercise and Health**, (ahead-of-print): 1-16.

Oliveira, T.A., Denardi, R.A., Tani, G., et al. (2013) Effects of Internal and External Attentional Foci on Motor Skill Learning: Testing the Automation Hypothesis. **Human Movement**, 14: (3): 194-199.

Orrell, A., Masters, R. and Eves, F. (2009) Reinvestment and movement disruption following stroke. **Neurorehabilitation and neural repair**, 23: (2): 177-183.

Paas, F., Renkl, A. and Sweller, J. (2004) Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. **Instructional science**, 32: (1): 1-8.

Paas, F., Tuovinen, J.E., Tabbers, H., et al. (2003) Cognitive load measurement as a means to advance cognitive load theory. **Educational psychologist**, 38: (1): 63-71.

Paivio, A. (1971) Imagery and verbal processes.

Pashler, H. (1994) Dual-task interference in simple tasks: Data and theory. . **Psychological bulletin**, 116: 220-244.

Pashler, H. and Johnston, J.C. (1998) **Attentional limitations in dual-task performance**. Hove UK: Psychology Press.

Pashler, H., McDaniel, M., Rohrer, D., et al. (2008) Learning styles concepts and evidence. **Psychological science in the public interest**, 9: (3): 105-119.

Peh, S.Y.C., Chow, J.Y. and Davids, K. (2010) Focus of attention and its impact on movement behaviour. **Journal of Science and Medicine in Sport**.

Pelz, D. and Frank, J. (2000) **The Putting Bible**. Doubleday.

Perkins-Ceccato, N., Passmore, S. and Lee, T. (2003) Effects of focus of attention depend on golfers skill. **J Sports Sci**, 21: (8): 593-600.

Pfurtscheller, G. (1992) Event-related synchronization (ERS): an electrophysiological correlate of cortical areas at rest. **Electroencephalography and clinical neurophysiology**, 83: (1): 62-69.

Pijpers, J., Oudejans, R.R. and Bakker, F.C. (2005) Anxiety-induced changes in movement behaviour during the execution of a complex whole-body task. **The Quarterly Journal of Experimental Psychology Section A**, 58: (3): 421-445.

Poletiek, F.H. (2013) **Hypothesis-testing behaviour**. Psychology Press.

Poolton, J., Maxwell, J., Masters, R., et al. (2006) Benefits of an external focus of attention: Common coding or conscious processing? **J Sports Sci**, 24: (1): 89-99.

Prinz, W. (1990) A common coding approach to perception and action.

R&A (2012) Golf Rules Illustrated 2012-2015.

Ravizza, S.M. and Ivry, R.B. (2001) Comparison of the basal ganglia and cerebellum in shifting attention. **Journal of cognitive neuroscience**, 13: (3): 285-297.

Reber, A.S. (1993) **Implicit learning and tacit knowledge.** Oxford University Press.

Reiterer, S., Berger, M.L., Hemmelmann, C., et al. (2005) Decreased EEG coherence between prefrontal electrodes: a correlate of high language proficiency? **Experimental brain research**, 163: (1): 109-113.

Rendell, M.A., Farrow, D., Masters, R., et al. (2011) Implicit practice for technique adaptation in expert performers. **International Journal of Sports Science and Coaching**, 6: (4): 553-566.

Richardson, A. (1977) Verbalizer-visualizer: A cognitive style dimension. **Journal of Mental Imagery**.

Riding, R. and Cheema, I. (1991) Cognitive styles—an overview and integration. **Educational Psychology**, 11: (3-4): 193-215.

Robazza, C., Pellizzari, M., Bertollo, M., et al. (2008) Functional impact of emotions on athletic performance: Comparing the IZOF model and the directional perception approach. **J Sports Sci***,* 26: (10): 1033-1047.

Roberts, R., Woodman, T., Hardy, L., et al. (2013) Psychological Skills Do Not Always Help Performance: The Moderating Role of Narcissism. **Journal of Applied Sport Psychology***,* 25: (3): 316-325.

Roger, D. and Nesshoever, W. (1987) The construction and preliminary validation of a scale for measuring emotional control. **Personality and Individual Differences.***,* 8: 527-534.

Ross, J.S., Tkach, J., Ruggieri, P.M., et al. (2003) The mind’s eye: functional MR imaging evaluation of golf motor imagery. **American Journal of Neuroradiology***,* 24: (6): 1036-1044.

Rotella, B. (1995) **Golf is Not a Game of Perfect**. Simon & Schuster.

Rousseau, N. (2010) Everyday Golf Coach.

Rousseau, N. (2011) Everyday Golf Coach Power.

Sadler-Smith, E. (1997) " Learning Style": Frameworks and Instruments. **Educational Psychology**.

Sadler-Smith, E. (2001) Does the Learning Styles Questionnaire measure style or process? A reply to Swailes and Senior (1999). **International Journal of selection and assessment***,* 9: (3): 207-214.

Saling, L.L. and Phillips, J. (2007) Automatic behaviour: efficient not mindless. **Brain Research Bulletin**, 73: (1): 1-20.

Sanders, A.F. (2001) Dual Task Performance. **International Encyclopedia of the Social & Behavioral Sciences**, 3888-3892.

Schack, T. (2004) The cognitive architecture of complex movement. **International Journal of Sport and Exercise Psychology**, 2: (4): 403-438.

Schack, T. (2012) Measuring mental representations. **Measurement in sport and exercise psychology**, 203-214.

Schack, T. and Mechsner, F. (2006) Representation of motor skills in human long-term memory. **Neuroscience letters**, 391: (3): 77-81.

Schmidt, R. and Lee, T. (2013) **Motor Learning and Performance, 5E With Web Study Guide: From Principles to Application**. Human Kinetics.

Schmidt, R.A. (1975) A schema theory of discrete motor skill learning. **Psychological review**, 82: (4): 225.

Schmidt, R.A. (2003) Motor schema theory after 27 years: reflections and implications for a new theory. **Research quarterly for exercise and sport**, 74: (4): 366-375.

Seger, C.A. and Spiering, B.J. (2011) A critical review of habit learning and the Basal Ganglia. **Front Syst Neurosci**, 5: 66.

Sheth, B.R., Janvelyan, D. and Khan, M. (2008) Practice makes imperfect: restorative effects of sleep on motor learning. **PLoS One**, 3: (9): e3190.

Shiffrin, R.M. and Schneider, W. (1977) Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. **Psychological review**, 84: (2): 127.

Shusterman, R. (2009) Body Consciousness and Performance: Somaesthetics East and West. **The Journal of Aesthetics and Art Criticism**, 67: (2): 133-145.

Shusterman, R. (2011) Soma, self, and society: Somaesthetics as pragmatist meliorism. **Metaphilosophy**, 42: (3): 314-327.

Siengsukon, C.F. and Boyd, L.A. (2009) Does sleep promote motor learning? Implications for physical rehabilitation. **Physical Therapy**, 89: (4): 370-383.

Silver, H.F., Strong, R.W. and Perini, M.J. (2000) **So each may learn: Integrating learning styles and multiple intelligences**. ERIC.

Singer, R.N. (1988) Strategies and metastrategies in learning and performing self-paced athletic skills. **The Sport Psychologist**.

Singer, R.N. (2000) Performance and human factors: considerations about cognition and attention for self-paced and externally-paced events. **Ergonomics**, 43: (10): 1661-1680.

Singer, R.N. (2002) Pre performance State, Routines and Automaticity: What does it take to realize expertise in self paced events?” Journal of Sport & Exercise. **Journal of Sport & Exercise Psychology**, 24: 359-375.

Singer, R.N., Lidor, R. and Cauraugh, J.H. (1993) To be aware or not aware? What to think about while learning and performing a motor skill. **Sport Psychologist***,* 7: 19-19.

Smith, M.E., McEvoy, L.K. and Gevins, A. (1999) Neurophysiological indices of strategy development and skill acquisition. **Cognitive Brain Research***,* 7: (3): 389-404.

Sohn, Y.W. and Doane, S.M. (2003) Roles of working memory capacity and long-term working memory skill in complex task performance. **Memory & cognition***,* 31: (3): 458-466.

Southard, D. and Miracle, A. (1993) Rhythmicity, ritual, and motor performance: A study of free throw shooting in basketball. **Research Quarterly for Exercise and Sport***,* 64: (3): 284-290.

Southard, D., Miracle, A. and Landwer, G. (1989) Ritual and free‚Äêthrow shooting in basketball. **Journal of Sports Sciences***,* 7: (2): 163-173.

Spiegel, M.A., Koester, D., Weigelt, M., et al. (2012) The costs of changing an intended action: movement planning, but not execution, interferes with verbal working memory. **Neuroscience letters***,* 509: (2): 82-86.

Springer, S.P. and Deutsch, G. (1985) **Left brain, right brain (rev**. WH Freeman/Times Books/Henry Holt & Co.

Stellwagen, J.B. (2001) A challenge to the learning style advocates. **The Clearing House***,* 74: (5): 265-268.

Stickgold, R. and Walker, M.P. (2007) Sleep-dependent memory consolidation and reconsolidation. **Sleep medicine***,* 8: (4): 331-343.

Stratton, S.M., Liu, Y.-T., Hong, S.L., et al. (2007) Snoddy (1926) revisited: time scales of motor learning. **Journal of motor behavior***,* 39: (6): 503-515.

Stuss, D.T. and Knight, R.T. (2013) **Principles of frontal lobe function**. Oxford University Press.

Sutton, J. (2015) Cognition in action: Meshed control and the veriates of skill experience.

Sutton, J., McIlwain, D., Christensen, W., et al. (2011) Applying intelligence to the reflexes: Embodied skills and habits between Dreyfus and Descartes.

Swailes, S. and Senior, B. (1999) The dimensionality of Honey and Mumfordís learning styles questionnaire. **International Journal of selection and assessment***,* 7: (1): 1-11.

Swann, C., Keegan, R.J., Piggott, D., et al. (2012) A systematic review of the experience, occurrence, and controllability of flow states in elite sport. **Psychology of Sport and Exercise***,* 13: (6): 807-819.

Swann, C., Piggott, D., Crust, L., et al. (2015) Exploring the interactions underlying flow states: A connecting analysis of flow occurrence in European Tour golfers. **Psychology of Sport and Exercise***,* 16: 60-69.

Tanaka, Y. and Sekiya, H. (2010) The Influence of Audience and Monetary Reward on the Putting Kinematics of Expert and Novice Golfers. **Research quarterly for exercise and sport***,* 81: (4): 416-424.

Tanaka, Y. and Sekiya, H. (2011) The influence of monetary reward and punishment on psychological, physiological, behavioral and performance aspects of a golf putting task. **Human Movement Science**, 30: (6): 1115-1128.

Thorpe, E. (2010) Brain Behavior is Related to Motor Behavior During Competition.

Toner, J., Montero, B.G. and Moran, A.P. (2015) The perils of automaticity.

Toner, J. and Moran, A. (2011) The effects of conscious processing on golf putting proficiency and kinematics. **J Sports Sci**, 29: (7): 673-683.

Toner, J. and Moran, A. (2014) In praise of conscious awareness: a new framework for the investigation of'continuous improvement'in expert athletes. **Name: Frontiers in Psychology**, 5: 769.

Toner, J. and Moran, A. (2015) Enhancing performance proficiency at the expert level: Considering the role of ‘somaesthetic awareness’. **Psychology of Sport and Exercise**, 16: 110-117.

Tremblay, L. and Proteau, L. (1998) Specificity of practice: The case of powerlifting. **Research quarterly for exercise and sport**, 69: (3): 284-289.

Unsworth, N. and Engle, R.W. (2007) On the division of short-term and working memory: an examination of simple and complex span and their relation to higher order abilities. **Psychological bulletin**, 133: (6): 1038.

Unsworth, N. and Spillers, G.J. (2010) Working memory capacity: Attention control, secondary memory, or both? A direct test of the dual-component model. **Journal of Memory and Language***,* 62: (4): 392-406.

Van Merrienboer, J.J. and Ayres, P. (2005) Research on cognitive load theory and its design implications for e-learning. **Educational Technology Research and Development***,* 53: (3): 5-13.

Van Merrienboer, J.J. and Sweller, J. (2005) Cognitive load theory and complex learning: Recent developments and future directions. **Educational psychology review***,* 17: (2): 147-177.

Van Zwanenberg, N., Wilkinson, L. and Anderson, A. (2000) Felder and Silverman's Index of Learning Styles and Honey and Mumford's Learning Styles Questionnaire: how do they compare and do they predict academic performance? **Educational Psychology***,* 20: (3): 365-380.

Voss, M.W., Kramer, A.F., Basak, C., et al. (2010) Are expert athletes ‘expert’in the cognitive laboratory? A meta‐analytic review of cognition and sport expertise. **Applied cognitive psychology***,* 24: (6): 812-826.

Walker, M.P. (2005) A refined model of sleep and the time course of memory formation. **Behavioral and Brain Sciences***,* 28: (01): 51-64.

Walker, M.P., Brakefield, T., Morgan, A., et al. (2002a) Practice with Sleep Makes Perfect Sleep-Dependent Motor Skill Learning. **Neuron***,* 35: (1): 205-211.

Walker, M.P., Brakefield, T., Morgan, A., et al. (2002b) Practice with sleep makes perfect: sleep-dependent motor skill learning. **Neuron**, 35: (1): 205-211.

Walker, M.P., Brakefield, T., Seidman, J., et al. (2003a) Sleep and the time course of motor skill learning. **Learning & Memory**, 10: (4): 275-284.

Walker, M.P., Brakefield, T., Seidman, J., et al. (2003b) Sleep and the time course of motor skill learning. **Learning & Memory**, 10: (4): 275.

Walker, M.P. and Stickgold, R. (2004) Sleep-Dependent Learning and Memory Consolidation. **Neuron**, 44: (1): 121-133.

Walker, M.P. and Stickgold, R. (2006) Sleep, memory, and plasticity. **Annu. Rev. Psychol.**, 57: 139-166.

Wang, W. (2007) **Learning Experiences in Terms of Verbalizer-visualizer Cognitive Style: Interviewing Verbal and Visual Learners**. ProQuest.

Weiss, S. and Mueller, H.M. (2003) The contribution of EEG coherence to the investigation of language. **Brain and language**, 85: (2): 325-343.

Williams, A. and Hodges, N. (2004) **Skill acquisition in sport: Research, theory and practice**. Routledge.

Williams, A.M., Davids, K. and Williams, J.G.P. (1999) **Visual perception and action in sport**. Taylor & Francis.

Williams, A.M. and Ericsson, K.A. (2005) Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. **Human Movement Science**, 24: (3): 283-307.

Wilson, M., Chattington, M., Marple-Horvat, D., et al. (2007) A comparison of self-focus versus attentional explanations of choking. **Journal of Sport & Exercise Psychology**, 29: (4): 439.

Winter, S., MacPherson, A.C. and Collins, D. (2014) “To think, or not to think, that is the question”. **Sport, Exercise, and Performance Psychology**, 3: (2): 102.

Wood, G., Vine, S.J. and Wilson, M.R. (2015) Working memory capacity, controlled attention and aiming performance under pressure. **Psychological research**, 1-8.

Wrisberg, C.A. and Pein, R.L. (1992) The pre-shot interval and free throw shooting accuracy: An exploratory investigation. **The Sport Psychologist**, 6.

Wu, Y.-H. and Latash, M.L. (2014) The Effects of Practice on Coordination. **Exercise and sport sciences reviews**, 42: (1): 37-42.

Wulf, G. (2007) **Attention and motor skill learning**. Human Kinetics Publishers.

Wulf, G. (2013) Attentional focus and motor learning: a review of 15 years. **International Review of Sport and Exercise Psychology**, 6: (1): 77-104.

Wulf, G., Chiviacowsky, S. and Drews, R. (2015) External focus and autonomy support: Two important factors in motor learning have additive benefits. **Human Movement Science**, 40: 176-184.

Wulf, G., Lauterbach, B. and Toole, T. (1999) The learning advantages of an external focus of attention in golf. **Research quarterly for exercise and sport**, 70: 120-126.

Wulf, G., McNevin, N. and Shea, C.H. (2001) The automaticity of complex motor skill learning as a function of attentional focus. **The Quarterly Journal of Experimental Psychology Section A**, 54: (4): 1143-1154.

Wulf, G., McNevin, N.H., Fuchs, T., et al. (2000) Attentional focus in complex motor skill learning (exp 2). **Research quarterly for exercise and sport**, 71: 10.

Wulf, G. and Su, J. (2007) An external focus of attention enhances golf shot accuracy in beginners and experts. **Research quarterly for exercise and sport**, 78: (4): 384.

Wulf, G., Zachry, T., Granados, C., et al. (2007) Increases in jump-and-reach height through an external focus of attention. **International Journal of Sports Science and Coaching**, 2: (3): 275-284.

Zhang, L.-F. and Sternberg, R.J. (2002) Thinking styles and teachers' characteristics. **International Journal of Psychology**, 37: (1): 3-12.

Zhang, L.-f. and Sternberg, R.J. (2005) A threefold model of intellectual styles. **Educational psychology review**, 17: (1): 1-53.

Zhang, L.-f. and Sternberg, R.J. (2006) **The nature of intellectual styles**. Psychology Press.

Zhu, F., Maxwell, J., Hu, Y., et al. (2010) EEG activity during the verbal-cognitive stage of motor skill acquisition. **Biological psychology**, 84: (2): 221-227.

Zhu, F., Poolton, J., Wilson, M., et al. (2011) Neural co-activation as a yardstick of implicit motor learning and the propensity for conscious control of movement. **Biological psychology**, 87: (1): 66-73.

APPENDICES

APPENDIX A: INFORMATION STATEMENT FOR GENERAL METHOD (CHAPTERS 4, 5, 6, 7 & 8)

Participant Information Sheet

This is a PGR student project, being carried out as part of Noel Rousseau's PhD studies at the University of Birmingham. The study will enable us to gain further information into optimum concentration levels and have a better understanding of performance under pressure. We are confident that you will find the session helpful for your coaching and playing alike. We request that you read this document providing you with information that will help you to decide upon your participation.

Task

Thank you for considering to take part in this study. This is a 2 part study comprising of an online questionnaire and a performance data session.

Should you agree to participate you will be required to attend a data collection session for approximately two hours. During this time you will be required to hit a set number of 5 iron shots into the screen in a swing room and fill out questionnaires.

Competition

A further requirement for participation is that you contribute £6 as a stake in a competitive set up. This is payable on the day in cash as are any winnings. Dependant on your performance on a target based game, you will be able to win back this money and win additional funds.

De-Brief

The design of the study is non-invasive and is conducted in a safe environment. When you have completed the performance data phase you will be de-briefed and given time with the researchers to discuss the purpose of the intervention and the implications within your own game and coaching. If you choose to take part, please sign the consent form and bring your 5 iron to each data collection session.

Should you have any further queries then please contact:

Noel Rousseau

[redacted]

[redacted]

APPENDIX B: CONSENT FORM FOR GENERAL METHOD

(CHAPTERS 4, 5, 6, 7 & 8)

Birmingham University

Consent Form

INVESTIGATION: CONCENTRATION IN ELITE GOLFERS.

Investigators: Noel Rousseau

Dr Matt Bridge

Dr Ian Boardley

Participant Name (please print):

I have read the attached information sheet and have had the opportunity to discuss the investigation with Noel Rousseau who has answered any questions I had and explained the procedures to my satisfaction. I understand that the results of my shots will be coded as to be made anonymous and may be used in the on going study.

I am willing to participate in the investigation but understand that I am free to withdraw at any time up to the completion of my shots without having to give an explanation. Any withdrawal up to this point will not effect either my previously amassed winnings or entitle me to a refund of my allotted stake. After the completion of my trials withdrawal is no longer permitted.

I fully understand the procedures and accept that the chances of winning my £6.00 stake back are around 50% and are based on my ability to hit a target repeatedly with a 5 iron. The target is equivalent in size to a small green in width and very generous on depth. I forego any responsibility of the researchers in relation to my form after this experiment.

Signed ……………………………………….

Witnessed ……………………………………….

Date ……………………………………….

Email Address ……………………………………….

Telephone ……………………………………….

APPENDIX B: INFORMATION STATEMENT (CHAPTER 6)

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This is a PGR student project, being carried out as part of Noel Rousseau's PhD studies at the University of Birmingham. The study will enable us to gain further information into optimum concentration levels and have a better understanding of performance under pressure. We are confident that you will find the session helpful for your coaching and playing alike. We request that you read this document providing you with information that will help you to decide upon your participation.

Task

Thank you for considering to take part in this study. This is a 3 part study spread over a 6 week period. Should you agree to participate you will be required to attend a data collection session for approximately two hours on day one of the study and again 6 weeks later. During this time you will be required to hit a set number of 5 iron shots at a target on the driving range and fill out questionnaires. In the 6 weeks between the test phases you will be required to practice a particular pre shot routine twice a week over a 6 week period for 10 minutes each time in duration. During this phase you will also be required to complete a brief online questionnaire that will be sent to you after the 1st day's testing.

Experimental Groups

You will be randomly assigned to the ‘control’ or ‘test’ group. The control group will be required to perform all shots in the test phases and practice in between using their normal pre-shot routine. The test group will hit their shots within a set time restraint. All participants will be scored based on your performance. At no point will you be given coaching advice or be required to make any changes to your swing.

Competition

A further requirement for participation is that you contribute £6 as a stake in a competitive set up. This is payable on the day in cash as are any winnings. Dependant on your performance on a target based game, you will be able to win back this money and win additional funds.

De-Brief

The design of the study is non-invasive and is conducted in a safe environment. When you have completed the second of the test phases you will be de-briefed and given time with the researchers to discuss the purpose of the intervention and the implications within your own game and coaching. If you choose to take part, please sign the consent form and bring your 5 iron to each data collection session.

Should you have any further queries then please contact:

Noel Rousseau

[redacted]

APPENDIX C: CONSENT FORM (CHAPTER 6)

Birmingham University

Consent Form

INVESTIGATION: CONCENTRATION IN ELITE GOLFERS.

Investigators: Noel Rousseau

Dr Matt Bridge

Dr Ian Boardley

Participant Name (please print):

I have read the attached information sheet and have had the opportunity to discuss the investigation with Noel Rousseau who has answered any questions I had and explained the procedures to my satisfaction. I understand that the results of my shots will be coded as to be made anonymous and may be used in the on going study.

I am willing to participate in the investigation but understand that I am free to withdraw at any time up to the completion of my shots without having to give an explanation. Any withdrawal up to this point will not effect either my previously amassed winnings or entitle me to a refund of my allotted stake. After the completion of my trials withdrawal is no longer permitted.

I understand the requirements of the study and am willing to carry out the required practice sessions in the 6 weeks between testing.

I fully understand the procedures and accept that the chances of winning my £6.00 stake back are around 50% and are based on my ability to hit a target repeatedly with a 5 iron. The target is equivalent in size to a small green in width and very generous on depth. I forego any responsibility of the researchers in relation to my form after this experiment.

Signed ……………………………………

Witnessed ……………………………………

Date ……………………………………

Email Address …………………………………….

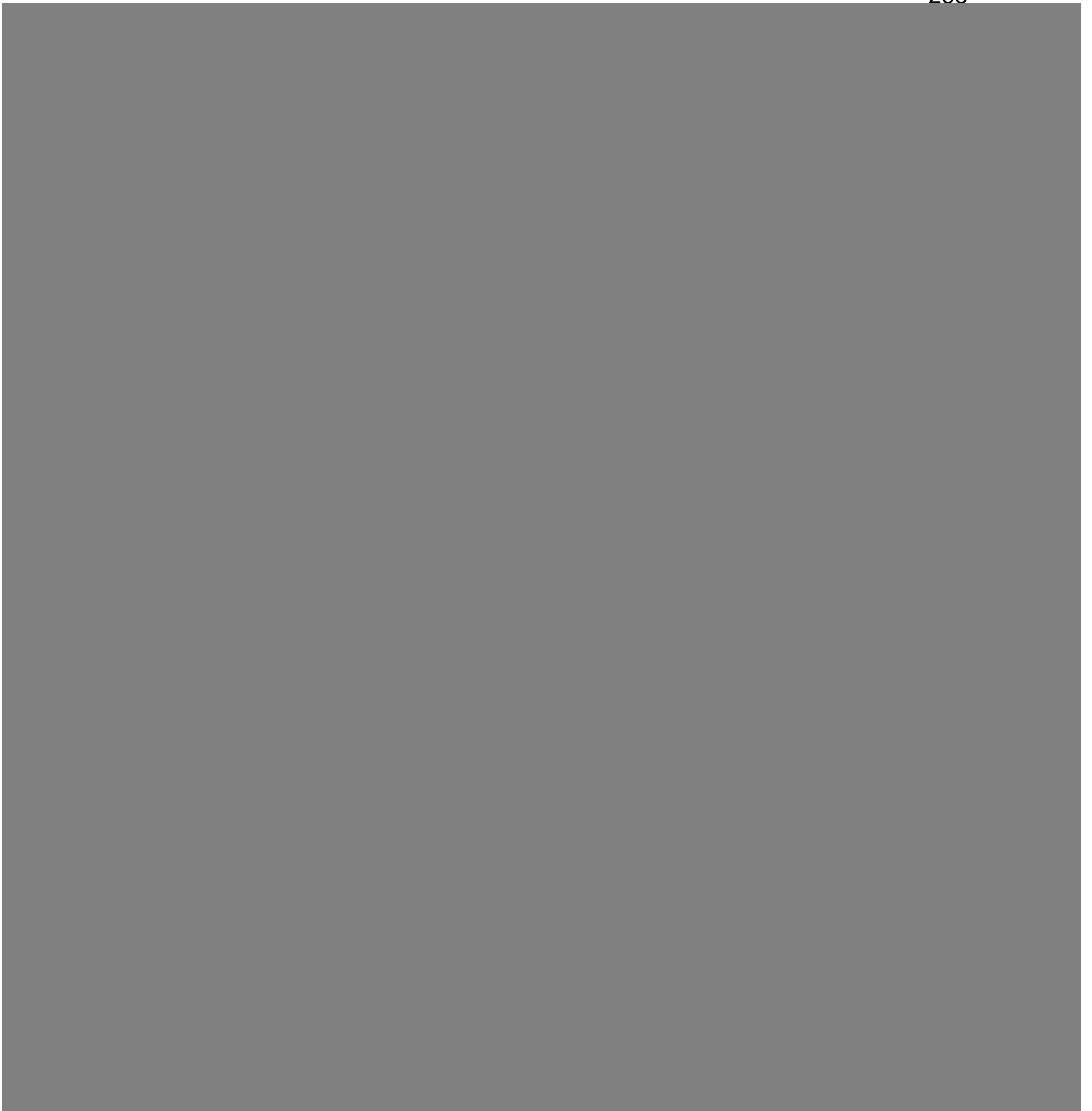
Telephone …………………………………….

APPENDIX D: MOVEMENT SPECIFIC REINVESTMENT FORM

THE MOVEMENT SPECIFIC REINVESTMENT SCALE

APPENDIX E: adjusted MOVEMENT SPECIFIC REINVESTMENT FORM

APPENDIX F: VISUALISER-VERBILISER QUESTIONNAIRE



APPENDIX G: LEARNING STYLES QUESTIONNAIRE (GOLF SPECIFIC)