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An Investigation Examining the Effects of Specificity within the Construct of Anxiety on Planning and Execution of Movement.

PRIFYSGOL
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UNIVERSITY

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Thesis submitted to the School of Sport, Health and Exercise Sciences, Bangor University, for the degree of Doctor of Philosophy.

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This Is Where The Adventure Begins!

Published work from the thesis

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Thesis Format

This thesis is made up of a literature review, three empirical research chapters and a general discussion. All three empirical chapters are written as three standalone research articles. The first was published in Psychological Research journal, and it is anticipated that the second and third experimental chapters will be submitted for consideration to a similar international psychology or motor control journal. For consistency, all manuscripts are written in the style adopted by the School of Sport, Health and Exercise Sciences, Bangor University, which is described in the American Psychological Association Publication Manual (6th Ed) and the current recommendations of Bangor University thesis preparation. All citations are included in a single section at the end of this thesis, illustrations are numbered consecutively and abbreviations are defined at their first appearance within each chapter of the thesis to facilitate reading. The contributions to the co-authors to each original manuscript are detailed in the 'acknowledgments' and 'published work from the thesis' sections. As all the manuscripts included in the thesis are independent but linked, at times there is necessary overlap in the content between chapters.

Outline of the thesis

The aim of this thesis is to examine and enhance the learning environment, by investigating the framework of specificity during practice (Henry, 1968; Gilligan & Bower, 1983; Proteau, 1992) within the construct of anxiety. That is, the thesis examines whether learning and subsequent recall is specific to the conditions under which practice occurred. To achieve this, chapter 2 investigates whether specificity of practice within the construct of anxiety depends on the complexity of the task and examines when anxiety should be introduced during learning, to achieve best performance. Chapter 3 furthers this by investigating the effects of specificity on the fundamental aspects of the motor control process (e.g., online; involved with movement execution and offline; involved with movement planning). The primary goal here was to investigate which processes developed specificity when training under either anxiety or control conditions. Finally, chapter 4 was designed to focus on the use of sensory afferent information used in both vision and non-vision conditions. This was conducted with recent advances in movement analysis technologies that allow researchers to more fully investigate the kinematics of movement. Specifically, chapter 4 explicitly investigated what parameters of movement are affected by anxiety. Additionally, chapter 4 examined if any alterations are maladaptive or adaptive to maintain and achieve successful performance.

Abstract

The specificity of practice hypothesis and the psychological construct of anxiety are well established bodies of literature within their respective fields of research. The purpose of the current thesis was to design a series of experiments that investigate whether anxiety conforms to the principles of specificity. All experiments within the thesis provide data indicating that a change in anxiety mood state between acquisition and transfer results in a decrement in performance; both if anxiety is added or removed between acquisition and transfer. That is, the optimal performance of movements are linked (directly or indirectly) to the mood state under which they were learnt. Furthermore, the latter half of the experiments aimed to investigate the motor control processes that are affected by the anxiety/mood specificity i.e. whether movement planning (offline processes) and/or adjustment to movements during execution (online processes) are affected. Results support a specificity framework within the construct of anxiety, indicating the motor control mechanisms responsible for this pressure-performance specificity interaction are associated with effortful and non-automatic parameterisation of movement. However, upon further detailed analysis we conclude that any changes in offline processes are a strategy to overcome the reduction in one's ability to utilise online control processes when performing and learning under anxiety. That is, practicing with anxiety conforms to specificity effects and the strategy that is deemed most useful for success under anxiety conditions is to enhance movement planning. This strategy appears to be due to anxiety disrupting the automatic processes associated with the use of online control. Specificity of practice also offers an alternative explanation for choking and raises important theoretical and practical issues within both the motor control domain and sport psychology domain. That is, experimental paradigms used and the conclusions drawn from them need to be considered with knowledge of the Specificity of Practice Hypothesis (Proteau, 1992).

CHAPTER 1

THESIS OVERVIEW AND INTRODUCTION

1.1. General Introduction

Enjoyment within sport can be gained from succeeding in our own performance (e.g., participating in running), or observing others perform (e.g., watching the Olympic Games). There were 900 million viewers who tuned in to watch the opening ceremony of the last Olympic Games and over 1.5 trillion people participate in running worldwide. The academic study of sport has assisted in this colossal growth by gaining and understanding knowledge within sport science. Sport science knowledge comes from a number of disciplines such as physiological, psychological, biomechanics, nutrition and motor control, all of which are contributing factors to successful performance.

Motor skills when viewed broadly are skills that allow the capacity to control one's body. The degree of skill human's possess is expressed through the ability to use movements to deal with the numerous problems encountered on a daily basis. Not only do humans utilize their skill base for everyday activity (e.g., walking, tying shoe laces etc.), humans are pursuing in their capacity for acquiring skill, demonstrated by the accomplishments shown by professional athletes, dancers and musicians. Acquiring and maintaining a skill contains both practice and learning, where one cannot be separated from the other. Without practice, no learning can take place. Motor learning research has both a theoretical and applied application by contributing to the academic knowledge. By observing how learning occurs can initiate the formation of successful training protocols along with creating optimal training environments.

1.2. Motor Learning

To be successful within learning and hence achieve success within performance, Fitts and Posner (1967) proposed three phases of learning which all individuals must progress through during the learning process. During the first stage called the cognitive stage of learning, the beginner focuses on cognitively processing problems related to what to do and how to do it. Performance during this stage is marked by numerous errors and the errors tend to be large. However, with correct practice beginners are able to progress onto the second stage of learning; this is called the associative stage. The transition into this stage occurs after an unspecified amount of practice and performance improvement. The cognitive demands change during this stage, as parts of the movements are controlled more automatically, allowing more attention to be directed to other aspects of performance. The individual can now attempt to associate specific environmental cues with the movements required to achieve the goal of the skill. The performer makes fewer and smaller errors as they have now acquired the fundamentals of the skill and are able to detect some of their own performance errors. Finally, only after extensive corrective practice and experience, people move into the autonomous stage of learning. Here the skill has become automatic. At this stage, people do not consciously think about their movements while performing the skill. Instead, performers are able to detect and correct their own performance error. Ericsson, Krampe, and Tesh-Romer (1993) reported that expertise in all fields is the result of intense practice for a minimum of ten years. A further critical point within this statement is ‘intense practice’. However, for performers to become experts within their field, this ‘intense practice’ needs to be effective and efficient in order to obtain an optimal training environment. If practice is not effective or efficient, then a good training environment would not be created and consequently learning would be poor.

To directly measure the success of practice on motor learning however, would involve observations within the central nervous system (CNS). Nevertheless, it is difficult to measure motor learning at this level (Magill 1989; Schmidt, 1988). Without the ability to peer into the CNS and see the changes that occur as a result of learning, we are forced to understand learning from observations on performance. Behavioural changes of learning are indicators of performance and can be used to assess learning by retention and transfer tests. Without such tests, research is only capable of assessing performance. A retention test of practice refers to a skill that a learner performs following an interval of time after practice has ceased. The purpose is to determine the degree of performance or persistence of the performance level achieved during practice; having a period of time in between practice and measures of retention allows this type of assessment. The critical assessment is the difference between the performers' performance level on the first day of practice and that on the test. If there is a significant improvement between these two periods of time, then a conclusion can be made in favour that learning has occurred. A transfer test examines the adaptability aspects of performance changes related to learning. This involves novel situations so that the performer must adapt the skill they have been practicing to the characteristics of this new situation (e.g., switching serving sides on court). Generally, there are four performance characteristics that are observed as skill learning takes place. The first example is skill improvement over a period of time (Magill & Anderson, 2014). Secondly, over a period of time, performance becomes increasingly more consistent (Magill & Anderson, 2014). This means that from one performance attempt to another, a person's performance characteristics should become more refined. Thirdly, the improved performance capability is marked by an increasing amount of time after a practice period has ceased or persistence (Magill & Anderson, 2014). This means that as the person progresses in learning the skill, the improved performance capability lasts over an increasing period of time. Finally, stability refers to how well skill performance can be maintained from perturbations that may be internal or external (Magill & Anderson, 2014). There are however limits to the amount of perturbation that can be overcome, for example a common internal perturbation is anxiety. Anxiety has been established as being hard to overcome, demonstrated by athletes failing to perform to their normal ability when experiencing a performance decrement under pressure conditions (Baumeister & Showers, 1986).

1.3. Anxiety

Optimal performance is the goal of all athletes, particularly when rewards are high. However, in pressure situations many athletes perform sub optimally despite high motivation to succeed (Baumeister & Showers, 1986). Within the field of sport psychology this may be described as ‘choking’; a phenomenon feared by both athletes and coaches. Nevertheless, dealing with anxiety is an integral part of competitive sport. Within the sport psychology literature, there is an abundant of theories and models that examine the effects of anxiety on performance. The first of its kind dates back to 1908 by researchers Yerkes and Dodson. Yerkes and Dodson tested the ability of mice to negotiate a maze while under different amounts of stress (conducted by electric shocks). Results showed that when arousal was low, performance was low. As arousal rose, an optimal level was reached where performance levelled off. However, if arousal continued to rise performance deteriorated until it eventually returned to a level equal to that during low levels of arousal. This created the Inverted-U shape relationship, which developed into the Inverted-U Theory (1908), also known as the Yerkes & Dodson law. Yerkes and Dodson further investigated into the complexity of a task by distinguishing complexity by the number of parts or components and the amount of information-processing demands that characterise a skill; more complex skills have more component parts and involve more information processing demands than less complex skills. The authors extended the Inverted-U Theory (1908) by concluding, the easier the task the higher level of anxiety is required for optimal performance whereas, the more complex tasks require lower levels of anxiety for optimal performance.

As a cause of being dissatisfied with the simplistic nature of the Inverted-U Theory, further theories have emerged for example the Cue Utilization Theory (Easterbrook, 1959); Hulls (1943) Drive Theory (that was later developed by Spence,1958); the Multidimensional Anxiety Theory (Martens, Burton, Vealey, Bump, & Smith, 1990) which lead on to the development of Catastrophe models (Hardy & Fazey, 1987). The Multidimensional Anxiety Theory (Martens et al., 1990) is based on the assumption that competitive anxiety is comprised of two distinct parts; a cognitive component (e.g., worrisome thoughts), and a somatic component (e.g., clammy hands). Both were hypothesised to have separate effects upon performance. Martens and colleagues proposed that somatic anxiety had an Inverted-U shaped relationship with performance, whilst cognitive anxiety had a negative linear relationship with performance. A third subcomponent discussed by Martens et al. (1990) was the individual difference factor of self-confidence. This encompasses the athletes' global perceptions of confidence and was shown to have a positive linear relationship with performance. The most complex of models is that of the Catastrophe Model which was originally developed by the French mathematicians Rene Thorn (1975) in the field of topology. In order to elucidate the relationship between anxiety, arousal and performance, Hardy and Fazey (1987) applied the cusp catastrophe model to sport performance. The three dimensional cusp catastrophe model is able to predict ones performance or behaviour based on an interaction of an individuals arousal and anxiety levels. The model proposes that anxiety is comprised of two sub-components. However, rather than using somatic anxiety as the asymmetry factor, Hardy & Fazey (1987) use physiological arousal, which may have a direct effect upon performance (i.e., actual heart rate and body tension rather than perceptions of). Hardy & Fazey (1987) state under conditions of low cognitive anxiety, an increasing level of physiological arousal shows an Inverted U relationship to performance. However, a performance catastrophe will occur if the individual is experiencing high cognitive anxiety.

That is, under high cognitive anxiety, an increase in physiological arousal will lead to a sudden and dramatic drop in performance. A central prediction of the catastrophe model is that when cognitive anxiety is high, the path followed by performance is different when physiological arousal is increasing to the path followed by performance when physiological arousal is decreasing. In other words, the catastrophic drop in performance occurs at a high level of physiological arousal. However, performance will only be reinstated after a significant drop in physiological arousal has occurred. This horizontal displacement of behaviour (performance) is termed hysteresis and should only occur under conditions of high cognitive anxiety. Support for the hysteresis effect has been found in both the initial studies that have directly tested it (Hardy & Parfitt, 1991; Hardy, Parfitt, & Pates, 1994). An extension of this model known as the Butterfly Catastrophe Model (Hardy, 1966) contains two further factors: a bias factor and a butterfly factor. The bias factor suggests that self-confidence might moderate the interaction between cognitive anxiety and physiological arousal in that, high levels of self-confidence will allow performers to tolerate higher levels of physiological arousal when they are cognitively anxious before suffering a decrement in performance.

The above review gives a brief overview into early theories/models that attempt to explain the relationship of anxiety on performance. However, these theories/models do not address the specific theoretical reasons for the detrimental effects of anxiety on performance. In attempts to explain the effects of anxiety on performance, two somewhat competing theoretical positions have emerged in the literature: one that is based on distraction and one that is based on self-focus.

1.4. Distraction Based Theories

Distraction theorists (e.g., Eysenck & Calvo, 1992; Wine, 1971) propose that pressure causes an individual's attention to be partially consumed by task irrelevant stimuli (e.g., worry) that consumes resources of the working memory system. It is proposed that anxiety has two detrimental effects. Firstly, anxiety uses up working memory capacity leaving less working memory resources for the task at hand. As a consequence, the resources available for the task at hand are reduced thus leading to decrements in performance. Further, any adverse effects of worry on task performance should be greater on tasks that exert large demands on the capacity of the working memory system. Secondly, high levels of cognitive anxiety can cause distraction away from the primary task.

One core theory within distraction based theories is Attentional Control Theory (ACT; Eysenck, Derakshan, Santos & Calvo, 2007). ACT is an extended theory which originated from Processing Efficiency Theory (PET; Eysenck & Calvo, 1992). ACT extended the scope of PET by precisely identifying the effects of anxiety on the functioning of the central executive. Whereas PET merely states that anxiety affects the central executive, but fails to specify which central executive functions are adversely affected by anxiety. It has been proposed by Smith and Jonides (1999) that there are five different functions within the central executive (e.g., switching attention between tasks; planning subtasks to achieve a goal; selective attention and inhibition; updating and checking the contents of working memory; and coding representations in working memory for the time and place of appearance). A major assumption within the theory is that, worry impairs the efficiency of the central executive by consuming resources in the processing and storage of a limited capacity working memory system (Baddeley, 1986). This theoretical position is founded in the assumption that attention is regulated by (1) a goal-directed attentional system, and (2) a stimulus-driven attentional system (Corbetta & Shulman, 2002). The goal-directed attentional system is governed by expectations, knowledge, and current goals that exemplifies top-down attentional control. In contrast, the stimulus-driven attentional control system is sensitive to salient stimuli, and exemplifies bottom-up attentional control. Importantly, ACT proposes that anxiety modulates the balance between these two attentional systems. Anxiety is associated with an increased influence of the stimulus-driven attentional system and a decrease influence of the goal-directed attentional system. To further explain, ACT makes specific predictions about the lower level functions of the central executive of working memory that are linked to the goal-directed attentional system (see below).

Eysenck et al. (2007) propose 6 hypotheses based within ACT. The first hypothesis is that anxiety impairs processing efficiency to a greater extent than performance effectiveness on tasks involving the central executive. However, the impairment within working memory does not necessarily lead to decrements in performance, provided that anxious individual's respond to processing inefficiency by using compensatory strategies such as enhanced effort and use of extra processing resources. The second hypothesis of ACT states that adverse effects of anxiety on performance become greater as overall task demands on the central executive increase. Therefore, it will become increasingly unlikely for anxious individuals to compensate for impairment through increased effort and use of resources as overall task demands/difficulty increases. The third hypothesis assumes that anxiety impairs attentional control by increasing the influence of the stimulus-driven attentional system. This assumption focuses on the general aspects of attentional control and how anxiety affects the stimulus-driven attentional system. The general assumption is that anxiety impairs attentional control either by a reduction in the inhibition function or shifting function. This was a major development within ACT that extended the scope of PET. The fourth hypothesis is that anxiety should disrupt the ability to suppress task-irrelevant information. For example, anxiety has been associated with impaired inhibition of task irrelevant material in the absence of threat (Ansari & Derakshan, 2011; Bishop, 2009; Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009; Righi, Mecacci, & Viggiano, 2009). Behaviourally, this effect has been shown particularly in the anti-saccade task. The anti-saccade task was identified as a simple task that is as "process pure" as possible so that findings obtained are interpretable (Miyake et al., 2000). The task involves a visual cue being presented to the left or right of the fixation point, and the instructions are to make an eye movement to the opposite side of the visual cue as rapidly as possible. The latency of the first saccade to the correct side is one of the main dependent variables of interest. There is also a control task (the pro-saccade task), in which the instructions are to fixate the cue when it appears. According to ACT, adverse effects of anxiety in terms of latency of the first correct saccade should be presented with the anti-saccade task but not the pro-saccade task. This was supported where high-anxious compared to low-anxious individuals, were slower to initiate an eye-movement away from neutral oval shape cues and angry face cues compared to happy and neutral face cues (Derakshan et al., 2009a). Furthermore, high-anxious individuals were no slower on pro-saccade trials where they were instructed to simply look towards the cues, eliminating the involvement of inhibitory processes (Derakshan et al., 2009a). The fifth hypothesis within ACT suggests that anxiety is associated with a reduced ability to shift attention between relevant task demands. The task-switching paradigm provides a relatively direct assessment of the shifting function (Miyake et al., 2009). The basic paradigm involves two conditions in each of which participants perform the same tasks (A and B). In the control condition, each block of trials is devoted to only one task. In the experimental condition, each block consists of a mixture of trials on task A and task B. The slowing and/or greater number of errors in the experimental than in the control condition provides an assessment of the shifting function. Derakshan, Smyth, & Eysenck (2009b) used pairs of task (multiplication and division or addition and subtracting) to investigate this hypothesis and found that high anxious participants were significantly slower in a task-switching paradigm than in a single task control condition. While low anxious participants showed no cost differences for either condition. Furthermore, the effects of anxiety on task switching were increased as a function of task complexity, such that high anxious individuals performed worse when switching between difficult compared with easier tasks. Finally, hypothesis six explains that anxiety impairs processing efficiency (and sometimes performance effectiveness) on tasks involving the updating function only under stressful conditions. This is defined as the ability to update and monitor representations in the working memory. According to ACT, updating does not directly involve attentional control. However, as the overall demands on the central executive are increased, there is a reduction in processing efficiency, which may produce impaired performance on updating working memory. It is therefore presumed that anxiety may only affect the updating system under stressful conditions. ACT has received empirical support from a number of studies (e.g., Behan & Wilson, 2008; Coombes, Higgins, Gamble, Cauraugh, & Janelle, 2009; Eysenck et al., 2007; Eysenck & Derakshan, 2011; Nieuwenhuys, Pijpers, Oudejans & Bakker, 2008; Vickers & Williams, 2007; Wilson, 2008; Wilson, Vine, & Wood, 2009a).

Recently, Wilson, Vine, and Wood (2009a) support the predictions of ACT in a sport setting using a basketball free throw task. The authors used the quiet eye period as a goal-directed measure of attentional control. Quiet eye period in the study was defined as the final fixation directed to a single location or object in the visuomotor workspace within 1 degree of visual angle or less, for a minimum of 120ms (Vickers, 1996). Findings in the study found that the duration of the quiet eye period significantly reduced (by 34%) in a high-threat compared to the control condition. Authors suggested these shorter quiet eye periods in the high-threat condition reflect a disruption caused by anxiety to the mechanisms involved with attentional control (Eysenck et al., 2007). Furthermore they speculate that these disruptions are due to an increase influence of the stimulus-driven attentional system at the cost of the goal-directed control system. This result is similar to previous studies that have investigated the effects of anxiety on the quiet eye period in far aiming tasks (Behan & Wilson, 2008; Vickers & Williams, 2007). The reduction in goal-directed attentional control led to a significant drop in performance effectiveness (reduced free throw percentage accuracy) as predicted by assumptions within ACT.

A second study by Wilson, Vine, and Wood (2009b) aimed to explore anxiety-induced attentional alterations contributing to suboptimal penalty kick performance, using ACT (Eysenck et al., 2007) as an overarching framework. Three gaze measures (i.e., time to first fixation on the goalkeeper; total fixation duration; total number of fixations) were adopted to reflect potential differences in the way participants oriented toward, and maintained attention on, the two target locations (i.e., goal and goalkeeper) in both conditions (i.e., low and high anxiety). Results revealed that experienced footballers looked at the goalkeeper significantly earlier and for longer periods when anxious, with these changes in attentional control negatively influencing resultant shot placement. The authors reported that these results are supportive of anxious individuals having an attentional bias toward threatening stimuli, probably owing to a disruption in the balance between the goal-directed and stimulus-driven attentional control systems.

Hardy and Hutchinson (2007) used a “real world” sport setting to examine the predictions of PET (Eysenck & Calvo, 1992) but results also support the predictions of ACT. Specifically, they conducted three experiments in which performance, anxiety, and effort were recorded as rock climbers scaled a challenging rock face. The three studies differed in the way that they controlled for learning effects. In the first study, anxiety was manipulated by assessing climbers leading climbs that were at the limit of their ability compared with climbs that were below this limit. In the second study, all participants led routes that were at the limit of their ability and those who responded with high levels of state anxiety were compared with those who responded with lower levels. In the third study, comparisons were made between experienced climbers leading a route at the limit of their ability and then seconding a similar route of the same difficulty. It was hypothesised that the more difficult climbs, and those that were led compared to top-roped, would elicit greater anxiety and effort. These hypotheses were supported in all three studies. Cognitive anxiety was greater during the leading condition in two of the three studies. Performance, indexed by ratings awarded by an experienced observer, improved with additional effort in two of the three studies. However, performance was impaired in the most anxious climbers in the remaining study (study 3). In this study, it appears that when anxiety is too elevated, compensatory strategies may eventually become of no use. Interestingly in study 3, somatic anxiety and not cognitive anxiety was related to an increase in effort. These findings support the suggestion that anxiety has both attentional and motivational effects, and that anxiety impacts processing efficiency more than performance effectiveness. Furthermore, the findings (from studies 1 and 2) support the predictions of ACT in that central task performance was maintained, at the expense of attentional processes in the anxiety conditions, through an increase investment of effort. This is not the only investigation to show that an increase in state anxiety can often be accompanied by an affiliated increase in compensatory effort (e.g., Oudejans & Pijpers, 2009; Williams, Nieto, Sanford, Couper, & Tyroler, 2002; Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006; Wilson, Smith & Holmes, 2007). Further, this increase in effort is associated with a performance enhancing self-regulatory process, leading to more effective attempts to counteract the negative effects of anxiety on performance (Lewis & Linder, 1997; Oudejans & Pijpers, 2009). Interestingly, Oudejans & Pijpers (2010) related their results from training with anxiety in a dart study to that of ACT, by speculating that the additional self-regulatory processes (i.e., increase in effort) eliminate the negative effects of anxiety on performance.

1.5. Self-focus Theories

An alternative self-focus explanation for anxiety induced performance failures have also received considerable support in the sport psychology literature (e.g., Baumeister, 1984; Beilock & Carr, 2001; Gucciardi & Dimmock, 2008; Lewis & Linder, 1997; Masters 1992). Self-focus theorist proposed that pressure raises self-consciousness/awareness, thus increasing the attention that is allocated to the skill in a step-by-step manner. The increase in self-awareness results from effortful allocation of attention to a previously automated process. Therefore, a breakdown of normal automatic processes and skilled performance occurs (Lewis & Linder, 1997). Masters' (1992) Conscious Processing Hypothesis (CPH) has emerged as one plausible self-focus model that attempts to explain the mechanisms underlying anxiety induced performance decrements. CPH predicts that an increase in state anxiety leads performers to direct their attention inward in an attempt to control their performed skill by using task relevant explicit knowledge. This is where highly skilled performers try to consciously monitor their performance in order to achieve success. However, what this actually does is interfere with the normal automatic task processing in exchange for inappropriate control strategies, as a result their performance suffers. Masters' work reflects upon the stages of learning (Fitts & Posner, 1967). His conceptualization is based on under stress; the unconscious covertly controlled process of a skilled movement becomes broken down, as performers attempt to gain conscious control over their actions. In doing so, performers adopt a form of control based on explicit or declarative knowledge, which is associated with early stages of learning (e.g., cognitive stage of learning). Masters hypothesised that if re-investment of conscious control over explicit knowledge disrupts performance, then minimising this information during the learning stages (implicit learning) should prevent breakdown of automatic processes under anxiety conditions (as there will be no access to explicit knowledge).

Masters (1992) examined CPH using a learning concept in which participants acquired the skill of golf putting over 400 trials, under implicit or explicit learning conditions (i.e., rule based learning). Masters found that stress had a detrimental effect on performance for the explicit learning group but not for the implicit learning group. However, the implicit learning group were required to perform articulatory suppression during the learning trials but not during the stress trials. As such, it is possible that the subjects in the implicit learning group continued to improve during the stress session simply because they were performing an easier task. Hardy, Mullen, and Jones (1996) replicated and extended Masters (1992) study. An additional implicit learning group was included, which was required to carry out articulatory suppression during both the learning trials and the stress trials. It was hypothesised the new implicit learning group would suffer the same disruption to performance as the explicit learning group. Results revealed that those participants who learnt explicitly suffered performance decrements, whilst both the implicit learners continued to improve. However, Hardy et al. (1996) gave an alternative explanation for their own findings. Proposing that the reason why the implicit learners did not have a decrease in performance was due to performing articulatory suppression task during the previous 400 acquisition trials, where subjects had become desensitized to self-generated verbal distractions. Thus, when exposed to the stress condition, subjects in these groups may have become immune to the effects of performance anxiety. Despite the limitations within the study, these results add support to CPH, although the desensitisation issue warranted further investigation.

Dissatisfied with results from Hardy et al. (1996) study, Hardy, Mullen, and Martin (2001) designed an investigated into CPH that was not confounded by such desensitization effects. A performance rather than a learning concept was adopted, where experience trampolinists were asked to perform using explicit knowledge under low and high anxiety conditions. The coach called out a coaching point for each move in the performers' voluntary competition routine, where the trampolinists were asked to concentrate on using the explicit cues to guide their performance. The combination of explicit knowledge and high anxiety condition resulted in a decrease in performance, thus supporting CPH. However, the authors again gave an alternative explanation to their results in a way of attentional threshold. That is the anxiety effects may have been caused by a combination of the task relevant cues and anxiety consuming attentional resources, leading to the suggestion that attentional capacity may have a role to play in performance decrements in conditions of high anxiety. However a previous study conducted by Mullen and Hardy (2000) addressed the possible attentional overload explanation for performance decrements under high anxiety in a golf-putting task. Where the results from the study were supportive of a distraction explanation of anxiety, as performance was impaired in the high anxiety task-relevant and task-irrelevant conditions. Participants were required to putt 10 putts in each of the three experimental conditions; task-irrelevant, task-relevant and control conditions in low and high anxiety phases. After the low anxiety condition putters were separated into two groups, better and poorer putters based on putting performance from the low anxiety condition. Results revealed a decrease in performance with regards to the higher ability performers when there was an increase in anxiety. Additionally a decrease in performance was seen in the task-relevant and task-irrelevant manipulations under low anxiety conditions also within the higher ability performers whereas, the weaker performers was unaffected by increases in cognitive anxiety. This finding within the low-anxiety condition was not predicted, but can be accounted for given that the better performers may have possessed stronger levels of automaticity than the poorer performers. Poorer performers (novices) are not yet automatic (Fitts & Posner, 1967) therefore, the autonomy of the skill cannot be disrupted by conscious control as movements are already processed in this way. Consequently, it could be that the more expert putters potentially possess a stronger level of automaticity making conscious processing effects more prominent and the outcome more obvious in expert performers. Beilock and Carr (2001) also examined golf putting tasks and found that experts did in fact have fewer and lesser detailed memories of particular putts during execution. That is, if anxiety does indeed induce conscious processing, this would certainly be damaging for expert performers that would have learnt under a step-by-step process. Therefore, resulting in a breakdown of normal automatic processes under pressure (i.e., CPH).

In review, the chapter so far has outlined several models that explain the anxiety performance relationship, and theories which offer mechanistic explanations for performance decrements in conditions of high anxiety. There have been critics to both ACT and CPH, where research cannot agree whether ACT or CPH is the better theory to explain performance decrements under pressure. A number of other avenues of research must also be explored in an attempt to highlight a variety of factors that could be considered to have a part to play in performance decrements.

It has been proposed in order to combat the effects of anxiety, learners should direct their attention to an external or internal focus (Beilock, Carr, MacMahon, & Starkes, 2002; Wulf & Prinz, 2001). Masters (1992) along with Hardy, Mullen and Martin (2001), focused upon the use of explicit knowledge in performance impairment. In contrast, Wulf and colleagues concentrated upon the notion of attentional focus. Attentional focus can be directed internally or externally. Wulf and colleagues have found consistent support for an external focus of attention, which encourages novices to focus on the effects of their movements rather than to the body movements itself (an internal focus). Research indicates that when novice participants make use of external focus, learning is more effective and therefore performance is enhanced (Landers, Wulf, Wallmann, & Guadagnoli, 2005; Totsika & Wulf, 2003; Wulf, Hob, & Prinz, 1998; Wulf & McNevin, 2003; Wulf, Shea, & Park, 2001). If this research is taken within the concept of CPH, a type of focus that directs a performer's attention away from the movement itself and discourages accessing explicit knowledge about the task, it is more likely to prevent conscious processing effects. Therefore, an external focus of attention would be more beneficial under condition of elevated anxiety than an internal focus of attention.

A related but slightly different view of research centred on CPH investigates a specific type of self-focus labelled explicit monitoring. Beilock and Carr (2001, 2011) establish that an increase in pressure led to impaired performance in a golf-putting task, providing evidence that self-focus leads to performance impairment when combined with an increase in pressure. Beilock and Carr went on to demonstrate that beginners who learnt under conditions with increased self-consciousness (i.e., internal focus of attention), eventually performed better with similar increased self-consciousness, by developing a performance enhancing self-regulatory process. This involves an increase in effort expended on task processing in an attempt to gain cognitive control. It is the learning with self-focus that protects against performance decrements in future anxiety situations (Beilock & Carr 2001; Lawrence et al., 2012a). Therefore, if we take the assumption that anxiety creates an increase in attention to consciously control movements from the framework of CPH, together with the finding produced by Beilock and Carr, (2011); beginners who learn under conditions with increased self-consciousness eventually perform better with similar increased self-consciousness. It would be reasonable to assume that the effects of learning with anxiety (i.e., increased self-consciousness) would perform better in similar anxiety induced conditions (i.e., increased self-consciousness). Supporting this “acclimatisation hypothesis” that demonstrates self-consciousness training reduces choking (Beilock & Carr, 2001; Lewis & Linder, 1997) hence, supports anxiety induced training.

1.6. Training with Anxiety

Despite previous research indirectly signifying the possible benefits of training with anxiety (e.g., to protect against choking), surprisingly little research within this area has emerged. Recently however, researchers have begun to directly test the effects of practicing under conditions of anxiety on anxiety retention tests (e.g., Nieuwenhuys & Oudejans, 2010; Oudejans, 2008; Oudjans & Pijpers, 2009). The first investigation of note (Oudejans, 2008), utilised a cohort of police officers and investigated performance under hand gun shooting tasks. Specifically, Oudejans used a pre-test, post-test, retention test design, where 27 police officers executed a shooting exercise against an opponent that did (high anxiety) or did not (low anxiety) shoot back using coloured soap cartridges. During the training sessions, the experimental group practiced with anxiety and the control group practiced without anxiety. All participants were then transferred to high anxiety conditions where results indicate for those police officers who practiced in control conditions and transferred to anxiety conditions shooting accuracy decreased significantly when they performed in high-anxiety conditions. However, those who practiced under anxiety conditions and transferred to anxiety conditions, shooting accuracy significantly increased.

The second study to investigate the effects of practicing with anxiety involved two experiments, basketball free throws and dart throwing (Oudjans & Pijpers, 2009). The first experiment had 17 expert basketball players practice free throws over a 5-week period with or without induced anxiety. In experiment 2, 17 expert dart players practiced dart throwing from a position high (anxious) or low (control) on a climbing wall. After training, all participants in both experiments were tested under low, mild, and high anxiety. Results demonstrated that the groups that had trained with anxiety performed equally well on all three tests, while performance of the control group deteriorated with high anxiety.

The Nieuwenhuys & Oudejans (2010) more recent investigation incorporated novices practicing dart throwing (similar to the procedures by Oudejans and Pijpers, 2009). Participants were stood on a platform low on a climbing wall either with or without mild anxiety. After training, participants were tested under low, mild, and high anxiety (in the latter case high on the climbing wall). In line with Oudejans and Pijpers (2009) the rational for this study was to examine whether the effects of training with high anxiety can be experienced from training with mild anxiety, also if these effects have both a short (same day) and long term (4 months) effect in future anxiety conditions. Findings revealed that the experimental group (those who practiced under mild anxiety) were able to maintain performance in future anxiety conditions compared to the control group. These results highlight that training under mild anxiety may have positive short and long term effects on 'dart players' accuracy under pressure.

In all of the above Oudejan and colleagues studies, participants were transferred to anxiety conditions at some point, allowing a conclusion that training with mild anxiety was effective in preventing deterioration in performance in subsequent similar anxiety induced conditions. During the same studies, an increase in anxiety was also associated with an increase in effort. Oudejans and colleagues proposed that this pattern of results reflects processing efficiency decreases that can be explained by ACT (Eysenck et al., 2007). That is, in order to combat the effects of anxiety, participants use compensatory strategies such as enhanced effort, and greater processing resources in order to maintain performance under the anxiety retention tests. Support for this can be seen from the congruent findings across all three studies, whereby the groups who practiced under control conditions were able to maintain performance when transferred to mild anxiety (presumed to be due to increases in task effort). However, performance decreased when the control groups were transferred to high anxiety conditions whereas, the group training under mild anxiety conditions were again able to maintain performance. The authors speculated about why training with anxiety may prevent choking, via the assumption that an increase in effort is due to an attempt to reduce or eliminate the negative effects of anxiety in order to inhibit distraction or interference from task-irrelevant information. Oudejans and colleagues conclude that these self-regulatory processes become more effective during training with anxiety. Whilst plausible, it is noteworthy that Oudejans and colleagues can only speculate about the precise nature of the self-regulatory process and the enhanced effectiveness under anxiety conditions because the research did not measure them directly.

Whilst Oudejans experiments demonstrate that participants can perform more effectively in anxiety tests preceding a period of training under anxiety conditions, the methodologies were designed such that participants in the anxiety training conditions completed all training under conditions of anxiety. Thus, it is not clear whether the positive effects of training with anxiety are subject to learning effects (i.e., whether the performance in the anxiety post-test increases as a function of the amount of practice under anxiety conditions). Furthermore, with participants completing all their practice under conditions of anxiety, Oudejans and colleagues were unable to investigate if it is important to consider where during the learning process anxiety should be introduced in order to achieve the most effective training environment. Additionally, the research designs did not allow investigations into whether the benefits of practicing with anxiety are transferred to low anxiety conditions. Thus, it is possible that the positive effects of anxiety training are specific to retention tests of a similar mood state. Testing this possibility is important because it has been proposed within the motor control and learning literature that participants develop a movement plan to optimize the sensory information present during acquisition, and that this movement plan is specific to the information available at acquisition (Elliott, Chua, Pollock, & Lyons, 1995; Khan & Franks, 2000; Khan, Franks, & Goodman, 1998; Mackrous & Proteau, 2007). If this specificity effect is present within the construct of anxiety then when participants practice in anxiety conditions, movement plans may be developed that are specific to the sensory information available during that condition (i.e., anxiety). Thus, when performers transferred to different mood conditions (i.e., control) the movement plans developed during acquisition will no longer be applicable for successful performance. Without these anxiety-practice to control-retention/transfer test comparisons, Oudejans and colleagues are unable to rule out specificity as an explanation for the positive effects of training with anxiety.

1.7. Framework of Specificity

Research within this domain can be traced back to nearly 50 years, to that of Henry (1968). Henry proposed that the best learning experiences are those that most closely approximate the movements of the target skill and the environment conditions of the target (i.e., specificity of learning). Henry agreed that practicing a particular movement improves performance of that movement, but argued that these improvements cannot be reliably used to predict performance changes in another related movement or situation. This is because he proposed that improvements or changes in performance are skill specific, and thus transfer from one practiced movement to another is difficult. There are several studies supporting this specificity notion dating back as far as Bachman 1961. Bachman investigated the degree of specificity in learning two motor skills both requiring balancing ability. Participants were required to practice both a stabilometer task and a freestanding ladder-climbing task. The rationale being that both tasks require a number of body systems to work together to ensure efficient balance and successful performance. Because the skeletal system (the muscles and joints and their sensory) work in coordination with each other to maintain balance (Torres-Oviedo, MacPherson, & Ting, 2006) one could therefore predict that, good performance in one balancing task would result in good performance in another balancing task. However, Bachman (1961) found that correlations between the two tasks were near zero and often negative, providing support that there is not a general motor coordination ability for balance, or that performance in a skill are specific to that skill i.e., that motor abilities are task specific for both performance and learning.

Another study by Adams, Goetz, and Marshal (1972) set out to investigate the use of feedback of motor learning where results further support specificity of learning. The study consisted of 4 groups, two that practiced with knowledge of results (KR) and two groups without KR. The two groups without KR were subdivided further into low amount of practice (i.e., 15 trials) and large amount of practice (i.e., 150 trials). The task was a linear position task whereby participants were required to place their hand at a fixed start position and then move to a target 10 inches away. After practice in their respective group, all participants were either transferred to the opposite KR condition or remained in the same condition and repeated the task a further 50 times. Results revealed that when participants changed KR conditions, performance decreased compared to that of acquisition. Furthermore, this decrease was greater for those who practiced in a condition for longer (i.e., participants who practiced for 150 trials had a larger decrease in performance under transfer conditions when compared to those who only practiced for 15 trials) offering support for specificity of practice.

Despite the results of the aforementioned research, the Specificity of Practice Hypothesis (SPH) was not explicitly coined until 1992 (Proteau, 1992) and offers explanations why retention and transfer performance tend to be better when the practice and test contexts are similar relative to (a) the sensory/perceptual information available (Proteau, 1992), (b) the environmental context in which the skill is performed (Henry, 1968), and (c) the congruity between the emotions at practice and transfer (Gilligan & Bower, 1983). Proteau's SPH, investigations have examined the effects of specificity on sensory conditions during acquisition primarily with the removal and/or the addition of the sensory information derived from the eye (i.e., vision). It has been identified through research that the removal of vision after moderate and extensive levels of practice results in a significant decrease in performance (Khan et al., 1998). More surprisingly, the addition of vision has also revealed a significant decrease in performance after moderate and extensive levels of practice without vision (Proteau, 1992). This provides compelling support for SPH since one would likely assume that providing vision during an aiming task would result in an increase in performance compared to a no vision condition. However, the finding that the addition of vision after an extended period practice with no vision resulted in a decrement in performance suggests that participants develop motor control strategies during acquisition that are specific to the sensory information available during that time. To the extent that if a significant source of information is added or taken following a period of practice the strategies developed are no longer suitable for successful performance.

One of the seminal research articles investigating specificity within the vision domain was conducted by Luc Proteau and colleagues (Proteau, Marteniuk, Girouard, & Dugas, 1987). The task consisted of a pointing aiming movement. Participants were divided into four experimental groups divided into two experiment groups (full vision and no vision). Where half the experimental groups completed a period of brief acquisition of 200 trials performed on a single day whilst the other two groups completed a period of extended acquisition of 2000 trials at a rate of 400 trials a day on five consecutive days. Following the last training trial and after a two-minute rest, all participants were submitted to 20 test trials with no vision. The results of the study demonstrated that full vision practice led to decreased target accuracy in the transfer condition relative to the groups that practiced in the no vision condition. Furthermore, the performance decrement was found to be more profound for the extended practice (2000 trials). These results reflect the development of a sensory specific movement representation with practice. That is, they demonstrate that the withdrawal of sensory information (i.e., vision) previously available during acquisition disrupts the performers' ability to accurately perform the same movement. This early work was supported by Proteau and colleagues (Proteau, Marteniuk, & Levesque, 1992), in their compelling no vision to vision experimental design. That is, they demonstrated the same pattern of specificity effects as observed in the Proteau et al.,'s (1987) study when the acquisition to transfer was from no vision to vision.

SPH has been postulated to occur in two parts: (1) learning is specific to the sources of afferent information available during acquisition, and (2) specificity increases as a function of practice. However, in a study concerning power lifting squats (Tremblay & Proteau, 1998), results revealed somewhat contrasting findings to the assumptions of SPH. The experiment required participants to squat and stabilize their thighs at a horizontal orientation under three different sources of afferent information conditions; (1) normal vision, (2) normal vision aided by a laser beam attached to the leg, or (3) lights off. Results revealed that transfer to a light off condition, only the group who practiced under normal vision aided by a laser beam experienced significant decrements in performance. Given the predictions of SPH, one might predict that removal of vision in the lights off transfer test would have resulted in a similar decrement in performance in the normal vision acquisition condition. Since no such effects were observed, Tremblay & Proteau amended SPH to include the proposal that performers process the source of afferent information, which is easier to use or more likely to improve performance to the detriment of processing other sources of afferent information. Thus, the specificity effect is only observed if a change in the predominant source of afferent information occurs between acquisition and transfer. To account for their power lifting findings, Tremblay and Proteau proposed that the participants who acquired the skill in normal vision conditions were able to maintain performance in transfer (i.e., lights off) because the source deemed most useful for successful performance during acquisition was actually proprioception not vision. Thus, when these participants were transferred to the lights off condition performance was maintained because the dominant source of proprioception was still available. However, it was proposed that the addition of the laser beam during acquisition was deemed by participants in that group to be a more useful source of information than vision or proprioception. Consequently when the laser was removed in transfer, performance could not be maintained.

In line with the specificity framework, research has shown that learning is enhanced when there is high congruity between a learner's mood state during acquisition and subsequent recall (i.e., as well as the sensory specificity effects proposed within the motor control and learning literature, emotions and mood states also conform to principles of specificity). The rational stems from Gilligan and Bower's (1983) network theory of affect, which states that emotions can be regarded as units within a semantic network that connects related events, ideas, and muscular patterns. According to Gillian and Bower, the brain stores information and memories in nodes, which then connect with associated memories linking to events, ideas, and muscular patterns. The activation of a node results in a spreading of this activation through the network to the linked associations. Nodes can be semantic (with straight forward meaning) or affective (with emotional meaning). Therefore, when the learner is required to recall what was learned, if the mood at time of acquisition is equal to that at recall, then the mood activation will lend to the activation of the appropriate emotional nodes. Importantly, the activation of the mood (e.g., anxiety) will activate the associations (e.g., events, ideas and muscular patterns) linked to that node resulting in greater recall of all associated aspects. Gilligan and Bower also associated nodes with inhibition. They suggest that nodes can inhibit one another as a form of negative association. Thus, when we are happy it is difficult to think of associations that were linked to a sad mood state, and vice versa. Therefore, if the match between mood at learning and mood at time of recall are not congruent, a form of negative association with nodes could be experienced which inhibits recall performance.

Bower, Monterio, and Gilligan (1978) investigated the principles of the network theory of affect by asking participants to learn a list of words in an induced sad or happy mood state, before asking them to recall the list in either the same or the opposite mood state. As predicted, recall performance was dependent on the congruency between the mood at the time of learning and that at the time of recall testing. The authors thus concluded that a person's emotional mood state does serve as a distinctive context for learning and retrieval of memories.

The mood retrieval paradigm has provided consistent support via the work of Teasdale and associates (Teasdale & Fogarty, 1979; Teasdale, Taylor, & Fogarty, 1980; Teasdale & Taylor, 1981). In their research participants' moods of elation or depression were induced before being asked to give a real life memory associated with a word stimulus (e.g. money). The authors predominantly found that happy memories would be recalled when the participant was induced with an elated emotion, whereas sad memories were recalled when participants were under a depressed emotion. Interestingly, the time it took participants to retrieve a memory was longer if their induced mood and the effective connections of the experience mismatched compared to matched conditions. Research has revealed mood congruity or specificity effects in similar word learning paradigms (Bower, 1981), as well as recall of past events (Snyder & White, 1982), and personal experiences (Alexander &

Guenther, 1986). Collectively, these data and findings provide solid empirical support for the concept that the activation of an affective node (with emotional meaning; e.g., happiness) leads to an increase in recall e.g., support the network theory of affect.

An important implication of this sort of network model of retrieval is that, memory for an event or fact depends on the similarities between the environmental and cognitive element present during retrieval. When those elements overlap, memories for the event or fact become probable. Hence, with relation to anxiety it is not surprising that a number of studies have found that learning with self-focus (i.e., consciously) protects against future induced anxiety situation (Beilock, Bertenthal, McCoy,& Carr, 2004; Beilock & Carr, 2001; 2011; Ford et al., 2005). Beilock and Carr demonstrated that beginners who learnt under conditions with increased self-focus (i.e., internal focus of attention), eventually performed better with similar increased self-consciousness. Thus introducing anxiety into the training environment to enhance subsequent performances under anxiety would support the principles of the network theory of affect. That is, both the learning and subsequent skill recall stages are mood congruent which should lead to enhanced performance.

1.8. Offline vs. Online Control

Sensory systems play a big role within everyday life, from picking up a glass of water to catching a ball. To carry out an action requires the gathering of information from the sensory systems such as proprioception and visual. An increase in knowledge about their anatomical and physiological basis and how they influence and limit the control of movement can only be of benefit to an athlete. By understanding the underlying mechanisms of movements and techniques proposed as to how one can measure these in an experimental setting, allows researchers within the stress and performance domain to further investigate the effects of pressure on performance.

Sensory information is an important source of feedback both during movement execution and in the assistant of planning a movement (see Elliott et al., 2001 and Khan et al., 2006 for reviews). When movement is rapid or ballistic, afferent sensory information is available, but humans cannot make movement corrections during execution because of the time limitation involved in processing and acting on the information available (Khan et al., 2003a). Within the literature of motor control the use of vision and no vision in performing accurate aiming movements have received a great deal of research attention (Khan, Lawrence, Franks, & Elliott, 2003b; Khan, Lawrence, Franks, & Buckolz, 2004; Khan et al., 2006; Mackrous & Proteau, 2014; Proteau, Marteniuk, Girouard, & Dugas, 1987). It is commonly accepted that the availability of sensory feedback improves movement accuracy provided that movement durations are long enough to encompass visuomotor delays (Calton, 1992). If movement durations are too short or vision is presented too late during a movement then the differences in accuracy between the vision and no vision conditions is reduced (Khan, Lawrence, Franks, & Elliott, 2003b; Khan, Lawrence, Franks, & Buckolz, 2004). Interestingly, researchers also acknowledge that the benefit of vision may not only be due to online processing of visual feedback whereby adjustments to the trajectory occur during movement execution. It is possible that visual feedback from a completed movement is processed offline as an enriched form of KR to adjust movement programming on subsequent movements (Abahnini, Proteau, & Temprado, 1997; Bedard & Proteau, 2004; Blouin, Bard, Teasdale, & Fleury, 1993; Khan et al., 2004b; Khan et al., 2003b; Khan et al., 2006; Lawrence, Khan & Hardy, 2012; Zelaznik, Hawkins, & Kisselburgh, 1993). Thus, visual feedback is not just used online (to correct movements) but also offline (to adjust movement planning) in order to successfully execute a movement.

Researchers have proposed several hypotheses to explain the motor control processes related to the speed-accuracy trade-off, most of which have elaborated on Woodworth's

(1899) original hypotheses. Woodworth hypothesised that aiming movements consist of two phases; the initial impulse phase which is designed to move the limb into the vicinity of the target (where the initial movement speed, direction, and accuracy are under the control of pre-programmed movement plan), and the error correction phase where visual feedback about the limb's position relative to that of the target is used to guide the final end point of the movement (i.e., the "homing in" phase of the limb to ensure its accuracy when landing on the target). The amount of time available is the primary determinant of whether a person can make movement corrections as the limb nears the target (for reviews see Elliott et al., 2001; 2010). This means that if the movement is too fast during the initial impulse phase there will not be sufficient time for visual feedback to generate a movement adjustment as the limb nears the target. Thus, successful performance would be dependent on successful planning of a movement offline as opposed to error detection and correction during movement execution online.

The question of what is the minimum amount of time required for movement corrections to be carried out on the basis of visual feedback dates back to more than a century to the work Woodworth (1899). Woodworth's experiments involved horizontal aiming movement tasks, where participants were instructed to produce reciprocal movements between lines a fixed distance apart or, to match the amplitude of a movement to the previous trial. In order to investigate the time in which information could be processed, Woodworth had participants perform the experiment under different movement time conditions where vision was manipulated by having participants open or close their eyes during the movements. Results demonstrated that movements with the shortest durations were no more accurate when the eyes were open to when they were closed, suggesting that vision is not available for use at very fast movement times. The results allowed further developments to this suggestion by indicating a positive relationship between an increase in movement times

(> 450ms) with a decrease in spatial error when eyes were open but, revealed no such relationship under the eyes closed conditions. This lead Woodworth to conclude that, the time to process visual feedback for the control of movement was around 450ms. For movements of duration longer than 450ms, Woodworth suggested that end-point accuracy is dependent on the time the performer has available for the current control.

Although Woodworth's (1899) description of how limb movements are controlled is well established, his estimates of time required for visual processing have proved largely inaccurate. Keele and Posner (1968) argued that Woodworth over-estimated the visual processing time due to the reciprocal methodology, which included not only the time needed to travel between the two targets lines but also the time needed to reverse the direction of the sliding movement at each of the target locations. Keele and Posner (1968) conducted an influential aiming study, where of interest was the finding that participants exhibited greater accuracy when they had vision available at all movement time conditions (150ms, 260ms, 350ms and 450ms) except 190ms. The results left the authors concluding an estimate of visual processing time to reside somewhere between 190ms and 260ms. This may seem a confusing conclusion since participants exhibited greater movement accuracy in the 150ms condition, yet significant empirical work by Keele and Posner (1968) further explains implications of why this is; Keele believed that the commencement of a goal-directed movement is under the control of a pre-planned set of muscle commands (e.g., offline) and is under the control of this motor program for approximately 200ms. That is, until the CNS has time to process visual and/or proprioception feedback (e.g., online)

Building on previous ideas presented by Crossman and Goodeve (1983), Keele (1996) formalised the concept of the motor program by defining it as "a set of muscle commands that are structured before a movement sequence begins, that allow the entire sequence to be carried out uninfluenced by peripheral feedback" (p. 387). Similar to Woodworth (1899), Keele and Posner (1968) believed that the commencement of a goal-directed movement is under the control of a pre-planned set of muscle commands (e.g., offline). The movement is under the control of this motor program for approximately 200ms until the CNS has time to process visual and/or proprioception feedback (e.g., online). The second phase of the movement (e.g., online error correction) is proposed to be under control of a new motor program and if time permits, feedback is used to detect and correct any errors. However, kinematic data that has become available, have found no consistency with the notion of these multiple corrective sub movements within movement control (Carlton, 1979; Langolf, Chaffin, & Foulke, 1976). Instead, researchers Beggs and Howarth (1970, 1972; Howarth, Beggs & Bowden, 1971) propose that a single ballistic movement brings the limb into the vicinity of the target, and where time permitting, a single corrective movement is made based on visual feedback about the relative positions of the limb and the target.

The congruency between the proposals of Woodworth (1899), Keele and Posner (1968), and Beggs and Howarth (1970, 1972) is that they all assumed an increase in spatial accuracy is a direct function of the amount of visual information picked up at the initiation of the movement. Where the first part of the movement (e.g., offline) must be nearly completed before visual feedback can aid movement accuracy (e.g., be used online). Carlton (1981) argued that the procedure used previously was incorrect. That if the visual information used to make response amendments did not become available until some portion of the response had been completed, then the time needed to obtain the error information should be subtracted from the processing estimate. In addition, a period of time must pass between the onset of the amendment and contact with the target area, and this time should also be subtracted from the estimate. From movement kinematics, Carlton (1981) found that visual feedback of the last 25% of the movement distance was in fact the most crucial for reducing spatial errors. That is, the last 25% of the movement distance is the most critical in movement execution to detect and correct errors online.

1.9. Kinematic Measures for Offline and Online Control

Recent advances in movement analysis technologies have allowed researchers to more fully investigate the kinematics of movements in order to further our understanding of the use of visual feedback, in the planning and execution of movement. Typically, a characteristic of an individual's movement trajectory is produced via velocity profiles, which are subjected to a differentiation to obtain acceleration. By observing symmetry and discontinues in velocity profiles between vision and no vision or online corrected and non-online correct movements, research can ascertain in more detail how a movement is planned before and/or controlled during execution. Movement initiation time and the characteristics early in the trajectory are assumed to reflect the movement planning processes related to offline control, whereas later portions of the movement trajectory and discontinuities in the trajectory are associated with movement execution process related to online control (Khan et al., 2006). Recently researchers have developed new methods to investigate the relative contributions of offline and online control (Khan, Elliott, Coul, & Lyons 2002; Khan & Franks, 2000) in order to address the inconsistencies in the results of research using the method above. That is; (a) when receiving visual information of the limb, movement trajectories contain more discrete corrections, which result in better movement accuracy (Chau & Elliott, 1993; Khan & Franks, 2000; Khan & Franks, 2003); (b) movements yield higher accuracy through the availability of vision even where no significant differences in the number of discrete corrections between visual conditions are observed (Elliott, Carson, Goodman, & Chau, 1991; Khan, Elliott, Coull, Chua & Lyons, 2002). The latter could be a result of visual information not being processed during movement execution but rather offline to improve movement programming.

These offline processes would result in significant differences in end-point accuracy between visual conditions without kinematic evidence for online control; and (c) visual guidance may be continuous rather than intermittent in nature. If this is the case then visual regulation would not be reflected in discrete corrections to kinematic profiles since these corrections would be ongoing and not iterative.

To address these issues the variability method was developed (Khan & Franks, 2002; 2003; Khan et al., 2003a; 2003b, 2004, 2006) which involves examining the variability in distance travelled at various stages throughout the movement trajectory along the longitudinal axis (e.g., 25%, 50%, 75% & 100%). Spatial variability is then defined as the within standard deviations of these directional errors (see Figure 1).

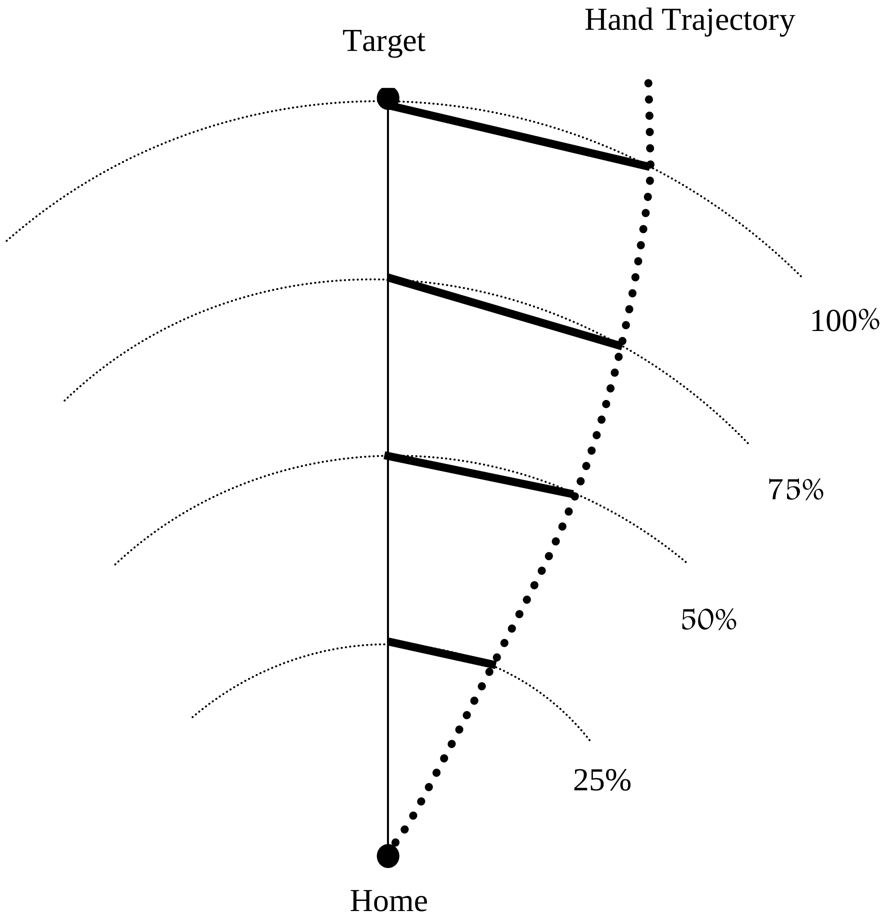

Figure 1. Schematic diagram of a limb trajectory to a target illustrating the calculation of directional errors at 25%, 50%, 75% and 100% of the longitudinal distance to the target.

Based on the finding that the variability of initial impulse endpoints were lower when vision was available, Khan and Franks (2003) proposed that the contribution of online and offline processing of visual feedback could be assessed by examining how spatial variability in the limb trajectory unfolds as the movement progresses. Using a directional aiming task with no amplitude constraints, Khan et al. (2003a) demonstrate that variability increased in a linear fashion in both vision and no vision conditions when movement times were short (i.e., 150ms). Although variability was lower in the vision compared to no vision conditions, the analysis of the ratios in variability revealed that the form of the variability profiles were similar under visual conditions. Hence, the greater consistency in directional accuracy in the vision compared to the no vision condition was due to offline processing. However, at longer movement times (e.g., 450ms) the form of the variability profiles in the vision condition deviated from that in the no vision condition. While variability increased linearly for the no vision condition, variability levelled off at about 75% of the movement in the vision condition, revealing a significant quadratic component to the distance variability relation. Hence, it appeared that the availability of visual feedback mediated adjustments in direction that altered the shape of the variability profile. The rational here being, if movements are pre-planned (i.e., offline) either due to selection of movement parameters or noise in the neuromotor system, any error early in the movement trajectory should increase as the movement continues. Hence, the variability in the limb trajectories (i.e., within-subject standard deviation of spatial position) would increase as the movement unfolds (Anderson & Pitcairn, 1986). Whereas any modifications of the movement trajectory during execution would indicate online control, (i.e., errors that occur early in the movement trajectory are not corrected and hence will be compensated for as the movement distance increases). The variability would deviate from those that describe movement, which is programmed in advance and not modulated online. It is important to note that if sensory information is being used offline to increase the programming of subsequent actions then variability at early kinematic markers (e.g., movement time, constant error, variable error) could be altered. Consequently, if sensory information is being used online during movement execution to detect and correct errors, then these alterations would occur in the later stages of variability profiles. In regards to the current thesis by comparing variability profiles between anxiety condition and control conditions, this methodology could advance researchers knowledge in the fundamental process of movement. Allowing researchers to explicitly investigate how pressure affects performance mechanisms.

1.10. Purpose of Investigations

In the first investigation (chapter 2) of this thesis, we were interested in whether the positive effects of practicing with anxiety shown by Oudejans and colleagues (Nieuwenhuys & Oudejans, 2010; Oudejans, 2008; Oudjans & Pijpers, 2009) adhere to the principles of specificity. That is, whether they depend on the amount of exposure to anxiety and the timing of that exposure in relation to where in learning the exposure occurs. This was investigated in both a simple task (i.e., golf putting; experiment 1) and a complex task (i.e., climbing task; experiment 2) to examine further, if specificity within the construct of anxiety differs with task complexity.

Investigation 2 (chapter 3) of this thesis, explored the question of ‘what’ aspects of motor control develop specificity when practicing under control or anxiety conditions. Where literature has primarily focused on outcome measures of performance (i.e., number of successful goals on target), this investigation sought to precisely quantify the effects of anxiety on the performance of either movement planning or execution. Specifically, we asked participants to make a series of complex upper limb movement patterns, in either a control or pressured learning environment before transferring them to the opposite condition.

The aim of the complex movement pattern allowed performance to be separated into variables associated with movement planning (e.g. reaction time, Henry & Rogers, 1960; Khan et al., 2006) and movement control (e.g. pause times and movement times, Khan et al., 2006). As such we were able to investigate what aspects of motor control (offline and/or online control) develop specificity when training under conditions of anxiety and control.

Finally, investigation 3 (chapter 4) of this thesis, set out to specifically measure the effects of anxiety on both movement planning and movement control by using, the robust variability method of Khan and colleagues (Khan & Franks, 2003, Khan et al., 2003a; 2003b, 2004, 2006). In addition, because there is evidence suggesting that participants develop strategies specific to their environment in order to plan and control movements under both vision and no vision conditions (Abrams et al., 1990; Elliott et al.,1999; 2004; Khan & Franks, 2003), the investigation examined specificity, anxiety and online and offline processing in both vision and no vision conditions. Thus, is the first of its kind to examine how anxiety affects the corrective processes of vision and proprioception information for the planning and execution of movements.

CHAPTER 2

PRACTICE WITH ANXIETY IMPROVES PERFORMANCE, BUT ONLY WHEN ANXIOUS: EVIDENCE FOR THE SPECIFICITY OF PRACTICE HYPOTHESIS

2.1. Experiment 1

2.1.1. Introduction

Even though anxiety has been shown to adversely affect performance (e.g., Craft, Magyar, Becker, & Feltz, 2003; Woodman & Hardy, 2003), no previous research has explicitly investigated anxiety effects under a specificity of learning framework. To date, the focus has been directed towards investigating the skill acquisition conditions under which anxiety may subsequently have less of an adverse effect on performance. Studies that have sought to investigate this process have primarily chosen to manipulate the learning environment such that the learners' knowledge associated with movement production of the skill is either developed implicitly (i.e., unconsciously) or explicitly (i.e., consciously; Hardy, Mullen, & Jones, 1996; Masters, 1992). Using this paradigm, researchers have shown that tasks are more likely to break down under anxiety if performers have accumulated accessible and conscious task-relevant knowledge used to control movement (Masters & Maxwell, 2008). Specifically, Masters (1992) proposed that if explicit learning can be minimized (i.e., knowledge of learning is reduced) then the typically observed breakdown of automatic processes under pressure is less likely to occur in future pressure situations, as the performer has no access to explicit knowledge.

The notion that proceduralized motor skills (acquired with explicit knowledge) are more likely than non proceduralized motor skills to break down under conditions of anxiety was further investigated by Beilock and Carr (2001). After practicing a golf putting task under one of three conditions (control; self-consciousness; dual-task) participants were required to perform the task under a high pressure situation both early and late in practice. When pressure was introduced early, performance was improved in all training conditions. Since novices are assumed to be concerned with the step-by-step procedures of skill performance (Fitts & Posner, 1967), it was suggested that the increase in attention to movement control (as a result of the increased pressure) served to enhance performance. Conversely, in the latter stages of learning, the presence of pressure resulted in a performance decrement, thus supporting the notion that proceduralized motor skills break down under pressure. Interestingly however, this performance decrement was only observed in the control and dual task conditions. Those individuals in the self-consciousness condition were unaffected by the presence of pressure. As such, the results demonstrated an alternative skill acquisition technique to that of adopting implicit learning strategies in order to reduce the negative performance effects of anxiety. That is, it appears training under conditions of self-consciousness can lead to a reduction in the performance decrements typically experienced under anxiety.

Through investigations from Oudejans and colleagues following training under conditions of mild anxiety, performance on hand gun shooting (Oudejans, 2008), basketball free throws (Oudejans & Pijpers, 2009), and dart throwing (Oudejans & Pijpers, 2010) did not deteriorate in subsequent anxiety-inducing conditions. However, Oudejans and colleagues were unable to investigate if it is important to consider where during the learning process anxiety should be introduced in order to achieve the most efficacious training effects. Thus, in the present investigation we were interested in whether the positive effects of practicing with anxiety shown by Oudejans and colleagues (Oudejans, 2008; Oudejans & Pijpers, 2009; 2010) adhere to the principles of specificity i.e., whether they are dependent on the amount of exposure to anxiety and the timing of that exposure in relation to where in learning the exposure occurs.

To achieve this, participants practiced a golf putting task either under anxiety throughout practice, anxiety in the early or late stages of acquisition, or without anxiety (i.e., control condition). Following acquisition, all participants were transferred to an anxiety condition. The anxiety condition during acquisition should result in greater congruity between the conditions at learning and the conditions of the anxiety transfer test. Thus, it was hypothesized that this increased congruity (i.e., greater specificity of learning) would result in performance benefits under subsequent anxiety conditions. Also, if the protective effect of practicing with anxiety is dependent on the amount of exposure to anxiety during acquisition, one would expect the participants in the anxiety throughout acquisition condition to show greater performance robustness under the anxiety transfer test, compared to when anxiety is induced only in the early or late stage of acquisition.

As well as investigating the exposure effects of practicing with anxiety, we were interested in whether the timing of exposure to anxiety during learning influences the efficacy of practicing with anxiety. To achieve this we investigated performance differences between the groups that experienced only half of acquisition with anxiety (i.e., during either the first half of or the second half of learning) to see whether the benefits of exposure to anxiety during acquisition are greater if participants begin practicing under conditions of anxiety from the start of learning or only once they have achieved a certain level of proficiency at the task (without anxiety). It was expected that the benefits of practicing with anxiety would be greater for those participants who were exposed to anxiety from the start of learning. This is due to one or a combination of two possibilities; (1) performers' developing a strong and robust semantic network that connects the mood state, ideas, and muscular patterns associated with the golf putt early in the learning process, (2) participants develop a representation of the skill that is adapted to the conditions from the start of learning (i.e., anxiety). As such, the earlier in the learning process that the mood is associated with the task, the more robust the performance will be in relation to that mood.

2.1.2. Method

Participants

Thirty-two right-handed university students participated in the experiment women, 20 men; mean age = 20.2 ± 1.6 yrs, age range = 18-26 yrs). All participants were novice golfers, naïve to the hypothesis being tested and provided written informed consent before taking part in the study. The experiment was carried out according to institutional ethical guidelines for research involving human participants.

Apparatus

Golf putts were performed on an Astroturf surface using a standard KT25Prosimmon putter and a standard Slazenger Raw Distance 432 dimple pattern golf ball. The start position was a 3cm diameter circle located on the centre line of the putting surface 40cm from the rear edge (see Figure 2). The target hole (10cm diameter) was located 225cm (centre to centre) from, and directly in line with, the start position. To increase task complexity, the putting surface included a 90cm incline slope of 22 degrees that started 72cm from the start position. The surface was then flat for the remaining distance to the target hole (65cm). Final ball position was recorded using a Casio Digital Camera (QV-2900UXCF) which was mounted to the ceiling 295cm directly above the target hole. Digital images were relayed directly to a Compusys 3.00GHz computer for analysis.

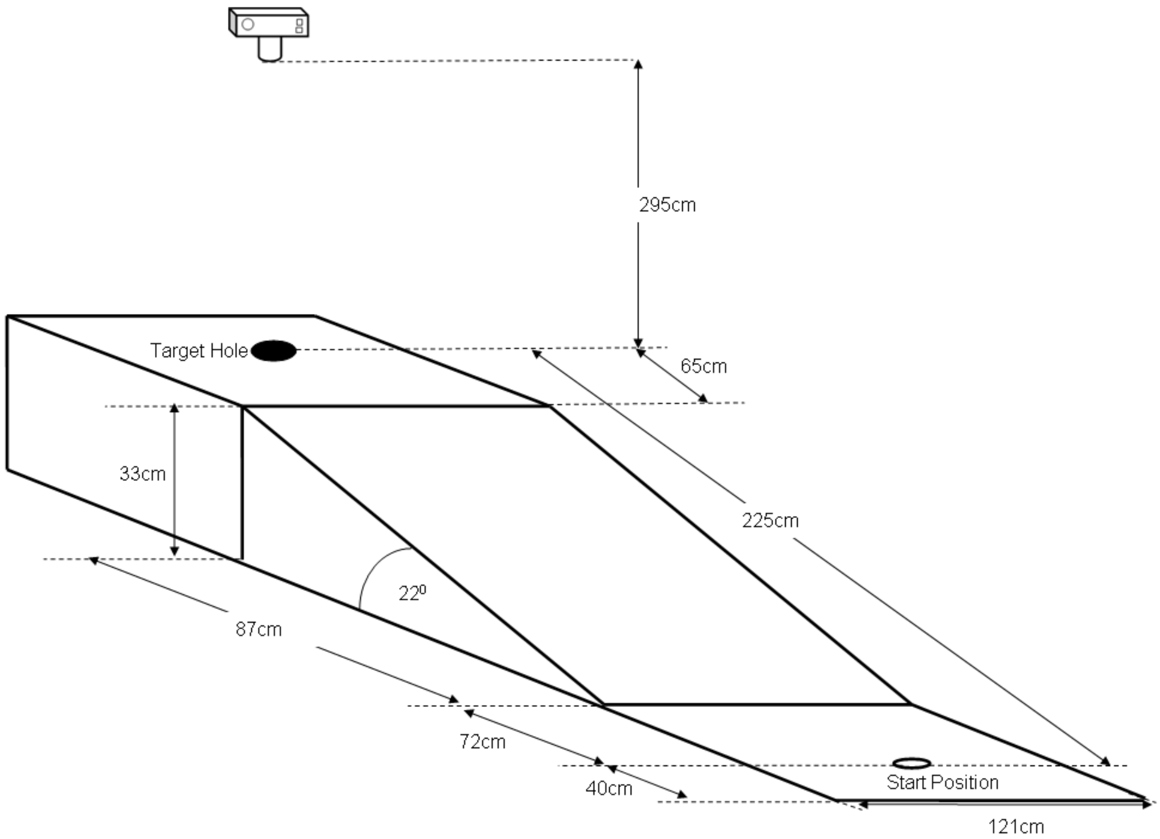

Figure 2. A schematic of the putting apparatus in Experiment 1.

Anxiety Questionnaire

Cognitive anxiety was assessed via the Mental Readiness Form-3 (MRF-3; Krane, 1994). The MRF-3 comprises three single-item factors that are each scored on an 11- point Likert scale: cognitive anxiety from 1 (not worried) to 11 (worried); somatic anxiety from 1 (not tense) to 11 (tense); and self-confidence from 1 (confident) to 11 (not confident). For the purpose of the present study only the cognitive anxiety factor was used.

Task and Procedure

At the start of testing, participants were informed that the purpose of the investigation was to examine the accuracy of golf putting over a period of practice trials. It was explained that the goal of the task was to putt the ball as accurately as possible and that putting performance would be assessed by the number of successful putts and the distance from the hole on unsuccessful putts. In all conditions participants completed a total of 300 acquisition putts consisting of six blocks of 50 putts each. Following each block, participants were given a short break (approximately 5 minutes) in order to minimize potential fatigue effects. Each participant was randomly assigned to one of our acquisition conditions: (1) in the control group participants completed all 300 acquisition putts under normal (low anxiety) conditions; (2) in the anxiety group participants were informed that each putt was being recorded for later analysis by a professional golfer. They were also informed before the start of putting, that they had been awarded £30 and that ten pence (£0.10) would be removed from this total for each unsuccessful putt; (3) in the anxiety-control group, participants performed the first 150 trials under conditions of anxiety identical to those described above except that total prize money was reduced from £30 to £15. Following the putts under anxiety, participants then completed a final 150 putts under normal (low anxiety) conditions identical to that of the control group; (4) in the control-anxiety group, participants followed the same procedure to that of the anxiety-control group with the exception that the order of the anxiety and the control putting conditions was reversed. Immediately following acquisition, all participants were given a 15-minute break after which they completed a transfer test that consisted of 25 putts under conditions of anxiety. Specifically, participants were informed of their mean putting performance from the final 25 trials of their acquisition and told that they would be eligible to win £30 if they improved their performance by 15% over the next 25 putts. However, it was also made clear to participants that in order for them to secure the £30, their percentage of improvement would need to be the highest of all individuals partaking in the experiment. In order to ensure that anxiety had been successfully manipulated, all participants completed the MRF-3 on three separate occasions: immediately before the start of acquisition; at the start of the 4th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively); and at the start of transfer (i.e., before the competition block of 25 putts).

Performance and analyses

Putting performance was measured via number of successful putts (NSP) and mean radial error (MRE). MRE was the absolute distance from the ball to the centre of the hole (cf. Mullen, Hardy, & Tattersall, 2005).

Analyses

The effectiveness of the anxiety interventions, as measured by the MRF-3, was assessed by a 4 (group: control; anxiety; anxiety-control; control-anxiety) × 3 (time: pre [immediately before acquisition]; mid [immediately prior to block 4]; and transfer [immediately prior to transfer]) ANOVA with repeated measures on the second factor. Performance data (NSP and MRE) were analysed during the acquisition phase using separate 4 Groups (control; anxiety; anxiety-control; control-anxiety) × 6 Blocks (1-6) ANOVAs with repeated measures on the second factor. In order to assess the effect of anxiety on performance in the transfer test, both NSP and MRE were further submitted to separate 4 Group (control; anxiety; anxiety-control; control-anxiety) × 2 Experimental Phase (acquisition; transfer) ANOVAs with repeated measures on the second factor. The last 25 putts of the acquisition phase and the 25 transfer putts were used in this analysis. To investigate the effects of introducing anxiety at different stages of learning we compared the change in performance of the control-anxiety group at the midpoint of acquisition (i.e., the last 25 trials of the final block of control conditions to the first 25 trials following the introduction of anxiety) to the change in performance of the control group between the last 25 trials of acquisition and the 25 trials of the anxiety transfer test using an independent t-test. The rationale here is that the change from control conditions to anxiety conditions occurred half way through learning (early transfer) in the control-anxiety group whereas the control group were not transferred to the anxiety condition until the end of acquisition (late transfer). Thus, greater performance decrements in late transfer compared to the early transfer would demonstrate specificity of practice. All significant effects were broken down using Tukey's HSD post hoc procedures ($p < .05$).

2.1.3. Results

Anxiety

The anxiety data are shown in Table 1. The ANOVA revealed a significant main effect of group (F 3, 28 = 11.66, $p < .001$) and time (F 2, 56 = 45.68, $p < .001$). Of more central interest, there was a significant group × time interaction (F 6, 56 =19.53, $p < .001$). Breakdown of this interaction revealed that the anxiety manipulation was successful within the acquisition and transfer phases where targeted and that the anxiety levels reported within the acquisition and transfer anxiety phase manipulations were not significantly different from one another.

Group	Time		
	Pre	Mid	Transfer
Control	2.50 (1.20)	2.00 (0.54)	6.00 (1.31)*
Anxiety	5.25 (1.28)	5.88 (1.25)	5.75 (1.75)
Anxiety-control	5.75 (1.04)	2.50 (0.92)*	6.00 (0.93)*
Control-anxiety	2.50 (0.93)	5.87 (1.13)*	7.00 (0.92)

Table 1. Experiment 1 Mean (SD) anxiety immediately before the start of acquisition (Pre); at the start of the 4th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively) (Mid); and at the start of transfer (i.e., before the competition block of 25 putts) (Transfer). * signifies a significant within subject change in anxiety from the previous time point at 95% (p < 0.05).

Number of successful putts; Acquisition

Means and *SDs* are reported in Table 2. The analysis revealed no significant main effect for group (F 3, 28 = .21, $p = .89$) or block (F 5, 140 = 1.46, p 20) and no significant interaction between the two factors (F 15, 140 = 1.46, $p = .21$).

Acquisition versus Transfer

Similar to the acquisition analysis, no significant main effects or interactions were observed (group main effect $F_{3, 28} = 1.86$, $p = .16$; experimental phase main effect $F_{1, 28} = .19$, $p = .66$; group × experimental phase interaction $F_{3, 28} = 1.20$, $p = .33$).

Mean radial error; Acquisition

Means and *SDs* are reported in Table 2. The ANOVA revealed a significant main effect for block ($F_{5, 140} = 9.54$, $p < .001$) (See Figure 2).

Specifically, all participants significantly improved putting accuracy over each block of trials for the first 150 putts (block 1 (mean = 473.65mm); block 2 (mean = 444.01); block 3 (mean = 410.41mm) after which putting accuracy reached asymptote since blocks 4 (mean = 398.48), 5 (mean = 376.96), and 6 (mean = 358.38) were not significantly different to one another. Thus, similar to previous research (e.g., Beilock & Carr, 2001; Hardy et al., 1996; Masters, 1992), performance asymptote occurred after approximately 200 practice trials. No group main effect or interaction was revealed ($F_{3, 28} = 0.58$, $p =.63$, and $F_{15, 140} = 1.38$, $p = .17$, respectively).

Variable	Group	Experimental Phase						
		Acquisition Block						Anxiety Transfer
		1	2	3	4	5	6	High
NSP	c	6.88 *3.52*	8.25 *3.20*	7.88 *2.80*	7.75 *3.45*	9.63 *4.90*	10.13 *5.03*	4.25 *1.16*
	a	6.50 *1.07*	8.88 *3.52*	8.50 *2.45*	9.13 *3.04*	9.13 *2.42*	6.00 *1.51*	6.63 *2.62*
	a-c	8.25 *1.04*	7.25 *1.67*	9.13 *2.03*	10.25 *3.15*	8.00 *2.20*	8.63 *3.66*	5.63 *0.92*
	c-a	8.25 *1.67*	8.00 *2.33*	8.88 *4.26*	7.25 *2.55*	7.25 *1.67*	7.63 *2.45*	4.88 *0.64*
MRE	c	471.17 *134.41*	429.59 *128.06*	434.76 *135.85*	431.96 *133.60*	408.72 *167.33*	342.21 118.19	466.20 236.88
	a	518.67 *203.19*	517.41 *236.59*	449.09 *198.95*	430.33 *150.14*	440.67 *183.94*	425.88 222.50	300.89 113.33
	a-c	491.41 *128.95*	426.17 *134.30*	391.97 *188.01*	310.94 *185.76*	307.47 *212.76*	341.88 258.89	335.93 198.78
	c-a	413.34 *144.30*	402.89 *120.71*	365.81 *122.69*	420.71 *122.55*	350.89 *105.87*	323.57 115.15	302.09 105.26

Table 2. Experiment 1 Means and *SDs* for all performance dependent variables as a function of group (c = control; a = anxiety; a-c = anxiety-control; c-a = control-anxiety) and experimental phase.

Acquisition versus transfer

As shown in Figure 3, the MRE transfer ANOVA revealed a significant group × experimental phase interaction ($F_{3, 28} = 3.23$, $p < .05$). Breakdown revealed that the control group showed a significant decrement in performance from acquisition to transfer whilst the anxiety group showed a significant improvement. The performance of the other two groups did not significantly change from acquisition to transfer. Finally, performance at transfer was significantly worse for the control condition compared to the other three conditions.

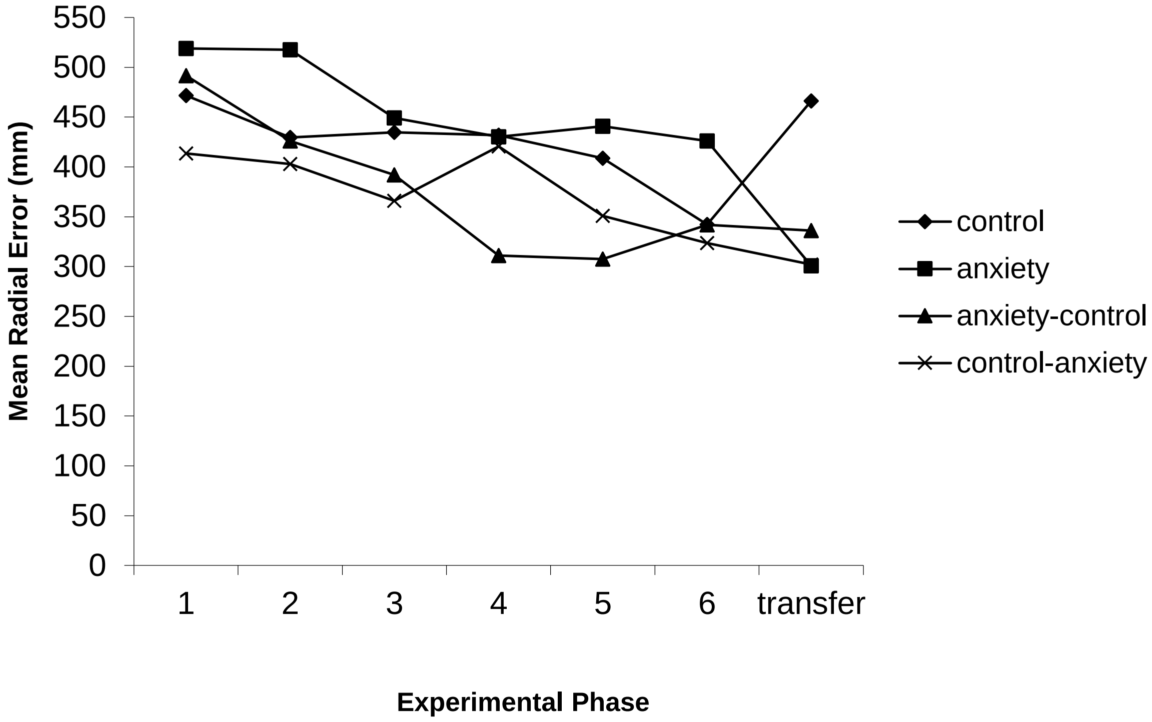

Figure 3. Experiment 1 Mean radial error during acquisition as a function of condition and block (1 = trials 1-50; 2 = trials 51-100……; 6 = trials 251-300, transfer =anxiety transfer trials).

Introducing anxiety early and late in practice

Comparison of the changes in performance from inducing anxiety half-way through acquisition (i.e., control-anxiety group) and at the end of acquisition (i.e., control group) revealed that the decrement in performance was greater in the late transfer (MRE = -108.96) compared to the early transfer (MRE = -54.89) (t_{14}= -2.84 p = .089) but only at the .1 alpha level.

2.1.4. Discussion

The objective of the current experiment was to examine whether the principles of specificity (Gilligan & Bower, 1983; Henry, 1968, Proteau, 1992) could be extended to the psychological construct of anxiety. Whilst specificity effects have previously been shown to be robust when examining sensory information (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau et al., 1987; Tremblay & Proteau, 1998, 2001) the hypothesis has not previous been explored in the anxiety, stress and performance literature. As such, we investigated whether acquiring a motor skill under conditions of anxiety removed the performance decrement typically observed in skilled movement production when anxiety is present (i.e., choking). We also tested whether any positive effects of practicing with anxiety on subsequent anxious performances are dependent on the amount of exposure to anxiety during acquisition and the timing of that exposure. The results demonstrated that learning under conditions of anxiety led to more robust performance under future conditions of anxiety and that learning without exposure to anxiety leaves one particularly vulnerable to its effects in subsequent performances. Hence, consistent with studies that have shown that learning is specific to sensory conditions (Elliott et al., 1995; Khan & Franks, 2000; Khan et al., 1998; Mackrous & Proteau, 2007) and mood state (Bower et al., 1978; Gillian & Bower, 1983; Schare et al., 1984) during acquisition, the present results indicate that specificity of learning extends to the psychological construct of anxiety.

Interestingly, and somewhat surprising, was the finding that missed putts actually finished closer to the hole in transfer compared to acquisition in the anxiety group. Whilst this may be an artefact of variability within the data set, another possible explanation for this increase in performance is that the time period, although relatively short, between acquisition and transfer allowed for some learning consolidation in the anxiety group and that the continued exposure to anxiety during acquisition increased post-acquisition stress-hormone which lead to an increase in learning (also see Cahill, Gorski, & Le, 2003). While one might also expect an increase in performance in the mixed practice groups following the period of consolidation, it is possible that these groups had less increases in stress-hormone compared to the anxiety only group because of the reduced exposure to anxiety period during practice. Future research may wish to investigate this possibility further.

Further support that learning is specific to the amount of exposure to anxiety during acquisition was revealed from the comparison between the change in performance of the control-anxiety group when anxiety was induced at the midpoint of acquisition and the change in performance of the control group between the end of acquisition to the anxiety transfer test. Here performance decrements were greater in late transfer compared to early transfer suggesting that the more participants practiced in non-anxious conditions the more they were dependent on the presence of those conditions for successful performance. This finding is consistent with observations from studies on manual aiming in which removing visual feedback was more detrimental late in learning compared to early in practice (Khan et al., 1998; Proteau et al., 1987) suggesting that the specificity effect could also be extended to the psychological construct of anxiety.

While the results of the present study demonstrated evidence for specificity of learning, there were no performance differences between the anxiety-control and control-anxiety groups at the final transfer phase. A possible explanation for this could be due to the complexity of the to-be-learned task. That is, a golf putt can be described as a simple discrete skill that is closed in nature (i.e., the task involves relatively few movements, has a very obvious beginning and end and is not subject to external factors such as time constraints; Schmidt & Lee, 2008). Thus, although anxiety from the start of acquisition negatively affected performance, possibly due to consuming resources of working memory (Eysenck et al., 2007), this was not sufficient to reduce learning. Perhaps introducing anxiety from the start of practice in a more complex and open skill would disrupt the acquisition process to such a degree as to increase learning time and reduce the benefits of training with anxiety from the start of practice as seen in the present investigation. This possibility was investigated in experiment 2.

2.2. EXPERIMENT 2

2.2.1. Introduction

The purpose of experiment 2 was twofold: (1) to investigate when learning with anxiety is most appropriate for a complex task; (2) to further investigate whether the principles of specificity (Gilligan & Bower, 1983; Henry, 1968, Proteau, 1992) should be extended to the psychological construct of anxiety. The results of experiment 1 revealed no performance differences in the anxiety transfer test between participants who practiced either with anxiety from the start or from the midpoint of acquisition; only the control group performed significantly worse at transfer. Since it is possible that this null finding was a result of the low complexity of the to-be-learned skill, experiment 2 investigated whether similar findings would be observed when the to-be-learned skill was of a more complex nature.

The design and procedure of experiment 2 were largely similar to those of experiment 1. However, two major methodological changes were made. First, in order to investigate whether the movement developed when practicing with anxiety is specific to those conditions we introduced a second (low anxiety) transfer test. If specificity of learning extends to practicing with anxiety, one would expect a decrement in performance for participants who practice with anxiety when they are transferred to a non-anxious condition (i.e., they experience a change in the environmental context or mood under which the task was learned). Second, a more complex whole body climbing task (involving the control of multiple movement components that were subject to a time pressure constraint) was adopted to investigate whether performance is influenced by the timing of anxiety induction during acquisition.

2.2.2. Method

Participants

Thirty-two novice climbers participated in Experiment 2 (4 women, 28 men; mean age = 26.35, *SD* ± 2.22 yrs, age range = 18-49 yrs). All participants reported no prior climbing experience, were naïve to the hypothesis being tested and gave their informed consent prior to taking part in the study. The experiment was carried out according to the institutional ethical guidelines for research involving human participants.

Apparatus

Climbing moves were performed wearing well-fitted standard rock shoes (Scarpa Vantage) on an indoor climbing wall, the floor of which was covered by a standard safety crash mat. The wall itself contained a 5.5m long low-level traverse (a horizontal sequence of climbing movements where the mean hold height was 1.23m from the floor, *SD* ± .46m) with a UK technical difficulty of 4a (easy). The height of the traverse meant that participants could simply step on and off the climb with ease at any point without safety risk. Consequently, the safety equipment typically associated with vertical climbing was not required. The 4a easy difficulty of the traverse was determined by three independent expert climbers, who each held an up-to-date Mountain Instructor Award and had more than 10 years of climbing experience (37 years combined experience). Cognitive anxiety was measured using the MRF-3 and task effort was measured using a retrospective 1 (no effort) to 10 (maximal effort) Likert scale (see Mullen et al., 2005). All climbs were recorded on a Sony Digital Video Camera Recorder (DCR-DVD106) positioned at a height of 1.2m, in line with the middle of the traverse and at distance from the climbing wall such that the entire 5.5m traverse was clearly visible.

Task and Procedure

At the start of testing, participants were informed that the purpose of the investigation was to examine the speed and accuracy of climbing over a period of practice trials. It was explained that the goal of the task was to climb as quickly and as fluently as possible. In all conditions participants completed a total of 100 acquisition climbs consisting of ten blocks of 10 trials split equally over two days. A 1-minute break was given between trials and participants were afforded a 10-minute break between blocks within which they were required to perform forearm recovery stretching exercises. Participants were instructed to perform each stretch three times and to hold the stretch for a total of 20 seconds. Similar to Experiment 1, each participant was randomly assigned to one of four acquisition conditions (each containing an equal number of males and females): (1) In the control group all acquisition trials were performed under normal (low anxiety) conditions; (2) in the anxiety group participants were informed that they were being videoed and that recordings would be watched and evaluated by an elite professional climber. They were also informed that the evaluations of their performance and the other participants would be displayed on a poster in text format for all other participants to view and that the best performer would be rewarded with the choice of one of four outdoor activity sessions (e.g., a day's climbing with a qualified mountain guide for two); (3) in the anxiety-control group the first half of acquisition was performed under conditions identical to that of the anxiety group and the remaining half were conducted under conditions that matched those of the control group (low anxiety); (4) in the control-anxiety group, participants followed the same procedure to that of the anxiety-control group with the exception that the order of the anxiety and the control conditions was reversed.

Immediately following acquisition, all participants were given a 1-hour break after which they completed two transfer tests that consisted of 10 climbs each. Anxiety transfer was performed under anxiety conditions and low anxiety transfer was performed under normal conditions (the order of the transfer tests was counterbalanced across participants). To manipulate anxiety, participants were informed of their mean climbing performance from the last 10 trials of acquisition and told that if they improved their performance by 15% over the next 10 trials they would be eligible to win a choice of outdoor activity sessions (these were identical to those available during the acquisition phase). However, it was also made clear to participants that in order for them to secure the prize, their percentage of improvement would need to be the highest of all individuals partaking in the experiment.

In order to ensure that anxiety had been successfully manipulated all participants completed the MRF-3 on four separate occasions: immediately before the start of acquisition; at the start of the 6th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively); and at the start of both transfer tests. To measure effort, participants completed the self-report effort scale following block 5 and block 10 of acquisition and at the end of both anxiety transfer and low anxiety transfer.

Performance and analyses

Similar to Pijpers et al. (2005), for each trial, the time of traverse (TOT), number of performed movements (NOPM), number of explored movements (NOEM) and number of ventured movements (NOVM) were determined from the DVD recordings. TOT was calculated as the time interval between the release of the first hold until the grasp of the final hold on the traverse. NOPM was defined as the number of moves made during the climb; a move was classified as the releasing of a hold and making contact with another hold that was used for support. NOEM was defined as the number of times a hold was touched without that hold being subsequently used as support. NOVM was calculated as the number of times a hold was released and then the limb was returned to the same hold. In order to accurately determine each dependent variable, the DVD recordings of each trial were rated simultaneously by two assessors. Both assessors were blind to the experimental hypotheses, competent with the calculation of all measures, and had access to this information during their assessments.

Analysis

MRF-3 data were assessed separately by a 4 (group: anxiety; control; anxiety-control; control-anxiety) × 4 (time: pre [immediately prior to acquisition]; mid [immediately prior to acquisition block 6]; anxiety transfer [immediately prior to anxiety transfer]; and low anxiety transfer [immediately prior to low anxiety transfer]) ANOVA with repeated measures on the second factor. Effort data were submitted to a similar 4 (group: anxiety; control; anxiety-control; control-anxiety) × 4 (time: mid [immediately following trial 50 of acquisition]; end [immediately following the final trial of acquisition]; anxiety transfer [immediately following anxiety transfer]; and low anxiety transfer [immediately following low anxiety transfer]) ANOVA with repeated measures on the second factor. Performance data (TOT, NOPM, NOEM and NOVM) were analysed during the acquisition phase using separate 4 (group: anxiety; control; anxiety-control; control-anxiety) × 2 (day: day 1, day 2) × 5 (block: blocks 1-5) ANOVAs with repeated measures on the last two factors. In order to assess the effect of the transfer tests (anxiety and normal conditions) on performance, TOT, NOPM, NOEM and NOVM were further submitted to separate 4 (group: anxiety; control; anxiety-control; control-anxiety) × 3 (experimental phase: acquisition; anxiety transfer; low anxiety transfer) ANOVAs with repeated measures on the second factor. The final 10 trials of the acquisition phase (i.e., the last block of day 2) and the 10 trials in both transfers were used in these analyses. Similar to Experiment 1, to investigate the effects of introducing anxiety at different stages of the learning process we conducted an independent t-test on the change in TOT from block 1 to 5 for the control-anxiety group and block 10 to anxiety transfer for the control group. All significant effects were broken down using Tukey's HSD post hoc procedures (p 3 < .05).

2.2.3. Results

Anxiety

Means and *SDs* are reported in Table 3. The ANOVA revealed a significant main effects of group ($F_{3, 28} = 117.92$, $p < .001$) time ($F_{3, 84} = 331.74$, $p < .001$) together with a significant group × time interaction ($F_{9, 84} = 97.62$, $p < .001$). As in Experiment 1, breakdown of this interaction revealed that the anxiety manipulation was successful in the acquisition and transfer phases where targeted and that the anxiety levels experienced in both the acquisition and transfer phase anxiety manipulations were not significantly different from one another.

Group	Time			
	Pre	Mid	Transfer1	Transfer2
Control	1.00 (*.83*)	1.00 (*.85*)	9.50 (*.75*)*	2.00 (*1.07*)*
Anxiety	9.38 (*.74*)	8.38 (*.52*)	9.50 (*.76*)	2.75 (*1.28*)*
Anxiety-control	8.75 (*.88*)	1.50 (*.92*)*	9.50 (*.75*)*	2.00 (*1.06*)*
Control-anxiety	1.13 (*.84*)	9.38 (*.74*)*	8.75 (*.89*)	2.13 (*1.25*) *

Table 3. Experiment 2 Mean (*SD*) anxiety immediately before the start of acquisition (Pre); at the start of the 6th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively) (Mid); at the start of the anxiety transfer test (Transfer 1); and at the start of the low anxiety transfer test(Transfer 2)* signifies a significant within subject change in anxiety from the previous time point at 95% (*p*<0.05).

Effort

Analysis of the effort data revealed no significance for either the main effects (group: $F_{3, 28} = .88$, $p = .46$; time: $F_{3, 84} = 2.12$, $p = .09$) or the interaction ($F_{9, 84} = .79$, $p = .61$). Thus, effort was similar for all groups and did not differ between anxiety and low anxiety situations (see Table 4).

Group	Time			
	Mid	End	Transfer1	Transfer 2
Control	7.75 (*1.03*)	8.00 (*.75*)	8.25 (*.46*)	7.88 (*.84*)
Anxiety	8.00 (*.75*)	7.75(*.46*)	8.00 (*.76*)	7.63 (*.74*)
Anxiety-control	8.13 (*.99*)	8.00 (*.53*)	8.63 (*.51*)	7.88 (*.64*)
Control-anxiety	7.88 (.64)	8.13 (*.64*)	8.25 (*.71*)	8.38 (*.74*)

Table 4. Experiment 2 Mean (*SD*) effort scores immediately following the end of block 5 (i.e., following the 50th trial of acquisition) (Mid); immediately following the end of acquisition (i.e., the 100th trial) (End); immediately following the end of the anxiety transfer test (Transfer 1); immediately following the end of the low anxiety transfer test (Transfer 2).

Performance Variables

For reasons of brevity, statistical values for all performance dependent variables have been omitted from the text and reported in Table 5.

	Experimental Phase									
	Acquisition					Acquisition versus Transfer				
Variable	Factor(s)	Statistical Value				Factor(s)	Statistical Value			
		F	df	p	η^2		F	df	p	η^2
TOT	Group	281.08	3,28	.001	.97	Group	51.98	3,28	< .001	.85
	Day	23.43	1,28	.001	.46	Experimental Phase	137.90	2,56	< .001	.83
	Block	86.12	4,112	< .001	.76	Group x Experimental Phase	5.73	6,56	< .001	.90
	Group x Day	838.07	3, 28	< .001	.99					
	Group x Block	4.45	12,112	< .001	.32					
	Day x Block	6.16	4,112	< .001	.18					
	Group x Day x Block	8.42	12,112	< .001	.47					
NOPM	Group	12.36	3,28	< .001	.57	Group	19.34	3,28	< .001	.68
	Day	4.88	1,28	< .05	.15	Experimental Phase	.73	2,56	< .05	.17
	Block	198.64	4,112	< .001	.88	Group x Experimental Phase	14.17	6,56	< .001	.60
	Group x Day	9.31	3,112	< .05	.50					
	Group x Block	3.32	12,112	< .001	.26					
	Day x Block	4.42	4,112	.05	.13					
	Group x Day x Block	1.98	12,112	.05	.18					
NOEM	Group	62.93	3,28	< .001	.87	Group	80.26	3,28	< .001	.89
	Day	13.74	1,28	< .001	.72	Experimental Phase	153.86	2,56	< .001	.85

	Block	68.29	4,112	< .001	.71	Group x Experimental Phase	89.15	6,56	< .001	.91
	Group x Day	284.34	3,112	< .001	.97					
	Group x Block	3.45	12,112	< .001	.27					
	Day x Block	7.85	4,112	< .001	.22					
	Group x Day x Block	2.69	12,112	< .05	.22					
NOVM	Group	82.21	3,28	< .001	.89	Group	17.51	3,28	< .001	.65
	Day	17.25	1,28	< .001	.38	Experimental Phase	240.87	2,56	< .001	.90
	Block	139.77	,112	< .001	.83	Group x Experimental Phase	120.54	6,56	< .001	.93
	Group x Day	80.30	3,112	< .001	.90					
	Group x Block	6.56	12,112	< .001	.41					
	Day x Block	4.57	4,112	< .05	.14					
	Group x Day x Block	13.85	12,112	< .001	.59					

Table 5. Experiment 2 statistical values for each performance dependent variable for both acquisition and acquisition versus transfer analyses.

Time of Traverse (TOT); Acquisition

All means and *SDs* are reported in Table 6. As shown in Figure 4, significant main effects for group, day and block were observed, in addition to significant group × day, group × block, day × block, and group × day × block interactions. The breakdown of the triple interaction indicated that whilst traverse times in all groups significantly decreased over day 1 (blocks 1 to 5) this decrease was significantly greater in the control and control-anxiety groups compared to both the anxiety and anxiety-control groups. Furthermore, traverse times significantly increased from the end of day 1(block 5) to the start of day 2 (block 6) for the anxiety, control and control-anxiety groups with this increase being significantly greater in the control-anxiety group. In the anxiety-control group however, time of traverse significantly decreased from block 5 to block 6. Finally, whilst time of traverse significantly decreased over day 2 from block 6 to block 10 in all groups, this decrease was significantly greater in the control and anxiety-control groups compared to the anxiety and control-anxiety groups.

Variable	Group	Experimental Phase											
		Acquisition block										Anxiety Transfer	
		1	2	3	4	5	6	7	8	9	10	High	Low
TOT	c	28.5	27.6	26.8	25.8	24.1	28.0	25.8	24.2	23.7	23.0	39.0	23.6
		0.92	*1.59*	*0.99*	*0.64*	*0.99*	*1.41*	*1.36*	*1.04*	*1.03*	*0.93*	*1.77*	*0.52*
	a	34.7	34.6	33.7	33.7	33.3	35.7	34.3	34.2	34.2	33.6	34.7	38.6
		0.88	*1.06*	*0.71*	*1.03*	*1.59*	*0.46*	*0.52*	*1.28*	*1.58*	*1.59*	*1.39*	*1.69*
	a-c	35.2	34.7	34.2	34.0	34.6	28.8	27.5	25.7	24.7	24.1	33.2	30.2
		.71	*1.03*	*1.04*	*0.53*	*0.91*	*1.12*	*0.76*	*1.28*	*1.28*	*0.83*	*2.12*	*4.09*
	c-a	28.2	27.7	27.2	25.8	24.6	35.1	34.5	34.0	33.7	33.5	32.0	28.3
		1.03	*0.70*	*0.71*	*0.83*	*0.92*	*0.64*	*0.93*	*0.53*	*0.89*	*1.06*	*1.51*	*1.06*
NOPM	c	27.6	27.0	25.8	24.5	23.3	25.1	23.5	23.3	22.5	21.8	28.6	21.8
		0.74	*0.76*	*1.13*	*0.76*	*1.06*	*0.64*	*1.06*	*0.92*	*0.53*	*1.12*	*3.66*	*1.55*
	a	31.3	30.0	28.7	28.0	28.1	29.8	29.13	28.5	28.4	28.5	27.88	29.5
		3.11	*2.67*	*3.06*	*2.32*	*2.16*	*2.10*	*2.23*	*1.77*	*2.26*	*1.90*	*1.88*	*2.61*
	a-c	31.2	30.2	28.6	28.5	28.1	27.8	27.0	25.8	25.3	24.87	26.7	27.2
		2.76	*2.96*	*2.77*	*2.56*	*2.90*	*0.64*	*0.75*	*1.22*	*1.16*	*0.99*	*1.28*	*1.48*
	c-a	27.6	27.1	26.1	25.6	23.7	29.8	29.63	28.1	27.5	27.1	24.6	24.6
		0.74	*0.83*	*1.36*	*0.74*	*0.07*	*3.72*	*4.24*	*2.99*	*2.61*	*2.29*	*0.74*	*1.06*
NOEM	c	4.8	4.5	3.8	3.6	2.9	4.0	3.5	3.0	2.3	1.6	11.1	2.3
		0.35	*0.75*	*0.64*	*0.51*	*0.35*	*0.76*	*0.92*	*0.53*	*0.46*	*0.51*	*0.83*	*0.74*
	a	9.2	8.25	8.6	9.0	8.0	9.8	9.0	7.5	8.1	7.8	7.3	8.0
		1.48	*1.04*	*1.06*	*1.69*	*0.76*	*1.88*	*1.19*	*0.53*	*0.83*	*0.71*	*0.46*	*0.01*
	a-c	10.5	10.6	9.1	9.0	9.5	5.3	4.3	3.3	3.1	3.0	8.1	5.8
		1.69	*2.06*	*1.35*	*1.19*	*1.77*	*1.06*	*1.18*	*1.03*	*0.64*	*0.53*	*0.83*	*1.03*
	c-a	5.1	4.0	3.8	2.8	2.25	11.1	9.5	7.9	7.6	7.9	7.0	5.1
		1.12	*0.01*	*0.64*	*0.64*	*0.71*	*2.36*	*1.51*	*0.64*	*0.51*	*0.35*	*1.06*	*1.25*
NOVM	c	6.7	5.8	4.8	3.8	2.9	4.1	2.3	1.0	0.6	0.1	14.4	1.1
		1.67	*2.25*	*2.49*	*2.76*	*2.36*	*1.24*	*0.70*	*1.41*	*0.91*	*0.35*	*1.69*	*0.99*
	a	10.6	10.5	10.0	9.5	9.6	10.5	9.7	9.5	8.8	8.6	9.0	8.9
		0.91	*0.76*	*0.53*	*0.92*	*1.06*	*0.76*	*1.16*	*0.93*	*2.18*	*2.33*	*2.14*	*2.10*
	a-c	11.3	11.1	10.4	9.9	9.8	6.8	4.3	3.0	1.13	1.0	9.6	6.6
		1.03	*0.99*	*0.92*	*1.12*	*1.16*	*1.35*	*0.70*	*1.42*	*1.36*	*0.93*	*0.91*	*1.41*
	c-a	6.3	5.8	4.4	3.9	1.9	10.5	10.4	10.8	9.75	10.4	8.8	6.1
		0.92	*1.39*	*2.13*	*1.55*	*1.24*	*0.75*	*0.92*	*1.04*	*1.16*	*0.92*	*1.91*	*1.13*

Table 6. Experiment 2 Means and *SD*s for all performance dependent variables as a function of group (c = control; a = anxiety; a-c = anxiety-control; c-a = control-anxiety) and experimental phase.

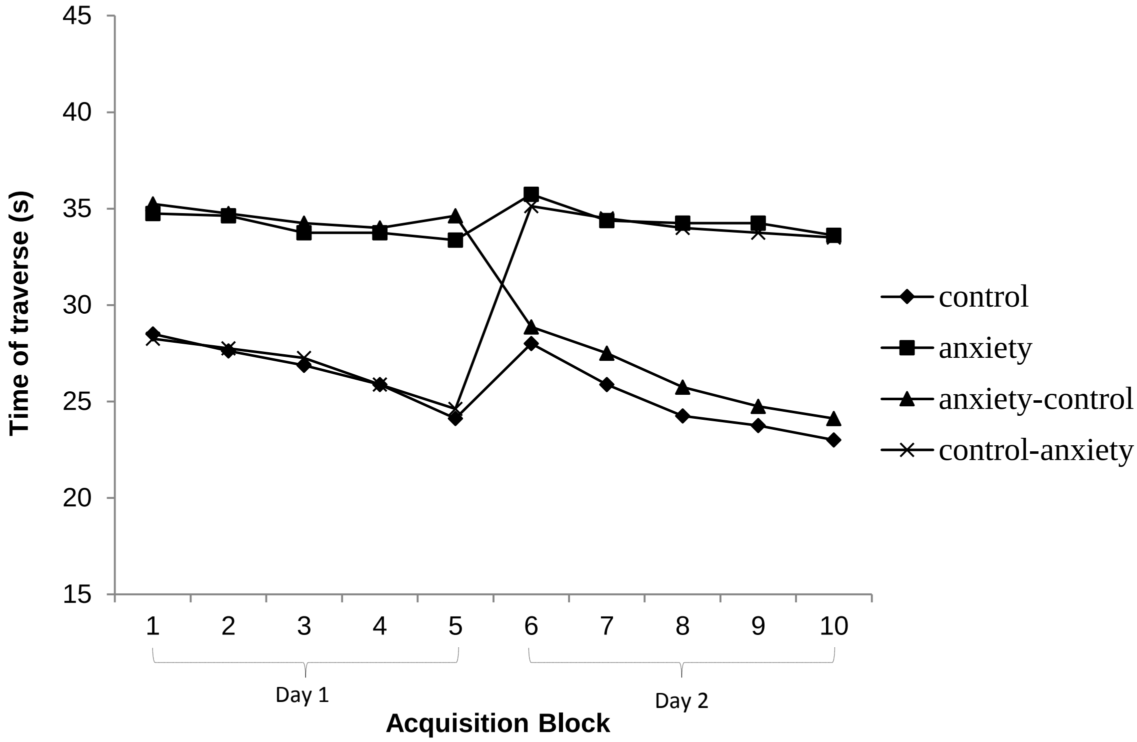

Figure 4. Experiment 2 Time of traverse (seconds) during acquisition as a function of group and block (1 = trials 1-10; 2 = trials 11-20……; 10 = trials 91-100).

Acquisition versus transfer

As shown in Figure 5, the analysis revealed a significant main effect of group and experimental phase as well as a significant group × experimental phase interaction. Breakdown of this interaction revealed that the transfer performance of the control and anxiety groups significantly decreased when the conditions at transfer did not match those of acquisition. Specifically, the traverse times of the control group were significantly greater in the high anxiety transfer test compared to both acquisition and low anxiety transfer (acquisition and low anxiety transfer were not significant different). Whereas, the time of traverse for the anxiety group remained constant between acquisition and the anxiety transfer and significantly increased from these levels in the low anxiety transfer test. Traverse times in the anxiety-control group significantly increased between acquisition and anxiety transfer whereas those of the control-anxiety group remained constant and significantly decreased between acquisition and the low anxiety transfer test. Between group comparisons revealed that, time of traverse at anxiety transfer was significantly lower in both the control-anxiety and anxiety-control groups (mean = 32.00 and 33.25, respectively) compared to the remaining groups (control mean = 39.00; anxiety mean = 34.75; the anxiety group was significantly lower than the control group). Furthermore, the control-anxiety group had significantly lower traverse times compared to both the anxiety and control group, whilst the control group had significantly longer traverse times compared to all other groups. Finally, traverse times in all groups were significantly different at low anxiety transfer. Specifically, time of traverse was fastest in the control group (mean = 23.63) followed by the control-anxiety (mean = 28.38), anxiety-control (mean = 33.25) and anxiety groups (mean = 38.63).

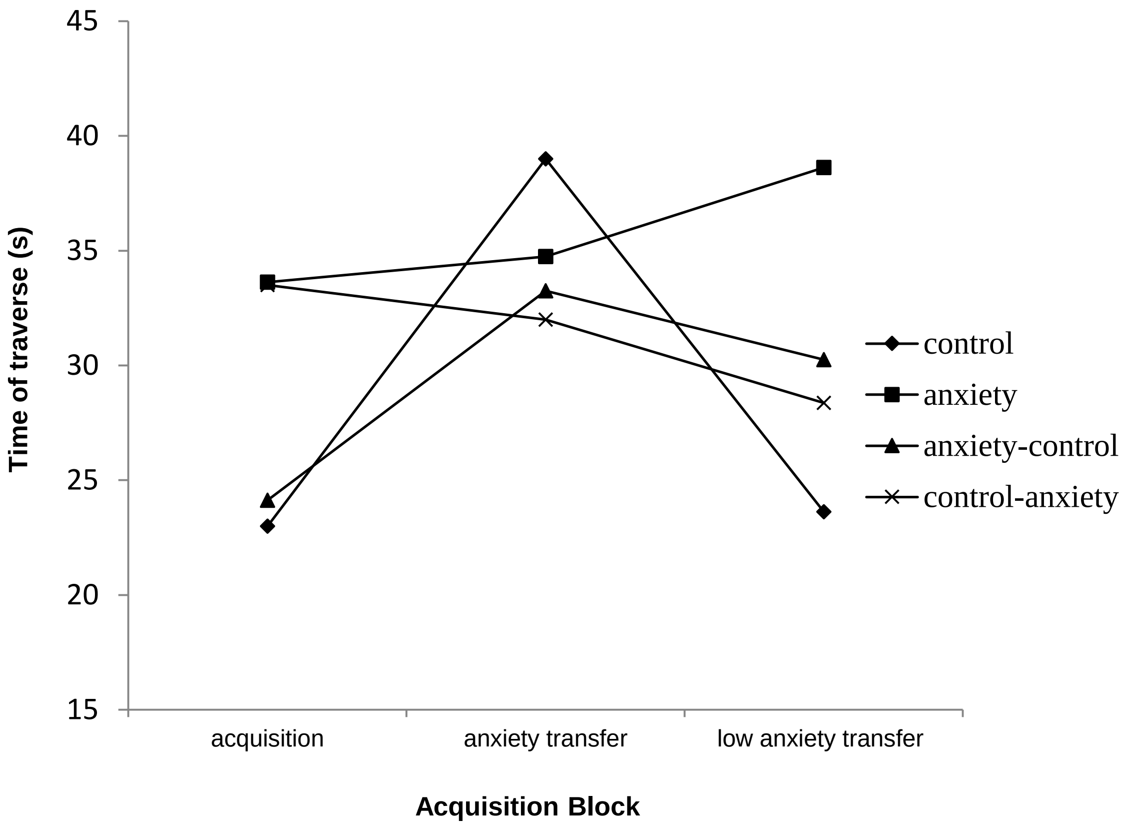

Figure 5. Experiment 2 Time of traverse (seconds) as a function of group and experimental phase; acquisition (last 10 trials), anxiety transfer and low anxiety transfer.

Introducing anxiety early and late in practice

The results of the t-test between the change in TOT from block 1 to 5 (early transfer) for the control-anxiety group and block 10 to anxiety transfer (late transfer) for the control group revealed that the decrement in performance was significantly greater in late transfer (TOT = -16.00) compared to early transfer (TOT = -10.50) (t 14 = -6.07 p = .001). Number of performed movements (NOPM), number of explored movements (NOEM) and number of ventured movements (NOVM).

Acquisition

Means and *SDs* are reported in Table 6. As shown in Table 5 and Figure 6, the analyses of the NOPM, NOEM and NOVM all revealed significant main effects for group, day, and block, as well as significant group × day, group × block, day × block, and group × day × block interactions. Breakdown of the interactions revealed that number of movements significantly decreased during acquisition when trials were being performed only under control conditions. Specifically, number of movements decreased over day 1 (blocks 1-5) for the control-anxiety group, day 2 (blocks 6-10) for the anxiety- control group and over both days (from block 1 to block 10) for the control condition.

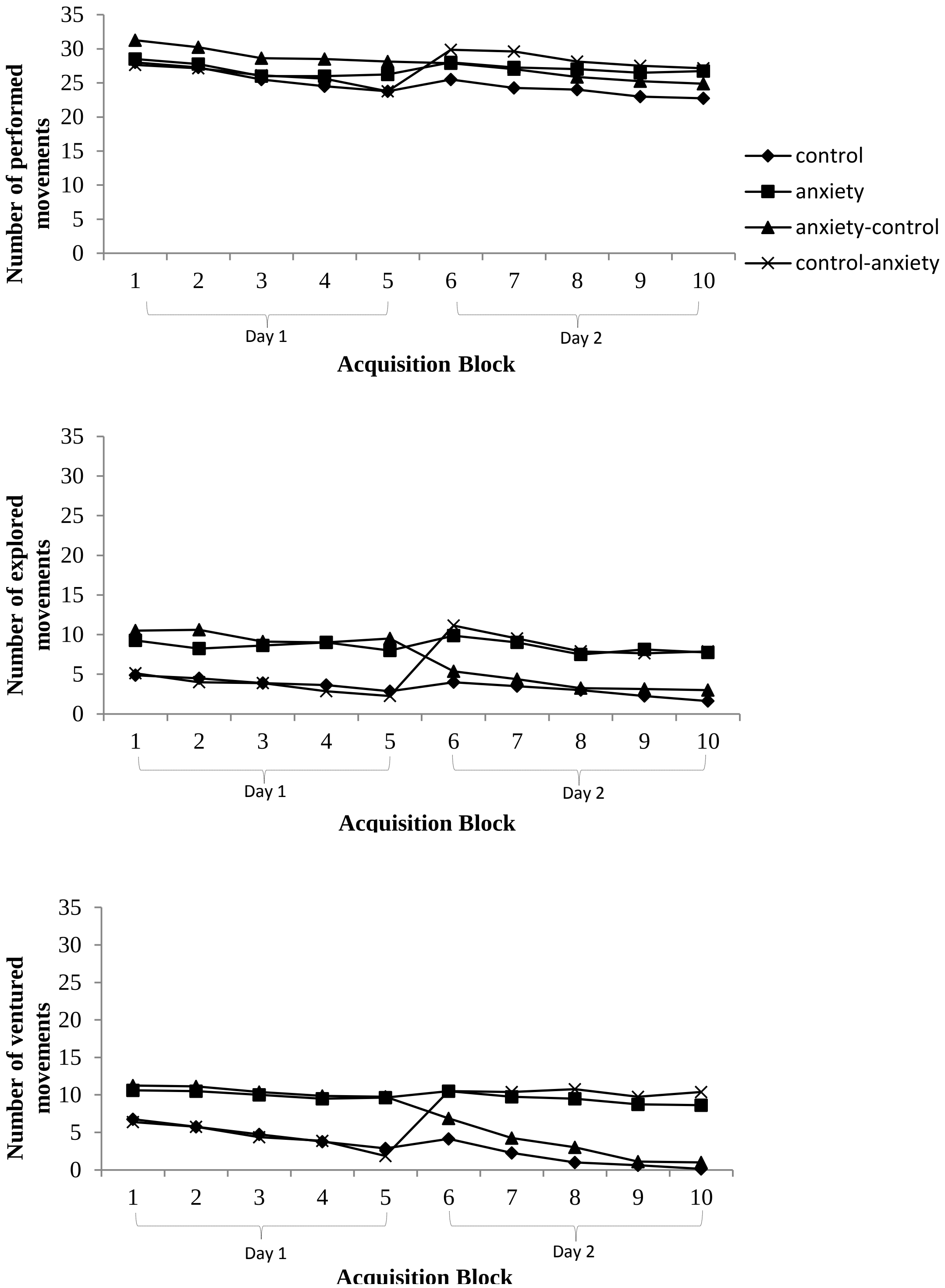

Figure 6. Experiment 2 Number of performed movements (top), number of explored movements (middle) and number of ventured movements (bottom) as a function of group and acquisition block (1 = trials 1-10; 2 = trials 11-20……, 10 = trials 91-100).

Acquisition versus transfer

The acquisition versus transfer data for the NOPM, NOEM and NOVM are shown in Figure 7. The analyses of all variables (see Table 5) revealed significant main effects for group and experimental phase as well as significant group × experimental phase interactions. These main effects and interactions showed the same significant pattern of results to that of the time of traverse data. Thus, for reasons of brevity the data have been summarized; the control group experienced only a significant decrease in performance from acquisition to anxiety transfer; the anxiety group experienced only a decrement in performance between acquisition and low anxiety transfer; the control-anxiety maintained performance between acquisition and anxiety transfer whereas performance was significantly greater in the low anxiety compared to both the anxiety transfer and acquisition phases; the anxiety-control group significantly decreased performance from acquisition to anxiety transfer.

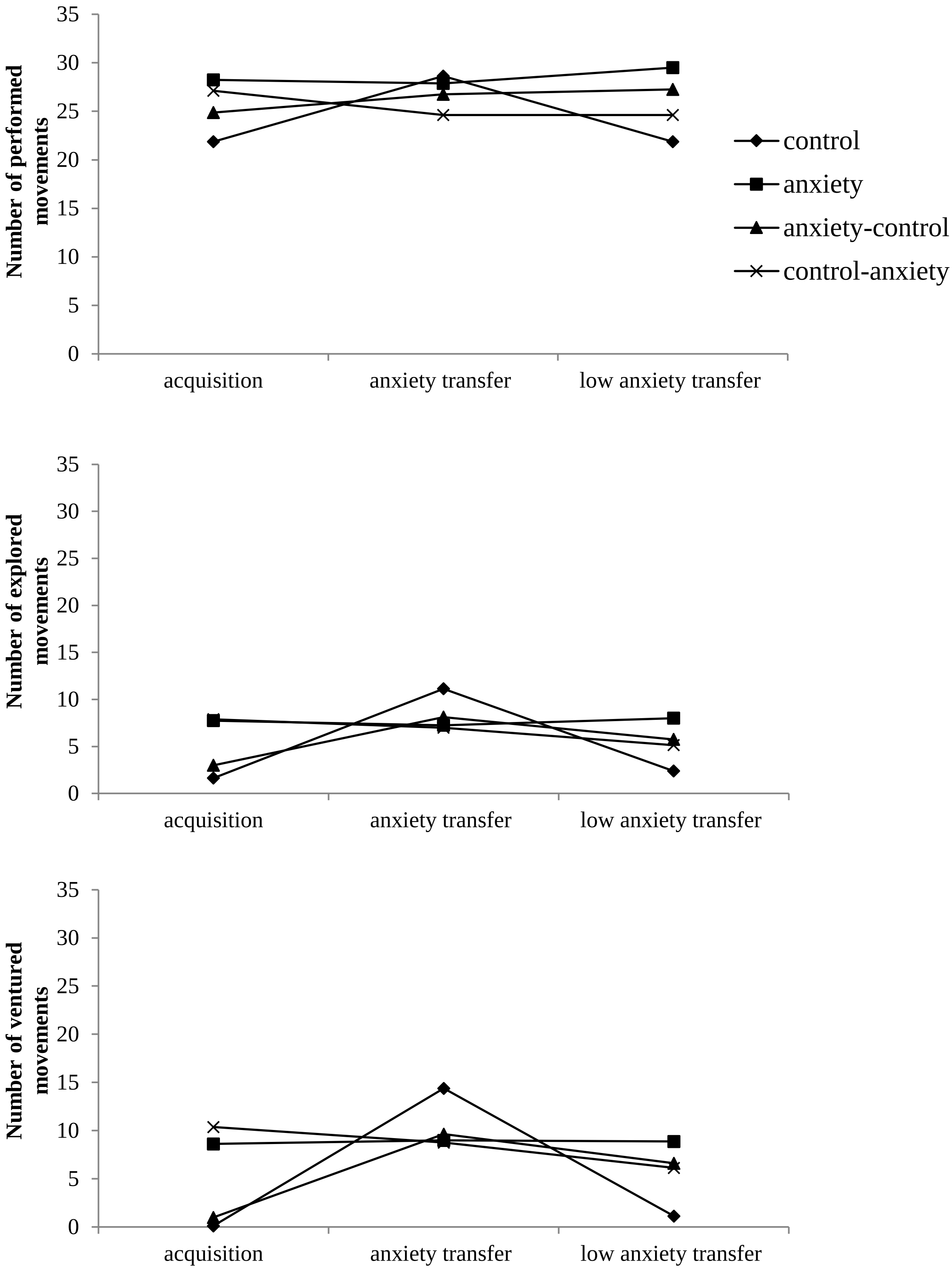

Figure 7. Experiment 2 Number of performed movements (top), number of explored movements (middle) and number of ventured movements (bottom) as a function of group and experimental phase; acquisition (last 10 trials), transfer 1 (anxiety) and transfer 2 (low anxiety/control).

2.2.4. Discussion

The purpose of Experiment 2 were to further investigate the possibility that the specificity of learning theoretical framework (Gilligan & Bower, 1983; Henry 1968, Proteau, 1992) can explain the positive effects of practicing with anxiety, and to examine when in the learning process practicing with anxiety is most appropriate for a complex task. Similar to Experiment 1, results showed that the manipulation of anxiety was successful where targeted. In addition, task effort was similar for all groups and did not change as a result of the presence of anxiety.

Results of the performance data between acquisition and anxiety transfer for the control and anxiety groups are consistent with findings from Experiment 1. That is, practice under conditions of anxiety leads to more robust performance under future conditions of anxiety compared to none anxiety practice conditions, and learning without exposure to anxiety leaves one particularly vulnerable to its effects in subsequent performances. The results at the additional low anxiety transfer test revealed that climbing times of the anxiety group significantly increased from acquisition to transfer whereas, there was no change between acquisition and transfer for the control group. Thus, performance decreased in both the control group and anxiety group when the transfer test resulted in a change in the conditions under which the skill had been practiced. These findings support a specificity perspective, since those participants who practiced under conditions of anxiety likely created associations during acquisition between the emotions of anxiety and the movements of the to-be-learned skill. As such, they developed representations of the movement during acquisition that were adapted to the presence of anxiety, whereas those participants in the control group developed movement representations that were adapted to the absence of anxiety. These findings are again consistent with evidence from manual aiming studies in which performance decrements have been observed following both the withdrawal (Khan et al., 1998; Proteau et al., 1987) and the addition of visual feedback (Proteau et al., 1992). Experiment 2 thus offers further direct evidence for the principles of specificity of practice in the context of affect, namely anxiety.

Comparison between the anxiety-control and control-anxiety groups enabled us to investigate when in the learning process practicing with anxiety is most appropriate. Unsurprisingly, traverse times for these groups only significantly improved during the low anxiety (control) acquisition conditions and the analysis of the performance data at the midpoint of acquisition (i.e., the removal of anxiety and the introduction of anxiety for the anxiety-control and control-anxiety groups, respectively) revealed that the presence of anxiety negatively affected performance. Specifically, the control-anxiety group significantly increased traverse times following the introduction of anxiety whereas the opposite was true for the anxiety-control group. Of more interest, with regard to investigating when in acquisition introducing anxiety is most appropriate, were the between group differences in performance at anxiety transfer and low anxiety transfer. Here, traverse times were greater in the low anxiety transfer test for the anxiety-control group compared to the control-anxiety group. Thus, for practice conditions, which included both anxiety and none anxiety training, experiencing anxiety from start of learning was less effective in subsequent low anxious situations compared to practice where anxiety was not introduced until later in the learning process. Importantly, the performance at anxiety transfer was significantly greater in both the anxiety-control and control-anxiety groups compared to the anxiety group alone. These findings indicate that a mix of both anxiety and control conditions during learning results in more robust performance in subsequent anxiety situations compared to practicing only with anxiety.

The specificity and the timing of anxiety introduction findings of time of traverse data are also supported by the number of movements performed (NOPM) and number of uncertain movements performed (NOEM, NOVM). Here data revealed that the performance at low anxiety transfer was greatest in the control condition (acquisition to transfer congruent condition) and lowest in the anxiety condition (acquisition to transfer incongruent condition). Revealing that a change in learning conditions (i.e., the removal of anxiety) resulted in both a significant decrement in performance and a significantly reduced performance compared to situations where acquisition and transfer conditions were matched. Furthermore, the significant difference between the anxiety-control and control-anxiety groups at the low anxiety transfer test (anxiety-control being significantly lower than control-anxiety) suggests that anxiety from the start of learning is detrimental to subsequent low anxiety performance conditions.

2.3. General Discussion

The main purpose of the present study was to investigate if the positive effects of practicing with anxiety (Oudejans 2008; Oudejans & Pijpers, 2009; 2010) can be explained through a specificity of learning perspective by investigating if these effects are dependent on the amount of exposure to anxiety and the timing of that exposure in the learning process. We investigated these issues using both a discrete golf putting task (experiment 1) and a more complex climbing (experiment 2) task.

The finding from both Experiments that learning with anxiety eliminated choking provided support for both mood and condition-congruent learning theories (e.g., the network theory of affect (Gilligan & Bower, 1983); specificity of learning (Henry, 1968); specificity of practice (Proteau, 1992). As explained earlier, the network theory of affect proposes that emotions be regarded as units within a network connecting related events, ideas, and muscular patterns. The activation of a unit creates somewhat of a ‘domino’ effect and other related units are also activated. As a result, a network is created between the emotional mood state at the time of learning and the muscular patterns of the to-be- learned skill (i.e., anxiety and the movements involved in golf putting in Experiment 1 and climbing in Experiment 2). In the present investigation, it may have been that the anxiety condition in the transfer test served to activate the emotions associated with this mood state which in turn resulted in the activation and subsequent recall of the muscular patterns required during transfer of the learned golf putting action of experiment 1 and the climb in experiment 2. As such, those participants who created a network during acquisition between the emotions of anxiety and the movements of the to-be-learned skill (i.e., those who experienced anxiety while practicing) were better able to recall the required action during the subsequent anxiety transfer test. Further support for these mood congruent learning effects can be found in the results of the control (low anxiety) transfer introduced in experiment 2. Here, participants who had received all practice under anxiety significantly increased climbing times from that of acquisition to the non-anxiety transfer test. Thus, when the transfer test resulted in a change in the conditions under which the skill had been learned (i.e., the absence of anxiety), a decrement in performance was observed.

These patterns of results can also be explained by the specificity principle. Henry (1968) proposed that the best learning experiences are those that most closely approximate the movements of the target skill and the environmental conditions of the target context, whilst Proteau (1992) and other researchers (Elliott et al., 1995; Khan & Franks, 2000; Khan et al., 1998; Mackrous & Proteau, 2007) suggest that participants develop movement plans during acquisition that are adapted and specific to the conditions available at the time of learning. As such, a change in the conditions under which the skill has been learned results in these movement plans no longer being appropriate for successful performance. This may explain why the only group to experience a decrement in performance during transfer to an anxious condition in experiment 1 and experiment 2 was that of the control. The movements developed by the participants in these groups were likely adapted to the conditions experienced during learning (i.e., the absence of anxiety) and thus a change in the conditions experienced between learning and transfer resulted in the movement no longer being effective for accurate performance.

Research investigating the specificity hypothesis has revealed that the effect is enhanced through increased practice (Khan et al, 1998; Proteau & Cournoyer, 1990; Proteau et al., 1987; Proteau, Marteniuk, & Levesque, 1992; Proteau, Tremblay, & DeJaeger, 1998). The results of the current investigation support this phenomenon when one considers the analyses of the early and late transfer effects. Specifically, we compared the change in performance of the control-anxiety group at the midpoint of acquisition (i.e., the last block of control conditions to the introduction of anxiety) to the change in performance of the control group between the end of acquisition and the anxiety transfer test. Since, the change from control conditions to anxiety conditions occurred at the midpoint of practice (early transfer) in the control-anxiety group and at the end of practice (late transfer) for the control group, greater performance decrements in late transfer compared to the early transfer would demonstrate specificity of practice. The results of these analyses revealed that the decrement in performance was greater in late transfer for both experiment 1 and experiment 2. These findings offer support for the specificity exposure effects hypothesized in that of the current investigation and the findings of previous research on specificity of practice (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau, Marteniuk, Girouard, & Dugas, 1987; Tremblay & Proteau, 1998, 2001) and thus, lend further support for considering this hypothesis when attempting to explain the choking phenomenon.

Investigating the effects of introducing anxiety at different stages of the learning process revealed in both experiments that those participants in the anxiety-control group significantly increased performance following the switch in acquisition conditions, whereas those in the control-anxiety groups decreased performance. Furthermore, the performance (for all dependent variables) in both the anxiety and low anxiety transfer tests of experiment 2 was greater in the control-anxiety group compared to anxiety-control group. These findings suggest that training with anxiety from the start of learning may actually be detrimental to skill learning. It is likely that the presence of anxiety at this cognitive stage of learning increases the task demands to a level that reduces the efficiency of the learner (Eysenck et al., 2007) and the effectiveness of the performer's learning strategies. However, this notion is task dependent, since the performance differences between the anxiety-control and control-anxiety groups seen at the mid-point of acquisition were only present at transfer in experiment 2 (the more complex climbing task). As such, introducing anxiety from the beginning of acquisition disrupts the learning process to such a degree as to reduce the benefits of training with anxiety from the start of learning, only in the more complex task. Whilst the present investigation demonstrated specificity effects, both experiments adopted short delays between the completion of acquisition and the start of the transfer test (15 minutes in experiment 1 and 1 hour in experiment 2). This was to ensure that the methodologies were in line with the seminal articles investigating specificity in manual aiming (e.g., Proteau et al., 1987, Proteau, 1992) and the experiments of Oudejans and Pijpers (2009) investigating training with anxiety on basketball and dart throwing. However, subsequent to completion of the current investigation, personal communication from the pioneer of the specificity hypothesis (Luc Proteau) clarified that the rationale for short delays in the manual aiming studies were due to the nature of the control group (typically a no vision condition). If longer delays between acquisition and transfer tests had been utilised participants in the control group would have had visual feedback to control their everyday movements between the end of practice and the retention/transfer test. The availability of this feedback would have likely washed out any potential differences in transfer between the experimental group, where visual feedback is available during practice, and the no vision control group. It appears that in the present investigation, longer delays between acquisition and transfer would unlikely result in the same confounding factor since the independent variable (anxiety) would not likely be experienced during that period to the same extent as the independent variable (vision) of the manual aiming studies. As such, future research should investigate the anxiety specificity effect with greater time intervals between the completion of training and the start of transfer to see if the specificity effects reported are more permanent in nature.

In conclusion, the specificity principle that has emerged from the motor learning literature offers an explanation for choking. That is, performance decrements occur due to a change in the conditions under which the task is practiced, both when conditions change from control to anxiety and anxiety to control. As such, the specificity principle should be considered in future research investigating the choking phenomenon. In addition, results revealed that training under anxiety should be adopted as a process for eliminating choking. Whilst performers and practitioners may find it difficult to replicate the anxiety experienced in 'real' high pressure situations (i.e., a soccer penalty shootout in the final of a cup game), utilizing anxiety manipulations similar to those in the present investigation (i.e., both internal and external competition together with incentives for loss) can still provide an effective training environment. Finally, the significantly greater performance of the control-anxiety group compared to the anxiety-control group in both the anxiety and low anxiety transfer tests of experiment 2, indicate that for more complex skills one should avoid introducing anxiety into training until later in the learning process. These findings highlight that introducing anxiety from the start of acquisition disrupts the learning strategies and results in less than optimum performance both in subsequent anxious and non-anxious situations.

CHAPTER 3

THE ASPECTS OF MOTOR CONTROL THAT DEVELOP SPECIFICITY TO ANXIETY DURING A COMPLEX UPPER LIMB MOVEMENT PATTERN

3.1. Introduction

Optimal performance is more often than not the goal of athletes, particularly when rewards are high. However, in pressure situations many athletes perform sub optimally despite high motivation to succeed (Baumeister & Showers, 1986). Within the field of sport psychology this phenomenon has been described as ‘choking’; the failure to perform to one’s normal ability as a result of state anxiety (a specific negative response to perceived pressure; Beilock & Gray, 2007). Recent literature within the motor control and learning field has revealed that the choking phenomenon can be eliminated if performers practice under anxious conditions prior to performing under pressure situations (Lawrence et al, 2012a; Nieuwenhuys & Oudejans, 2009, 2012; Oudejans, 2008; Oudejans & Pijpers, 2009, 2010). Furthermore, the 2 experiments within the previous chapter of this thesis provide direct experimental evidence that the positive effects of training under anxious conditions conform to the principles of Specificity of Practice (Proteau, 1992). Further, the stress-performance relationship is dependent on the amount of exposure to anxiety during practice, and the timing of that exposure in relation to the development of the to-be-learned skill’s movement plan. These findings were explained via the notion that the participants strategies and movement plans surrounding golf putting (experiment 1) and climbing (experiment 2) had adapted to and developed specificity associated with the anxious mood state; an explanation and pattern of results not consistent with the *traditional* theories proposed to explain the choking phenomenon (i.e., distraction and self-focus). Whilst there has been significant empirical support for both distraction (see Eysenck et al., 2007 for review, Hardy, Beattie, & Woodman, 2007; Murray & Jannelle, 2003) and self-focus theories (Baumeister, 1984; Beilock & Carr, 2001; Lewis & Linder, 1997; Masters, 1992; see Masters & Maxwell, 2008 for a review), limitation nonetheless still exist. For example, this literature has 1) not considered the notion of specificity of practice as an explanation for choking, and 2) primarily focused on outcome measures of performance and not sought to precisely quantify the effects of anxiety on the performance of either movement planning or movement execution. Therefore, the purpose of the present experiment was to further investigate the specificity effect on the psychological construct of anxiety by examining which aspects of motor control develop specificity to anxiety; the planning of movement parameters (i.e., offline control) or the adjustment of these parameters during movement execution (i.e., online control).

In a recent attempt to address the research lacuna surrounding what motor processes are affected by pressure, Coombes, Higgins, Gamble, Cauraugh, & Jannell (2009) investigated the effects of anxiety on the planning of movement. Here, researchers utilised a target force contraction task (e.g., a pinch action with the index and thumb digits of the right hand without concurrent visual feedback), assumed to be representative of an open loop pre-planned target directed movement (i.e., a movement that is not open to changes or adjustments during movement execution). This task was adapted to measure both motor planning efficiency (reaction time and rate of force change) and outcome performance efficiency (RMSE of actual production) in high and low anxious individuals. Results revealed that movement planning was only compromised by anxiety in the more difficult task (reproducing 10% of maximal voluntary force production) i.e., the task requiring greater working memory. Coombes et al. (2009) applied the principles of Eysenck et al. (2007) ACT to interpret their findings by suggesting that the results were due to reduced inhibition in the high anxiety group leading to a decrease in the goal driven system; specifically a reduction in the motor planning efficiency required to accurately produce the target force. However, their research design only allowed investigation into the effects of anxiety on movement planning and was thus unable to determine how anxiety might affect processes involved with online movement execution. In addition, the specificity of practice effect reported in the previous chapter of this thesis could be an alternative explanation to that of ACT when interpreting the findings of Coombes et al. (2009). That is, participants who practiced under control conditions may have developed movement strategies specific to both the information that was available during practice and the emotional mood state during practice. Therefore, when conditions changed during transfer (i.e., addition of anxiety), both the information that was available and the emotional mood states had been altered. This incongruity between acquisition and transfer would lead to the movement plan that was developed in practice (i.e., in the control condition) no longer being adequate for successful performance. However, even with the addition of this possible specificity explanation, the research design of Coombes et al. (2009) does not allow one to infer whether it is either one, the other, or a combination of both offline (planning) and online (corrections during movement execution) motor processes that are affected by anxiety.

In the present investigation we were interested in extending research on specificity of learning within the psychological construct of anxiety by attempting to investigate both the planning of movement parameters (i.e., offline control) and the adjustment to parameters during movement execution (i.e., online control). Specifically we asked participants to make a series of complex upper limb movement patterns in either a control or pressured learning environment before transferring them to the opposite condition. The aim of the complex movement pattern allowed performance to be separated into variables associated with offline control (e.g., reaction time, Henry & Rogers, 1960; Khan et al., 2006) and online control (e.g., pause times and movement times, Khan et al., 2006). As such, we were able to investigate what aspects of motor control (offline and/or online control) develop specificity when training under conditions of anxiety or control conditions. Based on the findings by Coombes et al. (2009), we hypothesised that the planning of the movement will be negatively affected by the presence of anxiety. Given the anxiety specificity effects reported in the previous chapter, it was expected that participants who learn under anxiety would adapt movement strategies to produce more accurate movement programmes (offline) in an attempt to control performance when under pressure. Thus, we predicted that the removal of anxiety in the transfer conditions would result in a decrement in planning performance (represented by an increase in RT) from that observed in acquisition (because the specificity of practice in relation to the construct of anxiety will be developed around movement planning). Furthermore, we expected that this planning specificity effect would increase as a function of practice and therefore hypothesised that the RT performance decrements between acquisition and transfer would be greater in late compared to early transfer.

3.2. Method

Participants

40 participants which consisted of 38 right and 2 left handed participants (17 male, 23 female; mean age = 24.07, *SD* = 7.05) with no previous experience in the experimental task, volunteered to participate in the study. All participants were naive to the hypothesis being tested and gave their informed consent prior to taking part in the study. The experiment was conducted in accordance with the ethical guidelines laid down by the ethics committee of the School of Sport, Health and Exercise Sciences, Bangor University for research involving human participants.

Apparatus

Participants held a digitising pen with their right hand and made movements on a Calcomp III digitizing tablet (size = 1220cm x 915mm, sample rate = 200 Hz, accuracy = ± 0.125mm) positioned horizontally in front of them. The position of the pen was represented by a cursor (1 cm in diameter) on a 37” Mitsubishi Diamond Pro computer monitor (refresh rate = 85Hz) situated 400mm in front of the participants and 200mm above the tablet. Visual displays of the start position, target regions, and a cursor representing the pen position appeared on the monitor screen (see Figure 8). Movements of the pen away from the participant’s body on the tablet corresponded to vertical movements of the cursor on the monitor. There was a one to one mapping between the movement of the pen and the movement of the cursor. All target regions consisted of a white circle (40mm in diameter) and were positioned equally in a 3 × 3 grid formation within a 200mm × 200mm area. The home position consisted of a green circle (40mm in diameter) and was located along the bottom line of the monitor at a distance of 100mm above the bottom of the monitor screens. The start position was located in the centre position on the bottom row of the 3 × 3 grid (see Figure 8). The participants chair was adjustable in height so that the participant’s eyes were at a level with the middle of the 200mm × 200mm target area. The participant’s arm and hand were hidden from their view by an opaque shield thus preventing direct vision of the limb throughout testing.

Anxiety and Effort scales

Cognitive anxiety, somatic anxiety, and confidence were assessed via the Mental Readiness Form-3 (MRF-3; Krane, 1994) and task effort was assessed via the Rating Scale of Mental Effort (RSME; Zijlstra, 1993). The MRF-3 comprises of three single item factors that are each scored on an 11 point Likert scale: cognitive anxiety from 1 (not worried) to 11 (worried); somatic anxiety from 1 (not tense) to 11 (tense); and self-confidence from 1 (confident) to 11 (not confident). For the purpose of the present study a combined score of cognitive anxiety and somatic anxiety were used to assess anxiety levels. The RSME comprises of a 150mm 1 to 150 vertical Likert scale with nine descriptors ranging from 3 ‘absolutely no effort’ to 114 ‘extreme effort’.

Task and Procedures

At the start of testing, participants were informed that the aim of the experiment was to investigate the accuracy and timing of their movement and that movement should be performed as accurately and quickly as possible. Participants were told they would be performing three aiming movement tasks that followed specific pathways. All tasks required three targets to hit, but the movement sequence between targets differed depending on which stimulus was presented (see Figure 8). Participants completed a total of 603 trials. The first 27 trials were performed with the assistance of a schematic of the three to-be-learned patterns. This was to familiarise participants with the movement of each pattern. The remaining trials (i.e., 576 trials) were randomised between the three tasks and distributed into an acquisition phase (18 blocks of 30) and two transfer tests (2 blocks of 18), and were administered over a 3 day period. The within participant randomisation procedure was set up such that none of the three movements were repeated before each task had been presented and each block contained an equal number of presentations of each movement task. This pseudo-randomisation procedure differed between participants such that whilst the number of tasks was always equal within each block, the order of these was different for each participant. To start, participants completed block 1 (day 1) which consisted of 27 trials (9 in each task) before being given a 5-minute break followed by an early transfer block (day 1), which consisted of 18 trials (6 in each task). After a further 5-minute break the acquisition phase continued in the form of 6 blocks of 30 trials (10 in each task) which totalled 180 trials (60 in each task). This block 1, early transfer and first acquisition phase (block 2 - 7) were all conducted on day 1. The following day consisted of an acquisition phase that was identical to that of the previous day (i.e., participants completed 6 blocks of 30 trials). On the final day, participants again completed another 6 blocks of acquisition, before completing the late transfer phase. The late transfer phase was identical to that of the early transfer phase in that participants completed a block of 18 trials (6 in each task). Consistent with day 1, participants received a 5-minute break before completing the late transfer test.

At the start of each trial participants was presented with a tone that required the participants to ‘get ready’. Following a variable (1500-2500ms) fore period, a stimulus then appeared which consisted of one of the targets from the top line changing colour from white to red; the change in colour of either the top left, top middle, or top right target were the stimuli informing the participants to execute pattern 1, 2 or 3, respectively (see Figure 8). Following the stimulus, participants were required to respond as fast as possible to complete the required movement pattern as smoothly, quickly, and accurately as possible before coming to a complete stop when they had reached the stimulus target (see Figure 8).

INSERT FIGURE 8 (see file titled Chapter 3 Figure 8)

Each participant was randomly assigned to one of four groups: (1) in the control-control group all acquisition and transfer trials were performed under normal (low anxiety) conditions; (2) in the anxiety-anxiety group all acquisition and transfer trials were performed under anxiety conditions; (3) in the control-anxiety group acquisition trials were performed under normal (low anxiety) conditions and both the early and late transfer tests under anxiety conditions; (4) in the anxiety-control group, participants followed the same procedure to that of the control-anxiety group with the exception that the order of the anxiety and the control conditions was reversed.

Anxiety Manipulation

Anxiety was manipulated through a combination of intrinsic and extrinsic competition. Specifically, during acquisition for the anxiety manipulation, participants were informed that their movements were being video recorded (of which a screen monitor was placed to the side of the participant demonstrating what was being recorded) for both live and later analysis by researchers within the University. In addition, participants were told that the person with the greatest movement accuracy and fastest reaction times would win £100. There were both a winners and losers board presented in the room representing the results for everyone to see. Further to this, participants were also subjected to a new 'experiment observer' during the anxiety transfer phases. This experimenter stood behind the participant and pretended to make notations regarding their movement patterns. Finally, during the anxiety transfer phase in addition to the £100 that could already be won during acquisition, it was made clear to participants that they had been partnered with another individual, that in order for them to secure the prize money (now £200; £100 per person), both them and their partner needed to achieve a 20% improvement. Participants were then informed that their partners had already completed the experiment and successfully achieved the required 20%

improvement. As a final point, all participants were told they would receive an email detailing who they were partnered with and how that individual had performed.

In order to ensure anxiety had been successfully manipulated, all participants completed the MRF-3 immediately prior to the start of block 1 day 1, early transfer, block 2 day 1, block 1 day 2, block 1 day 3 and late transfer. Effort, as determined by the RSME, was measured retrospectively at the same experimental phase (i.e., immediately post block).

Performance Measures

Performance data for each trial consisted of reaction time (RT), movement time to target 1 (MT1), pause time at target 1 (PT1), movement time to target 2 (MT2), pause time at target 2 (PT2), movement time to target 3 (MT3), overall movement time (OMT), and overall pause time (OPT). RT was the interval from the presentation of the stimulus to the movement of the pen at the home position. MT1 was measured from the movement of the pen at the starting position to touching T1. MT2 was measured from the movement of the pen from T1 to touching T2. MT3 was measured from the movement of the pen from T2 to touching T3. PT was the time between the pen reaching a target and leaving a target (e.g. PT1 was the time between the pen reaching T1 and the pen leaving T1). OMT was the sum of MT1, MT2, and MT3 whereas OPT was from the sum of PT1 and PT2.

Statistical Analysis

Psychological Measures

MRF-3 data used to measure anxiety (worry and tense) and confidence were assessed separately by a 4 (group: control-control; anxiety-anxiety; control-anxiety; anxiety-control) x 6 (time: block 1 day 1 (immediately prior to acquisition); early transfer block (immediately prior to transfer block); block 2 day 1 (immediately prior to original acquisition state); block

1 day 2 (immediately prior to acquisition); block 1 day 3 (immediately prior to acquisition); late transfer block (immediately prior to transfer block)) ANOVA with repeated measure on the second factor. Effort data were submitted to a similar 4 (group: control-control; anxiety-anxiety; control-anxiety; anxiety-control) x 6 (time: block 1 day 1 (immediately following the final trial of acquisition); early transfer block (immediately following the final trial of transfer); block 7 day 1 (immediately following the final trial of acquisition); block 6 day 2 (immediately following the final trial of acquisition); block 6 day 3 (immediately following the final trial of acquisition); late transfer block (immediately following the final trial of transfer)) ANOVA with repeated measure on the second factor.

Performance Data; Acquisition

In order to assess learning over each day RT, PT1, PT2, OPT, MT1, MT2, MT3 and OMT were submitted to separate 4 (group: control-control; anxiety-anxiety; control-anxiety; anxiety-control) x 3 (day: day 1; day 2; day 3) x 6 (time: block 1; block 2; block 3; block 4; block 5; block 6) ANOVAs with repeated measure on the second factor.

Early Transfer and Late Transfer

RT, PT1, PT2, OPT, MT1, MT2, MT3 and OMT were submitted to separate 4 (group: control-control; anxiety-anxiety; control-anxiety; anxiety-control) x 2 (time: block 1 day 1; early transfer block) ANOVAs with repeated measures on the second factor, to assess the effects at early transfer. The same performance measures were further submitted to separate 4 (group: control-control; anxiety-anxiety; control-anxiety; anxiety-control) x 2 (time: block 6 day 3; late transfer block) ANOVAs with repeated measure on the second factor, to assess late transfer effects. All significant effects were broken down using Tukey’s HSD post hoc procedures ($p < .05$).

3.3. Results

Psychological Measures

All means and *SDs* are in Table 7, and all statistical values for the anxiety, confidence, and effort analyses are reported in Table 8.

		Experimental Phase					
Variable	**Group**	**1**	**ET**	**2**	**3**	**4**	**LT**
Anxiety	C	5.80	4.70	3.30	2.50	2.30	2.00
		3.61	*2.49*	*1.25*	*0.70*	*0.48*	*0.00*
	A	11.4	12.6	14.1	14.8	14.4	14.7
		5.08	*5.23*	*5.23*	*5.09*	*5.23*	*5.81*
	CA	8.30	10.2	7.30	5.30	6.20	9.20
		3.33	*3.82*	*3.36*	*2.05*	*1.68*	*1.87*
	AC	9.60	8.00	11.2	10.9	12.3	5.20
		3.92	*3.97*	*4.13*	*4.72*	*5.07*	*2.09*
TOTAL		8.77	8.87	8.97	8.37	8.80	7.75
		4.39	*4.84*	*5.49*	*5.97*	*6.06*	*5.71*
Confidence	C	6.30	7.70	8.80	8.70	9.50	9.70
		2.40	*2.86*	*2.29*	*2.94*	*2.22*	*1.94*
	A	5.00	4.70	4.80	4.60	5.00	5.10
		2.10	*2.35*	*2.48*	*2.75*	*2.66*	*2.92*
	CA	7.00	6.70	7.30	7.60	7.80	6.40
		1.76	*1.94*	*2.11*	*2.06*	*1.68*	*1.42*
	AC	5.30	7.20	5.50	5.60	6.10	5.60
		2.94	*1.81*	*2.54*	*2.31*	*2.13*	*2.27*
TOTAL		5.90	6.57	6.60	6.62	7.10	6.70
		2.39	*2.47*	*2.77*	*2.94*	*2.73*	*2.79*
Effort	C	68.3	68.5	68.0	67.0	66.5	65.5
		17.2	*15.8*	*14.7*	*13.1*	*13.1*	*13.0*
	A	79.4	80.6	80.0	80.5	79.5	79.0
		19.9	*17.3*	*17.1*	*16.4*	*21.0*	*20.1*
	CA	69.6	71.7	67.5	67.3	67.0	64.6
		9.86	*9.03*	*11.0*	*13.3*	*10.5*	*14.9*
	AC	77.7	72.3	76.2	77.3	78.2	74.8
		19.0	*21.0*	*18.7*	*18.5*	*23.4*	*19.3*
TOTAL		73.7	73.2	72.9	73.0	72.8	70.9
		17.0	*16.3*	*16.0*	*16.1*	*18.2*	*17.5*

Table 7. All means and SDs for anxiety, confidence and effort as a function of group (c = control; a = anxiety; a-c = anxiety-control; c-a = control-anxiety).

		Statistical Value		
Variable	**Factor(s)**	**F**	**Df**	**P**
Anxiety	Block	1.58	5, 180	.189
	Condition	18.36	3, 36	< .001
	Block x Condition	8.71	15, 180	< .001
Confidence	Block	2.63	5, 180	.02
	Condition	6.82	3, 36	< .001
	Block x Condition	2.66	15, 180	< .001
Effort	Block	.551	5, 180	.651
	Condition	1.71	3, 36	.180
	Block x Condition	.456	15, 180	.903

Table 8. All statistical figures for anxiety, confidence and effort.

Anxiety

The ANOVA revealed a non-significant main effect of block, a significant main effect of group, and a significant block x group interaction. Breakdown of this interaction revealed that the anxiety manipulation was successful in the acquisition and transfer phases where targeted. Furthermore, the anxiety levels experienced in both acquisition and transfer were not significantly different from one another.

Confidence

The ANOVA revealed significant main effects for block and group together with a block x group interaction. Further breakdown of the results revealed that the anxiety-control group increased confidence from block 1day 1 (first block of acquisition) to early transfer (i.e., confidence increased when anxiety was taken away). Whereas, the control-anxiety group decreased in confidence from block 6 day 3 (last block of acquisition) to late transfer (i.e., confidence decreased when anxiety was induced). The analysis also revealed that confidence from block 1day 1 (first block of acquisition) to block 6 day 3 (last block of acquisition) increased throughout all groups.

Effort

The ANOVA revealed no significant main effects or interactions. Thus, effort was similar throughout all groups and did not differ between anxiety and control situations.

Performance Measures

Early Transfer (ET)

All means and *SDs* are reported in Table 9, and all statistical figures are reported in Table 10 for Reaction Time (RT), Pause Time 1 (PT1), Pause Time 2 (PT2), Overall Pause Time (OPT), Movement Time 1 (MT1), Movement Time 2 (MT2), Movement Time 3 (MT3) and Overall Movement Time (OMT).

		Experimental Phase			
Variable	**Group**	**D1B1**	**ET**	**D3B6**	**LT**
RT	C	671.7	595.6	490.3	474.5
		57.60	*83.30*	*90.80*	*92.60*
	A	695.8	632.2	501.4	483.6
		119.8	*82.70*	*76.40*	*73.90*
	CA	662.1	710.0	520.8	565.9
		133.0	*210.4*	*90.50*	*109.8*
	AC	770.7	816.0	491.0	576.1
		233.6	*188.0*	*80.90*	*114.3*
TOTAL		700.1	688.5	500.9	525.0
		150.4	*169.9*	*82.50*	*106.0*
PT1	C	271.9	240.6	199.3	201.8
		69.90	*52.40*	*125.8*	*129.8*
	A	240.7	246.3	207.9	223.8
		73.50	*111.9*	*75.20*	*75.70*
	CA	286.0	293.1	237.7	243.6
		109.5	*104.6*	*94.80*	*96.00*
	AC	294.9	293.3	191.6	250.5
		79.80	*75.50*	*59.50*	*86.70*
TOTAL		273.4	268.3	209.1	229.9
		88.90	*89.40*	*90.30*	*97.20*
PT2	C	285.9	260.1	184.2	184.8
		53.61	*54.60*	*134.2*	*135.0*
	A	251.6	221.1	202.3	221.5
		103.5	*141.1*	*96.90*	*96.90*
	CA	311.2	317.3	229.5	240.0
		121.7	*116.0*	*99.00*	*105.7*
	AC	320.5	301.6	183.8	267.6
		96.30	*84.90*	*69.30*	*105.4*

TOTAL		292.3	275.1	199.9	228.5
		97.00	*99.50*	*100.2*	*111.5*
OPT	C	622.3	549.7	383.5	386.7
		176.1	*117.7*	*259.3*	*263.7*
	A	492.4	467.5	433.1	460.6
		158.6	*214.6*	*209.4*	*192.3*
	CA	734.1	767.9	467.3	483.7
		317.4	*402.2*	*192.0*	*200.4*
	AC	691.0	651.0	375.4	518.2
		302.6	*219.9*	*127.2*	*188.4*
TOTAL		634.9	609.0	414.8	462.3
		256.7	*274.4*	*198.3*	*210.8*
MT1	C	320.9	238.9	170.9	167.4
		72.90	*65.00*	*80.70*	*76.50*
	A	303.7	242.1	189.8	191.1
		141.5	*88.40*	*60.90*	*47.40*
	CA	297.8	291.3	189.4	185.5
		84.40	*97.80*	*63.10*	*68.70*
	AC	346.6	295.6	159.9	227.7
		111.1	*109.3*	*47.30*	*87.20*
TOTAL		317.3	267.0	177.5	192.9
		103.5	*92.00*	*62.90*	*72.10*
MT2	C	201.7	155.6	121.6	123.9
		41.70	*37.40*	*49.80*	*47.80*
	A	207.0	150.2	130.1	141.1
		142.1	*41.90*	*31.60*	*43.20*
	CA	198.2	188.2	132.6	131.8
		70.20	*54.70*	*38.90*	*44.10*
	AC	194.8	166.5	114.5	175.4
		45.30	*33.30*	*22.80*	*73.40*
TOTAL		200.4	165.1	124.7	143.0
		81.80	*43.50*	*36.40*	*55.20*
MT3	C	260.4	213.4	152.2	143.6
		60.10	*49.10*	*55.10*	*58.20*
	A	244.0	197.9	149.1	171.0
		101.9	*64.20*	*42.30*	*56.60*
	CA	265.9	235.5	159.0	158.7
		87.10	*73.40*	*52.50*	*57.70*
	AC	242.8	210.3	138.0	220.4
		66.40	*44.50*	*35.90*	*115.3*
TOTAL		253.3	214.3	149.6	173.4
		78.10	*58.30*	*45.90*	*78.80*
OMT	C	783.2	607.9	444.7	434.9
		163.4	*143.9*	*180.6*	*179.8*
	A	754.8	590.3	469.1	503.4
		373.4	*189.8*	*132.9*	*125.6*
	CA	762.0	715.1	481.1	476.2
		227.0	*215.6*	*150.0*	*165.8*
	AC	963.8	840.8	412.4	623.6
		523.2	*500.0*	*97.00*	*268.1*
TOTAL		815.9	688.5	451.8	509.5
		347.8	*302.9*	*140.2*	*197.7*

Table 9. All means and *SDs* for all performance dependent variables as a function of group (c = control; a = anxiety; a-c = anxiety-control; c-a = control-anxiety) and experimental phase.

		Statistical Value					
		EARLY TRANSFER			LATE TRANSFER		
Variable	**Factor(s)**	**F**	**Df**	**P**	**F**	**Df**	**P**
RT	Block	.410	1, 36	.526	7.42	1, 36	.010
	Group	18.36	3, 36	.079	1.16	3, 36	.336
	Block x Group	3.44	3, 36	.027	7.97	3, 36	< .001
PT1	Block	.207	1, 36	.651	4.55	1, 36	.040
	Group	.972	3, 36	.417	.334	3, 36	.801
	Block x Group	.652	3, 36	.589	1.78	3, 36	.168
PT2	Block	2.61	1, 36	.115	6.16	1, 36	.018
	Group	1.65	3, 36	.195	.472	3, 36	.703
	Block x Group	.585	3, 36	.629	2.67	3, 36	.062
OPT	Block	1.12	1, 36	.296	5.07	1, 36	.030
	Group	2.29	3, 36	.094	.374	3, 36	.772
	Block x Group	.831	3, 36	.486	2.33	3, 36	.091
MT1	Block	22.52	1, 36	< .001	3.08	1, 36	.087
	Group	.525	3, 36	.668	.317	3, 36	.813
	Block x Group	2.26	3, 36	.098	3.96	3, 36	.015
MT2	Block	10.94	1, 36	.002	5.72	1, 36	.022
	Group	.146	3, 36	.932	.547	3, 36	.653
	Block x Group	.924	3, 36	.439	3.51	3, 36	.025
MT3	Block	20.80	1, 36	< .001	4.24	1, 36	.047
	Group	.402	3, 36	.753	.631	3, 36	.600
	Block x Group	.848	3, 36	.848	3.14	3, 36	.037
OMT	Block	25.39	1, 36	< .001	4.47	1, 36	.041
	Group	1.08	3, 36	.368	.485	3, 36	.695
	Block x Group	1.32	3, 36	.281	3.65	3, 36	.021

Table 10. All statistical figures for all performance dependent variables and experimental phase.

RT

Results revealed only a significant block x group interaction. Breakdown indicated that the anxiety-control and control-anxiety groups experienced a significant decrease in performance from block 1 day 1 (first block of acquisition) to early transfer (i.e., a change in practice conditions resulted in a decrement in performance). Whereas, the performance in the control-control and anxiety-anxiety group significantly increased in performance from block 1 day 1 (first block of acquisition) to early transfer (see Figure 9).

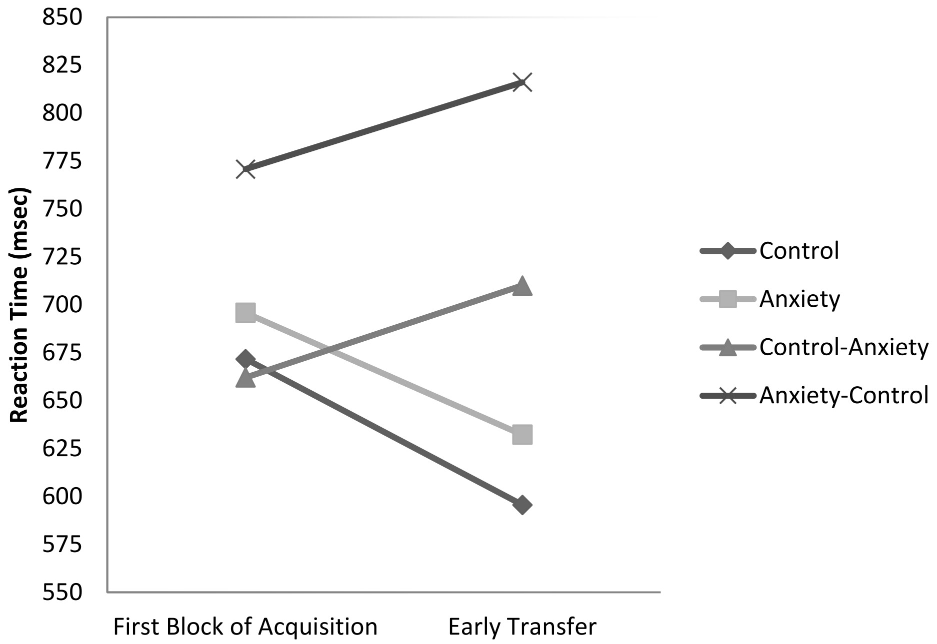

Figure 9. Reaction Time (milliseconds) during block 1 day 1 (first block of acquisition) and early transfer (trial 28-45).

PT1, PT2 and OPT

For all PT measures, the analysis revealed no significant main effects or interactions.

MT1, MT2, MT3 and OMT

For all MT measures, the analyses revealed significant main effects for block but non-significant main effects for group together with non-significant block × group interactions. Specifically, the data from all MT measures revealed that performance increased (MTs got faster) between block 1 day 1 and early transfer.

Acquisition

All means and *SDs* are reported in Table 11, and statistical figures are reported in Table 12 for Reaction Time (RT), Pause Time 1 (PT1), Pause Time 2 (PT2), Overall Pause Time (OPT), Movement Time 1 (MT1), Movement Time 2 (MT2), Movement Time 3 (MT3) and Overall Movement Time (OMT).

INSERT TABLE 11; 3 x pages (see file named Chapter 3 Table 11)

		Statistical Value		
		Acquisition		
Variable	**Factor(s)**	**F**	**Df**	**P**
RT	Group	.165	3, 36	.919
	Day	33.6	2, 72	< .001
	Day x Group	.595	6, 72	.732
	Block	20.1	5, 180	< .001
	Block x Group	.629	15, 180	.774
	Day x Block	1.73	10, 360	.107
	Day x Block x Group	1.08	30, 360	.429
PT1	Group	.047	3, 36	.986
	Day	5.27	2, 72	.007
	Day x Group	1.23	6, 72	.303
	Block	20.4	5, 180	< .001
	Block x Group	.985	15, 180	.450
	Day x Block	.377	10, 360	.870
	Day x Block x Group	.975	30, 360	.484
PT2	Group	.074	3, 36	.973
	Day	7.43	2, 72	.001
	Day x Group	1.35	6, 72	.249
	Block	39.9	5, 180	< .001
	Block x Group	1.00	15, 180	.433
	Day x Block	.527	10, 360	.707
	Day x Block x Group	.807	30, 360	.637
OPT	Group	.246	3, 36	.864
	Day	8.09	2, 72	.001
	Day x Group	1.31	6, 72	.268
	Block	36.8	5, 180	< .001
	Block x Group	.812	15, 180	.564
	Day x Block	.543	10, 360	.700
	Day x Block x Group	1.18	30, 360	.301
MT1	Group	.186	3, 36	.905
	Day	4.50	2, 72	.014
	Day x Group	1.23	6, 72	.300
	Block	32.5	5, 180	< .001
	Block x Group	1.24	15, 180	.285
	Day x Block	3.19	10, 360	.011
	Day x Block x Group	.952	30, 360	.504
MT2	Group	.238	3, 36	.869
	Day	3.46	2, 72	.037
	Day x Group	.918	6, 72	.480
	Block	26.8	5, 180	< .001
	Block x Group	.830	15, 180	.600
	Day x Block	.596	10, 360	.721
	Day x Block x Group	1.17	30, 360	.287
MT3	Group	.609	3, 36	.614
	Day	7.21	2, 72	.001
	Day x Group	.826	6, 72	.554
	Block	36.4	5, 180	< .001
	Block x Group	.622	15, 180	.775

	Day x Block	3.44	10, 360	.006
	Day x Block x Group	1.02	30, 360	.430
OMT	Group	.026	3, 36	.994
	Day	3.64	2, 72	.058
	Day x Group	1.28	6, 72	.291
	Block	48.1	5, 180	< .001
	Block x Group	.969	15, 180	.460
	Day x Block	3.45	10, 360	.008
	Day x Block x Group	1.19	30, 360	.285

Table 12. All statistical figures for all performance dependent variables and acquisition phase.

RT, PT1, PT2, OPT, MT1, MT2, MT3 and OMT

For all variables, the analyses revealed significant main effects for block and day but non-significant main effects for group. In addition, non-significant block x group, day x group, day x block, and day x block x group interactions were observed for all performance variables except MT1, MT3 and OMT, where the day x block interaction was significant. Breakdown of the main effects revealed a significant performance increase from block 1 (first block of acquisition on each day) to block 6 (last block of acquisition on each day; i.e., RTs, PTs, and MTs became quicker at the end of each day compared to that at the start of each day). Furthermore, significant increases in performance from day 1 to day 3 (i.e., RTs, PTs, and MTs became quicker on the last day compared to the first day) were also observed indicating that performance increased as a function of practice. Breakdown of the day x block interaction for MT1, MT3 and OMT, revealed that MT1 decreased between block 1 to block 2 on day 1, day 2 and day 3 (i.e., MT's got quicker on all days between block 1 and block 2 of acquisition). In addition, a similar significant effect occurred between block 2 to block 3 for MT1 on day 1 and day 2. The interaction for the MT3 data indicated that performance also increased (MTs got faster) on day 1 between block 1 and block 2 and between block 2 and block 3. On day 2, performance increased between block 1 and block 2 only. Finally, OMT performance increased from block 1 to block 2 on day 1, day 2, and day 3. Day 3 increased further between blocks 2 and 3 on day 1 and 2, and, increased again between blocks 4 and 5 on day 3 (i.e., OMT performance increased or MTs got faster as a function of practice).

Late Transfer (LT)

All means and *SDs* are reported in Table 9, and statistical figures are reported in Table 10 for Reaction Time (RT), Pause Time 1 (PT1), Pause Time 2 (PT2), Overall Pause Time (OPT), Movement Time 1 (MT1), Movement Time 2 (MT2), Movement Time 3 (MT3) and Overall Movement Time (OMT).

RT

Results revealed a significant main effect of block, a non-significant main effect of group, and a significant block x group interaction. Further breakdown of this interaction revealed that whilst performance in the control-control and anxiety-anxiety group did not significantly differ between acquisition and transfer, the anxiety-control and control-anxiety groups did reveal significant decreases in performance between acquisition and late transfer. Indicating that a change in practice conditions (mood) resulted in a decrement in performance associated with the planning of movement (see Figure 10).

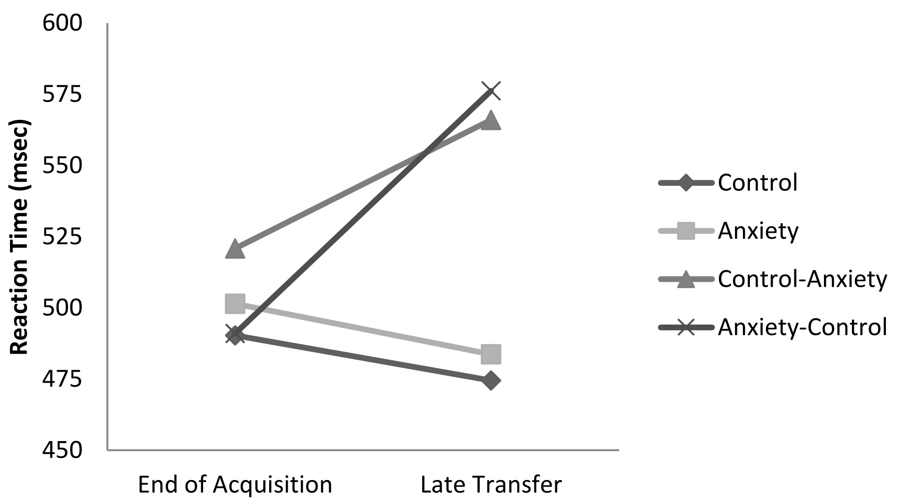

Figure 10.   Reaction Time (milliseconds) during block 6 day 3 (last block of acquisition) and late transfer (trial 182-199).

PT1, PT2 and OPT

The analysis revealed a significant main effect of block, a non-significant main effect of group and a non-significant block × group interaction. Breakdown of the block main effect revealed that pause times were significantly longer in transfer compared to the last block of acquisition.

MT1, MT2, MT3 and OMT

The analysis revealed no main effect of block for MT1 but revealed a significant main effect of block for MT2, MT3 and OMT. Furthermore, for all MTs the analyses revealed significant block x group interactions. Breakdown of these interactions revealed that the anxiety-control group significantly decreased in performance from the last block of acquisition to transfer (i.e., a change in practice conditions resulted in a decrement in performance) whereas, the MTs in the control-anxiety, control-control and anxiety-anxiety group did not differ between the last block of acquisition and transfer (see Figure 11). No significant main effects involving group were found.

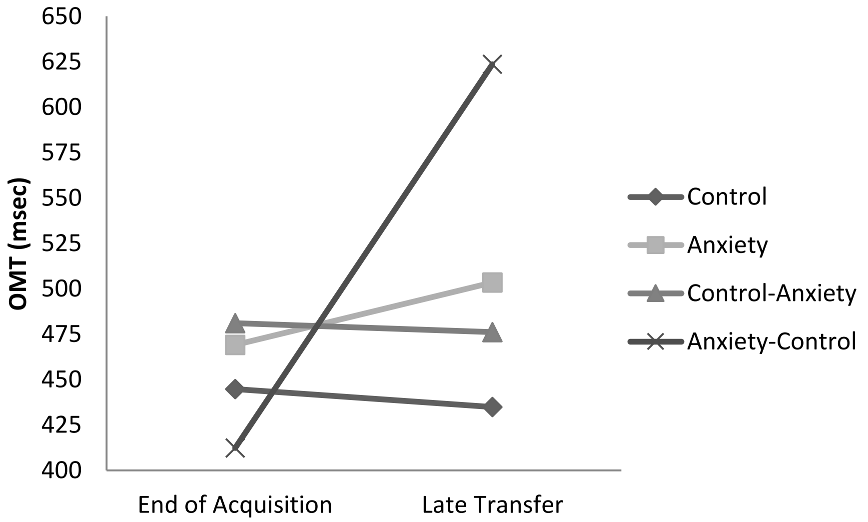

Figure 11. Overall Movement Time (milliseconds) during block 6 day 3 (last block of acquisition) and late transfer (trial 182-199).

3.4. Discussion

The purpose of the current experiment was to further extend specificity of practice research within the psychological construct of anxiety (Gilligan & Bower 1983; Henry, 1968, Proteau 1992), and in particular to examine *what* aspects of motor control develop specificity. Unlike previous research (e.g., Coombes et al., 2009) the objective of the current investigation was to examine not only the planning of movement (i.e., offline control; as measured by reaction times) but also the adjustment to parameters during movement execution (i.e., online control; as measured by pause times and movement times). Similar to experiments 1 and 2 of the previous chapter, results showed that the manipulation of anxiety was successful where targeted. Also, task effort was similar for all groups and did not change as a result of the presence of anxiety indicating that any significant performance results are not due to an increase or decrease in task effort. In addition, confidence revealed that the anxiety-control group increased in confidence from the first block of acquisition to early transfer (i.e., when anxiety was removed) whereas, the control-anxiety group decreased in confidence between the last block of acquisition and late transfer (i.e., when anxiety was induced). These results support Woodman and Hardy’s (2003) meta-analysis on confidence and anxiety. That is, there is generally a negative correlation between the two. Note that the increase or decrease in confidence had no effect on task effort.

Given the anxiety specificity effects reported in the previous chapter, it was expected that participants who learn under anxiety would adapt movement strategies to produce more accurate movement programmes (offline) in an attempt to control performance when under pressure. Thus, we predicted that the removal of anxiety in the transfer conditions would result in a decrement in planning performance (represented by an increase in RT) from that observed in acquisition (because the specificity of practice in relation to the construct of anxiety will be developed around movement planning). Additionally based on the findings by Coombes et al. (2009), we hypothesised that the planning of the movement will be negatively affected by the introduction of anxiety in the transfer phase. Results of the reaction time performance data support the notion of specificity. That is, both the control-anxiety and anxiety-control groups experienced a significant decrease in performance (shown by an increase in RT), between the last block of acquisition and late transfer. These findings are consistent with experiment 1 and 2 of the previous chapter and demonstrate that when there is a change in the mood state between the acquisition practice environment and the subsequent test environment, (i.e., the withdrawal or addition of anxiety between acquisition and transfer) a performance decrement is experienced. This decrease in performance was significant in both early and late transfer. However, a bigger decrement in performance was seen in late compared to early transfer for the anxiety-control group, whereas the performance decrement was greater in early compared to late transfer for the control-anxiety group. Research investigating the specificity exposure hypothesis has revealed that the effect is enhanced through increased practice (see Khan et al., 1998; Proteau & Cournoyer, 1990; previous chapter of this thesis). The results of the current investigation offer support for this phenomenon when looking at the data of the anxiety-control group, but not when looking at the control-anxiety group. The added information diagram (detailing the movement patterns of each task) that was presented in the first block of acquisition trials (e.g., trials 1-27) being removed before the start of the early transfer (i.e., trials 28-45) could explain this. This was protocol for all participants and possibly created a higher anxiety condition in early transfer than later transfer manipulations for the control anxiety group i.e., the removal of the visual aid designed to aid understanding of the experimental tasks between block 1 and early transfer acted as another increase to anxiety in addition to those that were specific to the anxiety manipulation protocols. Results from the anxiety data for the control-anxiety group did in fact reveal that anxiety levels were greater in early (10.2) compared to late transfer (9.2). However, this difference was not significant and thus represents only a trend in the data. Whilst speculative, this trend may have led to the greater decrement in planning performance in the early compared to late transfer phases of the control-anxiety group. The possible increased anxiety effect that occurred when the visual target aid was removed after the first block of acquisition may have also increased the anxiety levels of the anxiety-control group at early transfer. Therefore, it is possible that this effect meant that there was not a complete change in mood state between acquisition and early transfer for the anxiety-control group i.e., anxiety was still present in the early (control) transfer. Again this effect is partially supported by the trends of the MRF-3 anxiety data. Here, whilst non-significant, anxiety levels were higher at early (8.0) compared to late (5.2) transfer. These trends in the anxiety data (as a result of the removal of the visual aid directly before early transfer), may have led to the specificity results not completely supporting the typical exposure effect. Nevertheless, RT performance did alter in both the anxiety-control and control-anxiety groups in both early and late transfer when there was a change in condition (i.e., mood), which supports the overall specificity of practice effect.

Similar to the specificity effects observed in the RT data, pause time (PT) revealed a significant increase between the conditions of acquisition (i.e., last block of acquisition) and late transfer. Since there was no group interaction, this pattern of results was not limited to the groups that experienced a change in conditions (i.e., the anxiety-control and control-anxiety groups). However, when there *was* a change in conditions (i.e., addition or removal of anxiety) there was a resultant increase in the time participants spent pausing at targets which, in itself, is supportive of the specificity effect. Another possible explanation could be accounted for by the principles of ACT. The increase in PTs could be an indication of the updating working memory system being negatively affected. Alternatively, results could also be explained by CPH from an explicit monitoring ‘dechunking’ standpoint. As once performance is ‘dechunked’, each unit must be activated and run separately, which could explain why PTs increased (got slower). However, an increase in PT’s is not a direct indicator of a performance decrement or any detrimental effect to the motor control systems; it may indicate a change in the strategies of the amount of online adjustments been made to correct errors in an already planned movement response. Considering the increase in PT’s occurred for all groups between the last block of acquisition and late transfer, one could conclude both a maladaptive or adaptive reaction to a change in condition. That is, results cannot explain if these changes were negative or positive to performance. Negative to performance in that a change in conditions resulted in a decrease in the efficiency of the online detection and correction processes or, positive to performance in that the alteration seen from the data was indicative of enhanced online detection and correction processes. Consequently, the increases in PTs when there was a change in the conditions between acquisition and transfer could have had ‘knock on’ effect that resulted in the significant increase in RT’s that were observed when conditions are altered (i.e., anxiety-control and control-anxiety groups). Specifically, planning alterations (i.e., offline processes) could be combating the effects of specificity in relation to a reduction in the online detection and correction processes. However, given the performance measures of the current investigation were not detailed enough to fully explore either the micro details or efficiency of movement execution (i.e., the trajectories of movements), it is beyond the scope of this experiment to explore these possibilities outside simple speculation.

When looking at the performance measure of MT’s during early transfer, results revealed a significant increase in performance (i.e., significantly got faster). Since there were no significant interactions, the pattern of results were not limited to the groups that experienced congruity between conditions (anxiety-anxiety and control-control groups). Consequently, the results from the RT data from the anxiety-control and control-anxiety groups when looking at acquisition to early transfer (e.g., decrease in RT), could provide further support for the combat mechanism as described when explaining the PT results. That is, the alterations seen in RT's are positive to performance. The decrease in RTs when there was a change in the conditions between acquisition and transfer occurs in an adaptive rather than maladaptive way to combat the negative effects associated with specificity. Specifically, planning alterations (i.e., offline processes) is thought to be combating the effects of specificity in relation to a reduction in the online detection and correction processes as seen by PT's. The findings within MT's during late transfer are similar to the findings in experiment 2 (of the previous chapter), in that, the anxiety-control group significantly increased MT's from acquisition to late transfer (i.e., slowed down movement time in transfer; when anxiety was taken away). This finding supports specificity in that after a long practice period in a certain condition, if the condition changes (e.g., removal of anxiety) a decrease in performance was experienced (e.g., an increase in MT). Support for specificity is also evident since MT's did not significantly alter when conditions were constant between acquisition and transfer (anxiety-anxiety and control-control groups). However, for specificity to be fully supported it was expected that MT's of the control-anxiety group would have significantly increased (slowed down) between acquisition and transfer (i.e., when there is a change in conditions); no significant differences were found in the current data. Similar to MT data during early transfer and PT data, a possible explanation for this pattern of results may reside in the different distribution of offline planning and online control strategies adopted when there was a change in conditions. That is, offline alterations (e.g., changes in planning as measured by RT) could be combating the effects of specificity in order to maintain performance in light of online control (as measured by PT's and MT's) no longer being effective.

The purpose of the present experiment was to specifically examine what aspects of motor control (i.e. online or offline) develop specificity. The task allowed movement patterns to be separated into different performance variables to achieve this specific aim. The study associated RT (Henry & Rogers, 1960; Khan et al., 2006) with movement planning (offline) whereas, pause times and movements times (Khan et al., 2006) were associated with movement execution (online). When considering the RT data, it is proposed that the anxiety-control and control-anxiety groups developed a movement strategy to optimize the sensory information present during acquisition and that this plan was specific to the mood that was present during that phase of the experiment. Consequently, when the mood changed between acquisition and transfer, the movement plan developed was no longer adequate to maintain performance without subsequent changes in the strategies of how planning and online control processes of movement execution were distributed. When looking at the data holistically, it appears that under anxious conditions participants need to utilise processes associated with effective planning because the ability to process and utilise afferent information online is reduced (also see Lawrence et al., 2012b). This reliance on offline aspects for motor control may be associated with a non-automatic, effortful and conscious strategy (i.e., the planning of specific movement parameters to reach the directed goal without subsequent intervention) because of the disruption to the proposed more automatic and reflexive processes (Biere & Proteau, 2001) involved in online movement control. However, it is unclear whether this alteration during transfer is indeed negative or positive to overall performance accuracy, as no accuracy or error measurements on targets were calculated during the present experiment. Nevertheless, when examining overall movement time performance tends to increase supporting the notion of a combat mechanism involving changes in the strategies of how planning and online control processes of movement execution are distributed.

In conclusion, the results of the current experiment revealed that when participants practice under specific sensory conditions, a change in these conditions during transfer cause significant alterations to performance both early and late in practice. This is achieved by; (1) participants developing a strong and robust semantic network that connects the mood state, ideas, and muscular patterns of the to-be-learned task to the conditions of practice, and (2) participants develop a representation of the skill that is adapted to the conditions during acquisition. The current experimental results are therefore consistent with the findings in experiment 1 and 2 of the previous chapter of this thesis and support the specificity of practice principle as an explanation for the choking phenomenon. Finally, the results revealed that the more conscious processes used in programming strategies of offline control were significantly altered as a result of the specificity effect, rather than the automatic process involved in the processing of information for online control. It is proposed that participants adopt this reliance on offline control as a strategy to protect overall performance from a reduction in efficiency of the online control system as a result to the presence of anxiety. This would suggest a reduction in the automatic system associated with assumptions within CPH (Masters, 1992) and could therefore, not be easily explained by the principles of ACT (Eysenck et al., 2007) which involve a more conscious and effortful process involved with the planning of a movement.

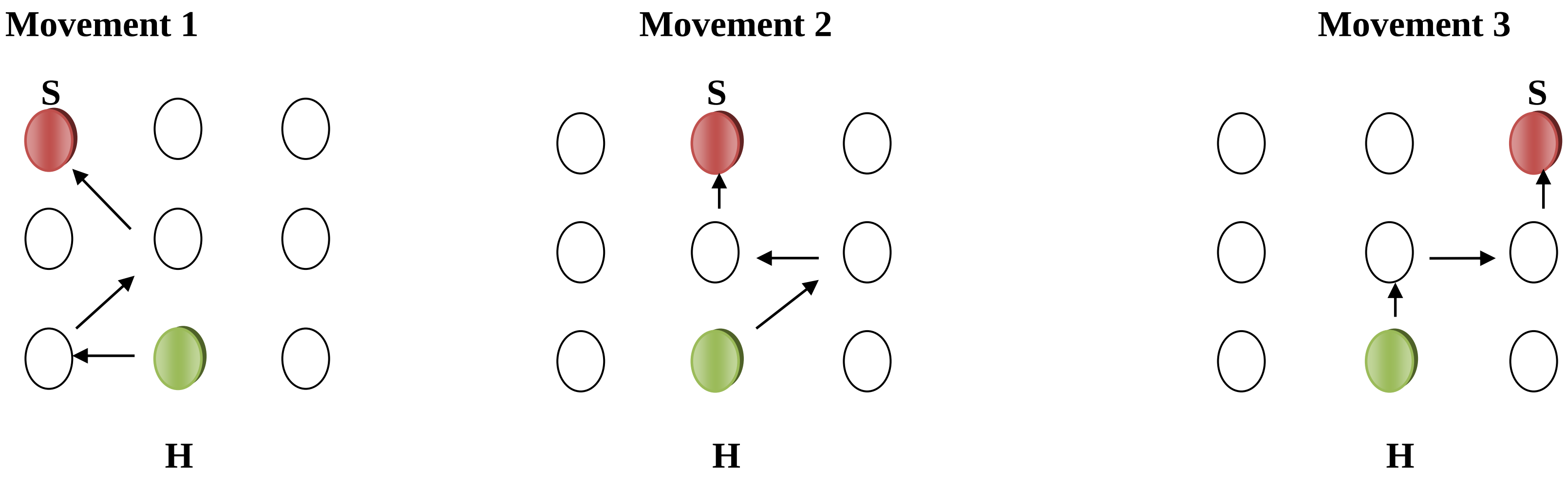

Figure 8. Schematic diagram of movement patterns 1, 2, and 3 signified by the stimulus red signal (S). Home position signified by a green circle (H).

		Acquisition Phase																		
Variable	**Group**	**D1B1**	**D1B2**	**D1B3**	**D1B4**	**D1B5**	**D1B6**	**D1B7**	**D2B1**	**D2B2**	**D2B3**	**D2B4**	**D2B5**	**D2B6**	**D3B1**	**D3B2**	**D3B3**	**D3B4**	**D3B5**	**D3B6**
RT	C	671.7	590	602.4	581.8	583.6	562.3	575.7	569.3	541.0	534.6	533.6	513.8	520.9	512.5	513.1	513.8	500.2	496.9	490.3
		57.6	*73.51*	*101.0*	*118.2*	*123.0*	*126.4*	*129.2*	*89.6*	*89.9*	*102.8*	*123.3*	*118.9*	*118.3*	*111.0*	*102.2*	*129.4*	*95.8*	*114.0*	*90.8*
	A	695.8	587.3	597.5	595.4	587.9	566.8	564.7	567.5	567.8	560.3	556.9	546.2	550.9	534.6	516.3	514.4	499.7	508.7	501.4
		119.8	*87.6*	*83.9*	*102.2*	*78.7*	*73.8*	*81.4*	*74.8*	*87.1*	*90.9*	*86.6*	*72.6*	*93.7*	*84.3*	*80.9*	*66.1*	*71.8*	*86.1*	*76.4*
	CA	662.1	665.1	656.4	634.4	626.7	589	601.4	590.6	571.7	553.2	540.5	532	523.8	525.8	521.6	520.6	508.5	519.7	520.8
		133.0	*137.7*	*152.6*	*134.2*	*122.7*	*96.5*	*121.6*	*114.1*	*103.3*	*108.5*	*114.7*	*94.0*	*85.9*	*93.7*	*92.3*	*87.3*	*89.1*	*88.7*	*90.5*
	AC	770.7	639.1	606.7	600.1	579.9	574.7	566.1	569.4	555.1	562.9	545.8	536.5	532.7	529.6	507.8	511.6	499.5	492.4	491.0
		233.6	*90.2*	*77.5*	*100.8*	*99.8*	*89.1*	*70.0*	*84.0*	*76.7*	*67.5*	*75.3*	*84.3*	*75.7*	*84.1*	*73.4*	*64.3*	*83.3*	*80.3*	*80.9*
TOTAL		700.1	620.4	615.8	602.9	594.5	573.2	577.0	574.2	558.9	552.8	544.2	532.1	532.1	525.6	514.7	515.1	502.0	504.4	500.9
		150.4	101.9	106.4	111.9	*105.2*	*95.0*	*100.7*	*88.7*	*87.1*	*90.7*	*98.3*	*91.1*	*91.8*	*90.6*	*84.6*	*87.2*	*82.2*	*90.1*	*82.5*
PT1	C	271.9	252.8	253.2	243.8	243.3	240.9	239.1	254.0	221.6	222.6	222.0	210.8	211.8	222.7	204.9	195.2	196.4	194.8	199.3
		69.9	*72.04*	*106.9*	*99.6*	*94.5*	*99.8*	*98.4*	*101.7*	*106.5*	*106.7*	*105.6*	*107.0*	*112.0*	*101.6*	*112.3*	*119.3*	*127.6*	*129.7*	*125.8*
	A	240.7	231.4	201.3	220.4	221.0	220.3	219.0	232.2	219.3	216.3	225.7	221.8	218.0	231.5	214.2	218.2	213.0	207.1	207.9
		73.5	*84.0*	*84.4*	*64.8*	*61.9*	*49.9*	*47.7*	*78.0*	*75.6*	*63.6*	*62.3*	*65.4*	*62.8*	*83.9*	*77.0*	*83.4*	*81.9*	*73.0*	*75.2*
	CA	286.0	268.3	249.2	236.7	243.2	234.2	224.8	229.9	217.5	206.2	214.9	219.0	210.8	241.8	230.1	230.7	231.7	226.6	237.7
		109.5	*89.1*	*81.9*	*84.6*	*87.2*	*90.5*	*76.7*	*78.6*	*90.5*	*87.6*	*95.4*	*104.0*	*101.0*	*92.3*	*85.1*	*87.4*	*85.9*	*88.0*	*94.8*
	AC	294.9	296.7	248.6	245.3	242.6	229.5	227.8	235.7	215.3	208	206.2	204.4	202.9	221.3	208.8	200.9	203.5	193.6	191.6
		79.8	*85.9*	*74.0*	*75.6*	*79.3*	*74.6*	*75.7*	*72.6*	*79.9*	*75.3*	*65.9*	*67.2*	*68.4*	*66.0*	*60.3*	*56.4*	*59.3*	*62.1*	*59.5*
TOTAL		273.4	255.6	238.1	236.6	237.5	231.2	227.7	237.9	218.4	213.3	217.2	214.0	210.9	229.3	214.5	211.3	211.2	205.5	209.1
		88.9	*81.2*	*87.0*	*79.5*	*79.0*	*78.1*	*74.1*	*80.8*	*85.5*	*81.8*	*81.4*	*85.0*	*85.2*	*83.9*	*83.0*	*87.1*	*89.4*	*89.3*	*90.3*
PT2	C	285.9	262.4	258.2	247.1	256.3	245.9	237.1	261.7	223.8	224.2	213.4	202.0	201.5	218.6	198.4	191	183.9	183.2	184.2
		53.61	*84.2*	*108.6*	*106.6*	*105.1*	*112.4*	*104.1*	*117.2*	*120.4*	*123.6*	*114.4*	*117.2*	*118.2*	*122.2*	*125.5*	*129.9*	*128.8*	*133.8*	*134.2*
	A	251.6	223.6	217.8	207.3	214	207.3	214.9	235.0	219.7	215.1	219.4	214.8	210.2	229.3	211.4	214.8	207	204.9	202.3
		103.5	*97.6*	*79.9*	*81.4*	*82.6*	*76.2*	*76.7*	*92.1*	*92.2*	*89.4*	*87.1*	*85.1*	*85.7*	*109.3*	*98.7*	*108.7*	*103.4*	*103.4*	*96.9*
	CA	311.2	290.4	262.1	250.7	248.1	242.4	234.1	293.5	223.9	209.3	210.9	214.8	201.3	248.7	230.1	230.5	220.2	220.2	229.5
		121.7	*108.3*	*102.0*	*99.9*	*103.0*	*99.6*	*96.9*	*104.9*	*103.4*	*107.6*	*114.2*	*119.7*	*109.6*	*99.97*	*91.5*	*91.0*	*87.8*	*84.8*	*99.0*
	AC	320.5	278.6	255.8	251.3	246.3	239.2	233.7	242.2	215.3	213.2	206.7	196.0	193.8	223.9	209.2	202.3	204.1	193.8	183.8

		96.3	*88.3*	*78.8*	*72.2*	*87.0*	*84.1*	*95.8*	*81.3*	*83.3*	*83.9*	*84.2*	*80.7*	*81.8*	*68.3*	*64.8*	*63.2*	*68.5*	*73.2*	*69.3*
TOTAL		292.3	263.8	248.5	239.1	241.1	233.7	230.0	244.6	220.7	215.5	212.6	206.9	201.7	230.1	212.3	209.7	203.8	200.5	199.9
		97.0	*64.8*	*91.4*	*89.5*	*92.7*	*91.8*	*90.7*	*96.4*	*96.9*	*98.5*	*97.2*	*98.6*	*96.3*	*98.6*	*94.4*	*98.4*	*96.6*	*98.4*	*100.2*
OPT	C	622.3	566.6	558.4	536	543.7	525.8	514.4	515.7	445.5	446.8	435.4	412.8	413.4	441.4	403.3	386.3	380.3	378.1	383.5
		176.1	*186.1*	*219.7*	*220*	*213.1*	*212.2*	*201.2*	*217.3*	*225.6*	*228.5*	*217.3*	*222.5*	*228.8*	*222.8*	*236.3*	*248.4*	*255.8*	*263.2*	*259.3*
	A	492.4	455.5	439.1	426.6	435.4	425.2	432.6	467.3	439.1	431.4	445.2	436.6	428.3	491.3	463.2	471.7	453.7	432.8	433.1
		158.6	*180.2*	*139.7*	*144.8*	*143.0*	*124.8*	*123.3*	*169.5*	*167.3*	*152.1*	*148.6*	*149.6*	*148.2*	*250.7*	*240.3*	*256.5*	*242.4*	*206.8*	*209.4*
	CA	734.1	675.7	606.1	572.5	575	558.2	532.8	509.8	486.4	460.8	470.6	477.9	454.4	490.6	460.2	461.3	452.0	446.9	467.3
		317.4	*271.5*	*205.5*	*203.2*	*208.0*	*226.0*	*188.5*	*268.7*	*289.0*	*296.7*	*305.0*	*308.0*	*294.1*	*191.3*	*175.3*	*177.8*	*172.0*	*171.5*	*192.0*
	AC	691.0	600.1	554.4	546.6	538.5	517.3	509.7	478.0	430.6	421.3	413.0	400.4	396.7	445.3	418	403.3	407.6	387.4	375.4
		302.6	*225.4*	*204.8*	*203.4*	*214.4*	*212.8*	*224.5*	*153.4*	*161.8*	*158.0*	*148.7*	*146.7*	*148.0*	*132.8*	*123.9*	*118.1*	*124.9*	*133.8*	*127.2*
TOTAL		634.9	574.4	539.5	520.4	523.2	506.6	497.4	492.7	450.4	440.1	441.1	431.9	423.2	467.1	436.2	430.6	423.4	411.3	414.8
		256.7	*225.1*	*197.3*	*195.6*	*196.5*	*196.8*	*184.9*	*200.1*	*209.7*	*209.0*	*207.4*	*210.6*	*206.5*	*197.6*	*193.8*	*203.2*	*200.2*	*194.0*	*198.3*
MT1	C	320.9	217.7	225.5	204.6	204.6	192.2	195.7	211.5	200.1	188.8	190.1	185.9	186.6	188.5	179.8	180.2	177.4	175.0	170.9
		72.9	*65.5*	*79.7*	*67.1*	*72.9*	*69.5*	*73.2*	*81.7*	*86.8*	*81.3*	*81.8*	*82.7*	*84.9*	*86.9*	*83.1*	*82.9*	*81.4*	*85.3*	*80.7*
	A	303.7	212.4	206.6	191.2	195.1	186.3	193.6	197.0	183.0	181.9	186.5	183.1	185.5	217.2	203.9	200.1	205.9	194.6	189.8
		141.5	*61.0*	*42.7*	*49.5*	*48.6*	*40.9*	*42.9*	*50.6*	*49.5*	*52.5*	*55.0*	*53.9*	*60.3*	*75.8*	*73.6*	*71.8*	*71.6*	*60.6*	*60.9*
	CA	297.8	245.5	216.8	195.9	191.8	194.2	181.9	221.6	204.9	191.4	181.8	194.8	193.7	202.1	196.1	196.3	192.3	185.4	189.4
		84.4	*9.02*	*65.7*	*59.9*	*57.7*	*61.2*	*63.4*	*100.7*	*82.7*	*73.5*	*68.3*	*75.2*	*76.8*	*65.8*	*68.0*	*70.6*	*64.7*	*63.3*	*63.1*
	AC	346.6	219.0	201.6	199.4	191.6	183.0	177.9	196.2	178.4	173.8	172.2	168.2	164.9	346.6	295.6	159.9	227.7	159.9	159.9
		111.1	*54.6*	*45.4*	*47.1*	*48.0*	*42.9*	*44.1*	*55.5*	*57.4*	*57.7*	*54.4*	*53.6*	*53.7*	*111.1*	*109.3*	*47.3*	*87.2*	*47.3*	*47.3*
TOTAL		317.3	267.0	117.5	192.9	117.5	159.9	159.9	159.9	159.9	159.9	159.9	159.9	159.9	175.7	168.9	171.5	167.6	165	177.5
		103.5	*92.0*	*62.9*	*72.1*	*62.9*	*47.3*	*47.3*	*47.3*	*47.3*	*47.3*	*47.3*	*47.3*	*47.3*	*50.6*	*48.7*	*57*	*48.8*	*48.4*	*62.9*
MT2	C	201.7	147.9	151.8	149.7	148.3	142.4	145.1	148.3	141.0	137.7	135.2	133.1	130.5	139.2	126.9	122.8	123.4	120.6	121.6
		41.7	*40.6*	*52.2*	*59.7*	*51.2*	*40.5*	*44.8*	*42.9*	*46.8*	*45.7*	*47.2*	*46.8*	*50.4*	*52.6*	*46.6*	*49.1*	*47.3*	*49.5*	*49.8*
	A	207.0	139.4	138.5	131.1	130.2	129.7	133.0	141.0	129.7	126.7	129.8	131.6	130.3	142.2	136.1	138.5	135.6	134.1	130.1
		142.1	*27.4*	*21.6*	*25.1*	*25.8*	*23.1*	*22.2*	*24.8*	*27.5*	*28.6*	*30.8*	31.3	*30.6*	*37.3*	*35.8*	*38.6*	*33.4*	*32.6*	*31.6*
	CA	198.2	161.1	144.7	137.7	135.4	132.7	131.6	143.2	139.4	132.8	127	137.8	133.1	137.3	132.8	131.7	131.6	129.5	132.6
		70.2	*46.1*	*40.7*	*33.8*	*41.7*	*31.2*	*40.9*	*48.0*	*49.4*	*44.3*	*42.5*	*44.0*	*45.8*	*39.5*	*40.8*	*40.6*	*34.8*	*38.6*	*38.9*

	AC	194.8	143.5	136.4	133.9	133.6	128.1	123.1	133.1	124	124.3	121.7	118.2	117.4	134.2	121.3	119.1	120.6	115.6	114.5
		45.3	*27.4*	*26.0*	*22.0*	*29.3*	*22.2*	*22.3*	*29.1*	*29.4*	*27.3*	*30.0*	*27.1*	*26.7*	*35.1*	*27.8*	*26.0*	*27.7*	*22.2*	*22.8*
TOTAL		200.4	148	142.9	138.1	136.9	133.2	133.2	141.4	133.5	130.4	128.5	130.1	127.8	138.2	129.3	128	127.8	125	124.7
		81.8	*35.9*	*36.2*	*37.3*	*37.5*	*29.5*	*33.8*	*36.4*	*38.6*	*36.4*	*37.2*	*37.4*	*38.6*	*40.1*	*37.3*	*38.7*	*35.6*	*36.4*	*36.4*
MT3	C	260.4	203.4	190.6	184.0	178.0	177.2	181.3	185.7	170.3	163.3	165	161.6	158.1	169.7	160.9	152.3	159.6	153.5	152.2
		60.1	*30.4*	*48.9*	*48.9*	*49.9*	*47.9*	*60.0*	*45.6*	*57.8*	*62.1*	*58.3*	*60.0*	*61.8*	*56.7*	*57.4*	*59.2*	*54.0*	*58.0*	*55.1*
	A	244.0	175.4	173.0	164.0	160.2	152.9	156.3	161.6	148.3	145.0	146.7	147.2	147.9	171.4	162.6	159.9	159.1	156.2	149.1
		101.9	*38.9*	*32.9*	*40.8*	*38.0*	*32.8*	*32.0*	*36.0*	*35.5*	*33.5*	*34.9*	*39.8*	*36.9*	*49.4*	*44.7*	*43.5*	*44.5*	*41.3*	*42.3*
	CA	265.9	206.3	186.9	163.9	164.5	167.1	161	179.3	172.1	164.9	160.9	167.7	164.4	169.7	161.7	159.9	163.9	157.8	159.0
		87.1	*68.7*	*48.7*	*41.4*	*48.4*	*46.5*	*58.1*	*61.6*	*59.9*	*52.3*	*51.3*	*56.3*	*60.1*	*56.7*	*53.4*	*54.7*	*59.5*	*52.2*	*52.5*
	AC	242.8	176.5	165.5	154.8	158.3	148.4	145.8	155	148.7	145.5	143.5	140.0	136.9	138.7	140.3	138.4	139.4	138.0	138.0
		66.4	*41.3*	*38.7*	*37.4*	*43.8*	*41.9*	*42.2*	*49.2*	*43.7*	*44.8*	*41.2*	*38.9*	*43.0*	*32.6*	*36.2*	*35.2*	*39.1*	*38.7*	*35.9*
TOTAL		253.3	190.4	179	166.7	165.2	161.4	161.1	170.4	159.9	154.7	154	154.1	151.8	161.1	156.4	152.6	155.5	151.4	149.6
		78.1	*47.5*	*42.4*	*42.1*	*44.2*	*42.6*	*49.3*	*48.7*	*49.6*	*48.3*	*46.4*	*49.0*	*50.7*	*48.4*	*47.6*	*48.0*	*48.9*	*47.0*	*45.9*
OMT	C	783.2	569.1	568.0	538.4	531	511.9	522.3	545.6	511.5	490	490.5	480.7	475.3	497.5	467.6	455.4	460.5	449.2	444.7
		163.4	*134.5*	*170.3*	*168.8*	*167*	*148.7*	*161.9*	*167.3*	*188.3*	*184.4*	*183*	*187.5*	*193.9*	*190.9*	*182.4*	*185.2*	*172.4*	*187.0*	*180.6*
	A	754.8	527.2	518.2	486.3	485.5	469.0	483.0	499.7	461.0	453.7	463.2	462.0	463.8	530.9	502.7	498.7	500.6	484.9	469.1
		373.4	*124.7*	*93.1*	*110.3*	*106*	*92.5*	*91.2*	*108.3*	*109.5*	*113.2*	*118.2*	*122.8*	*124.8*	*158.3*	*152.0*	*152.6*	*145.7*	*132.5*	*132.9*
	CA	762.0	613	548.5	497.6	491.8	494	474.6	544.2	516.5	489.2	469.9	500.4	491.2	504.1	490.7	488.1	487.9	472.7	481.1
		227.0	*198.4*	*151.1*	*131.1*	*142.3*	*133.7*	*159.4*	*201.9*	*187.6*	*165.2*	*158.1*	*168.9*	*178.0*	*151.8*	*158.3*	*161.5*	*156.1*	*151.8*	*150.0*
	AC	963.8	690.6	653.8	637.1	622.7	599.9	584.1	484.4	451.2	443.7	437.5	426.5	419.2	448.7	430.6	429.1	427.8	418.8	412.4
		523.2	*447.0*	*445.6*	*442.9*	*418.1*	*415.5*	*411.6*	*128.5*	*126.2*	*126.5*	*121.6*	*115.6*	*118.3*	*102.4*	*105.7*	*112.1*	*106.9*	*101.5*	*97.0*
TOTAL		815.9	600.0	572.1	539.9	532.8	518.7	516.0	518.5	485.1	469.1	465.3	467.4	462.4	495.3	472.9	467.8	469.2	465.4	451.8
		347.8	*258.3*	*249.8*	*249.5*	*239.0*	*231.4*	*234.2*	*152.1*	*153.7*	*145.7*	*143.2*	*148.2*	*153.5*	*151.1*	*148.8*	*151.6*	*144.3*	*143.1*	*140.2*

Table 11, All means and *SDs* for all performance dependent variables as a function of group (c = control; a = anxiety; a-c = anxiety-control; c-a = control-anxiety), day (D1 = Day 1; D2 = Day 2; D3 = Day 3), and block (B1 = Block1; B2 = Block 2; B3 = Block 3; B4 = Block 4; B5 = Block 5; B6 = Block 6).

CHAPTER 4

ONLINE VERSUS OFFLINE PROCESSING OF VISUAL AND PROPRIOCEPTION FEEDBACK IN A DIRECTIONAL AIMING TASK; AN INVESTIGATION INTO THE SPECIFICITY FRAMEWORK

4.1. Introduction

The majority of research in the stress and performance domain has concentrated on one's macro performance (i.e., outcome result; Hardy & Hutchinson, 2007; Smith, Bellamy, Collins, & Newell, 2001; Williams, Vickers, & Rodrigues, 2002). However, similar to the previous experimental chapter there is a body of motor control literature that examines performance at a micro level (i.e., movement planning and movement control). The use of the latter approach within the stress and performance domain has provided a clearer insight into how the effects of anxiety impact on the mechanisms involved in the planning (i.e., offline) and the subsequent execution (i.e., online) of movement (Beatty, Fawver, Hancock, & Janelle, 2014; Coombes, Higgins, Gamble, Cauraugh & Janelle, 2009; Ciucurel, 2012; Nibbeling, Oudejans & Daanen, 2012). However, these studies have generally been limited to examining offline and online control separately.

To address this limitation, Lawrence, Khan, and Hardy (2012b) measured the concurrent effects of anxiety on both movement planning (i.e., offline) and movement control (i.e., online). The study aimed to address the effects of anxiety on the processing and utilisation of afferent information to detect and correct errors, both during movement execution and in the planning of upcoming movements. Lawrence et al. (2012b) examined the relationship between state anxiety on both online and offline use of afferent information processing in both a directional aiming task (experiment 1) and an amplitude task (experiment 2). Participants practiced the experiments under controlled conditions before been transferred to anxiety conditions. In both experiments, results revealed that anxiety negatively affected performance. Furthermore, the use of afferent information to adjust movement trajectories online was disrupted when movements were performed with anxiety. Whereas, there were no differences in the offline processing of afferent information between the control and the anxiety conditions. As a result, Lawrence et al. (2012b) suggested that it is the automatic process involved in the use of information to control and adjust movement during execution that are negatively impacted under conditions of anxiety, rather than the more conscious process involved in the use of information for offline purposes. The authors related their finding to the principles of conscious processing hypothesis (CPH; Masters, 1992), as anxiety led to outcome performance decrements by reducing the automatic processes involved in the use of afferent information to correct movement planning errors during movement execution. These findings cannot be easily explained by attention control theory (ACT; Eysenck et al., 2007) since the online movement adjustments that were affected under anxious conditions are said to be reflexive in nature and not under conscious, effortful control (Beiere & Proteau, 2001). However, in line with experiments 1, 2, and 3 of the current thesis, results could be explained by the framework of Specificity of Practice Hypothesis (SPH; Proteau, 1992), Specificity of Learning (SOL; Henry, 1968), and Specificity of Mood (SOM; Gilligan & Bower, 1983). The specificity framework could account for the decrement in performance experienced under conditions of anxiety given that the practice environment in which the skill was learnt had changed (i.e., from control to anxiety). Hence, the strategy adopted during acquisition by participants (i.e., afferent information was used to detect and correct error during movement execution) was no longer adequate following the change in mood.

The results of the Lawrence et al.'s research revealed that anxiety altered the utilisation of online processes and revelled no adjustments within offline process. This finding could be interpreted as contradictory to the results from the previous chapter whereby a change in mood condition, lead to the alteration of offline processes (e.g., reaction time). However, the alteration in online processes and no alteration within offline processes in Lawrence et al. (2012b) led to a negative effect on overall performance. Whereas, the alterations associated with offline processes within the previous chapter did not result in a direct decrease in performance. Specifically, in line with the findings of Lawrence et al. (2012) it was proposed that the adjustments within offline control were a change in participants control strategies in an attempt to combat the negative impact of anxiety and specificity on the effective utilisation of online processes.

There are several studies that have looked at the relationship between motor performance and anxiety, where a wide scope of research concluded that anxiety hampers vision proficiency such as gaze behaviour, search rates and quite eye durations (Behan & Wilson, 2008; Janelle 2002; Janelle, Singer, & Williams 1999; Murray & Janelle, 2003; Nieuwenhuys, Pijpers, Oudjans, & Bakker, 2008). It is commonly accepted that the availability of visual feedback improves movement accuracy provided that movement durations are long enough to encompass visuomotor delays (Calton, 1992). However, researchers also acknowledge that the benefit of vision may not only be due to online processing of visual feedback whereby adjustments to the trajectory occur during movement execution. It is possible that visual feedback from a previous completed movement is processed offline as an enriched form of knowledge of results (KR) to adjust movement programming on subsequent movements (Abahnini, Proteau, & Temprado, 1997; Blouin, Bard, Teasdale, & Fleury, 1993; Zelaznik, Hawkins, & Kisselburgh, 1993). Thus, visual feedback is not just used online (to correct movements) but also offline (to adjust subsequent movement planning) in order to successfully execute a subsequent movement. It is important to note that there are alternative corrective processes other than vision that can be based on proprioception. There are also clear amounts of evidence suggesting that participants in both vision and no vision conditions develop strategies specific to their environment in order to plan and control movements (Abrams et al., 1990; Elliott et al., 1999; Elliott et al., 2004; Khan & Franks, 2003).The notion that participants develop strategies specific to their environment supports a specificity framework. That is, SPH (Proteau, 1992) assumes that participants use the source of information deemed most useful for success to achieve the task. Therefore, when vision is available in aiming tasks, performance becomes specific to visual afferent information and the use of it for online and/or offline processes. Whereas, when vision is unavailable participants use proprioception for the same processes as it is deemed the most useful source of information to achieve success.

It has been reported that in order to create greater movement accuracy in a directional aiming task information from peripheral vision is of more importance than that from central vision (Khan, Lawrence, Fourkas, Franks, & Buckolz, 2004). This is due to the proposed two-channel model (i.e., kinematic and static channel; e.g., Paillard & Amblard, 1985). Specifically the static channel is proposed to be primarily responsible for controlling the amplitude of movements and operates within the central vision. That is, when the limb enters the relatively slow 'homing in' phase of it's' trajectory, whereas the kinematic channel is proposed to play an important role in controlling the direction of movement and processes high speed visual information. The kinematic channel operates within the peripheral vision and supports in improving accuracy in tasks requiring only a directional constraint (Abahnini et al., 1997; Abahnini & Proteau, 1999; Bard, Hay, Fleury, 1985; Brad et al., 1990). By fixating on the target prior to limb movement or relatively early in the limb trajectory (Abrams, Meyer, & Kornblum, 1990), the limb can be seen in the peripheral visual field during the early stages of the trajectory and enters the central visual field upon approaching the target. This is of particular interest considering the findings within chapter 3 of the current thesis and Lawrence et al. (2012b), where results indicate that under pressure the online control is disrupted and participants can adopt strategies of enhanced offline control in order to combat this when vision is available. Thus, a directional aiming task will allow explicit monitoring of both online and offline control by examining limb trajectory of the movement. That is, the later stages of the movement trajectory are related to the processing of online regulation involved in movement execution (Blouin, Brad, Teasdale, & Fleury, 1993) and the early stages of the movement trajectory are related to the processing of offline processes involved in the planning of a movement (Khan et al., 1998, 2006). Specifically, comparing trajectories between control and anxiety conditions will allow an investigation into how anxiety affects strategies between the two processes that regulate movement control. Online regulation of movement is the predominate role of visual feedback which creates higher levels of accuracy (Blouin, Brad, Teasdale, & Fleury, 1993), yet the role of vision that is processed offline to improve subsequent movement programming also plays an important role. It has been suggested that these offline processes would likely be more predominant in situations in which movement time is relatively short or in situations in which vision is not available (Khan et al., 2002). Where visual feedback is available, the processing of this feedback dominates and therefore, limits the processing of other sources of sensory information (Tremblay & Proteau, 1998). However, it is possible that the use of processing proprioceptive feedback can be utilized in the absence of vision during movement (online) and on planning subsequent movements (offline). Therefore, the current study was not only interested in the relationship between anxiety and vision but also whether anxiety effects movement in a similar way when vision is not available; something that has not been previously investigated.

The purpose of the experiment is twofold. Firstly, we set out to replicate and follow up from chapter 2 by identifying if any parameters of movement are specific to the learning conditions in which the movement/skill had been learnt. Secondly, we wanted to develop findings from chapter 3 by identify whether any effects of specificity differ depending on the afferent information available to perform planning and corrective processes (e.g., vision and /or proprioceptive feedback). For specificity to explain any performance decrements it was hypothesised that any change from practice conditions to transfer (i.e., the removal or addition of anxiety) would have a negative effect on performance. More specifically it was proposed that, participants under anxiety adopt a strategy whereby afferent information obtained from the previous action is used to more accurately plan (offline) subsequent movements (Lawrence et al., 2012b). This would be due to anxiety prohibiting the ability to make use of afferent information to correct errors (online) during movement execution. Therefore, participants practicing under anxiety conditions would develop strategies within offline control to plan a movement. Consequently, when anxiety is taken away the ability to detect and correct error during movement execution (online) will now hinder performance. Due to the strategy developed during practice being specific to the afferent information available under anxiety conditions, and no longer appropriate for successful performance under control conditions. The reverse of this would be true for participants transferring to anxiety. That is, strategies will be developed without anxiety specific to the utilization of online afferent information. Hence, when transferred to anxiety conditions the strategy to detect and correct error that was available during practice is no longer accessible, due to anxiety prohibiting the ability to make use of online afferent information. Consequently, the strategy developed during practice specific to the afferent information available under anxiety conditions, no longer apply under control conditions. That is, the use of afferent information and the consequent online and/or offline control strategies will differ in each condition (e.g., anxiety and control). Hence, strategies developed under one condition will not be appropriate for successful performance in the other condition. Participants would therefore experience a decrease in performance during the later stages of the movement, which will be seen from adjustments late in kinematic markers and relate to anxiety effecting the efficiency of processes in the online regulation of movement. That said, from the findings of chapter 3 it is proposed that offline processes are enhanced/altered to combat these effects. Therefore, adjustments within the kinematic markers early in limb trajectory to enhance offline process involved with the planning of the movement would be seen to achieve successful performance. Thus, performance will not be negatively affected and a decrease in performance in the later stages of movement will be maintained. Interestingly it is proposed that anxiety will not affect the use of proprioception to control actions, as it is the offline process involved in the planning of the movement that is the more predominant process when vision is not available (Khan et al., 2002).

4.2. Method

Participants

40 participants (22 male, 18 female; ranging from 18 – 42 yrs old) with no previous experience in the experimental task, volunteered to participate in the study. All participants were naive to the hypothesis being tested and gave their informed consent prior to taking part in the study. The experiment was conducted in accordance with the ethical guidelines laid down by the ethics committee of the School of Sport, Health and Exercise Sciences, Bangor University for research involving human participants.

Apparatus

The aiming movements were performed with a pen on a Calcomp III digitising tablet (size = 1220cm x 915mm, sample rate = 200 Hz, accuracy = ± 0.125mm) positioned horizontally in front of the participant. The tablet was interfaced with the host PC via a serial link. The position of the pen was represented by a cursor (1 cm in diameter) on a 37" Mitsubishi Diamond Pro computer monitor (refresh rate = 85Hz) located 33cm in front of the participants and 20cm above the tablet. Visual displays of the start position, target regions, and a cursor representing the pen position appeared on the monitor screen. Movements of the pen away from the participant's body on the tablet corresponded to vertical movements of the cursor on the monitor. There was a one to one mapping between the movement of the pen and the movement of the cursor. The home position consisted of a round dot (1cm in diameter) and was located at the bottom of the monitor. Three circular targets (1cm in diameter) were located above the home position along an invisible arc of radius 24cm. The centre target was located directly above the home position while the other two targets were located 10 degrees to either side of the centre target (i.e., angle subtended from the home position) (see Figure 14). The distance of 24cm between the home and each target marker yielded a visual angle of 40 degrees. All visual stimuli were generated through the use of Visual Basic and Direct X software. The participants chair was adjustable in height so that the participant's eyes were at a level midway between the home position and target markers. The participant's arm and hand were hidden from their view by an opaque shield thus preventing direct vision of the limb throughout testing.

Anxiety and Effort Scales

Cognitive anxiety, somatic anxiety, and confidence were assessed via the Mental Readiness Form-3 (MRF-3; Krane, 1994) and task effort was assessed via the Rating Scale of Mental Effort (RSME; Zijlstra, 1993). The MRF-3 comprises of three single item factors that are each scored on an 11 point Likert scale: cognitive anxiety from 1 (not worried) to 11 (worried); somatic anxiety from 1 (not tense) to 11 (tense); and self-confidence from 1 (confident) to 11 (not confident). For the purpose of the present study a combined score of cognitive anxiety and somatic anxiety was used to assess anxiety levels, as the investigation was examining the effects of state anxiety within the realm of the specificity framework. The RSME comprises of a 1 to 150mm vertical Likert scale with nine descriptors ranging from 3 'absolutely no effort' to 114 'extreme effort'.

Task and Procedure

At the start of testing, participants were informed that the aim of the experiment was to observe the accuracy and timing of their movement. Furthermore, instruction indicated that the movement should be performed as smoothly as possible and was required to sweep through the target in a movement time of 450ms (± 10%). Previous research has shown this movement time to be sufficiently long enough for online corrections to occur in this type of video aiming task (Khan et al., 2003). It was explained to participants that reaction time was not important.

In all conditions participants completed four blocks of 30 trials (totalling 120 trials), with the first 90 trials consisting of an acquisition phase (block 1 = trials 1-30; block 2 = trials 31-60; and block 3 = trials 61-90) and the last 30 trials consisting of the transfer phase (block 4 = trials 91-120). In order to familiarise participants with the apparatus (i.e., the experimental task and the criterion movement time), the experimenter demonstrated 4 trials with the appropriate movement time. Participants then performed an acquisition phase consisting of 3 blocks of 30 trials (i.e., 30 to each target) under normal (low anxiety) or high anxiety conditions. This was followed by a transfer phase where participants performed a single block of 30 trials (i.e., 10 to each target) in the opposite condition (i.e., low anxiety or high anxiety). No target was repeated consecutively and participants were given a 5-minute break between each block. At the start of each trial, participants were required to place the cursor on the home position. Once the cursor was steadily aligned participants were presented with one of the targets changing colour from red to green, which informed the participant that this was the target to aim towards. A 500ms period followed this target colour change, and then a tone was presented signalling the participants to initiate the required movement. Since participants were not required to stop on the target, the task had a direction but no amplitude measure.

Each participant was randomly assigned to one of four groups. Group 1 was labelled no vision control-anxiety group (NVCA). All acquisition and transfer trials were performed without the aid of the cursor to represent limb movement. Acquisition trials were under normal (low anxiety) conditions and transfer trials were under anxiety conditions. Group 2 was labelled no vision anxiety-control group (NVAC). All acquisition and transfer trials were performed without the aid of the cursor to represent limb movement. Acquisition trials were under anxiety conditions and transfer trials were under normal (low anxiety) conditions. Group 3 was labelled full vision control-anxiety group (FVCA). All acquisition and transfer trials were performed with a visible cursor representing limb movement. Acquisition trials were under normal (low anxiety) conditions and transfer trials were under anxiety conditions. Finally, group 4 was labelled full vision anxiety-control group (FVAC). All acquisition and transfer trials were performed with a visible cursor representing limb movement. Acquisition trials were under anxiety conditions and transfer trials were under normal (low anxiety) conditions. All participants were given movement time feedback (presented in numerical form in ms on the monitor) after each trial. Anxiety was manipulated through a combination of intrinsic and extrinsic competition styles. Specifically, during acquisition for the anxiety manipulation participants were informed that their movements were being video recorded (of which a screen monitor was placed to the side of the participant demonstrating what was being recorded) for both live and later analysis by researchers within the University. In addition, participants were told that if they improved their performance by 20% over the next 30 trials they would be eligible to win £100 (mean performance was presented after each trial). Both a winners and losers board was presented in the room representing the results for everyone to see. Further to this, anxiety was also manipulated by having somebody standing behind the participant noting his or her movement patterns during the anxiety transfer phases. Finally, during the anxiety transfer phase in addition to the £100 that they could win in acquisition, it was made clear to participants that they had been partnered with another individual and that in order for them to secure the prize money of now £200 (£100 per person), both them and their partner needed to achieve a 20% improvement. Participants were then informed that their partners had already completed the experiment and successfully achieved a 20% improvement. As a final point, all participants were told they would receive an email detailing who they were partnered with and how that individual had performed.

In order to ensure anxiety had been successfully manipulated, all participants completed the MRF-3 immediately prior to the start of each block (block 1, block 2, block 3 and block 4). Effort, as determined by the RSME, was measured retrospectively at the same experimental phase (i.e., immediately post trial).

Performance Measures

Performance data for each trial consisted of movement time (MT), constant error (CE), and variable error (VE) at the end of the movement. MT (ms) was defined as the interval from the start of the movement to when the pen crossed arc subtended by the three targets. Error at the arc subtended by the three targets was calculated from the centre of the cursor representing limb movement to the centre of the required target on that given trial. Errors to the left of target were designated as negative while errors to the right were designated as positive. CE was then calculated as the within-participant mean of these errors and VE as the within-participant standard deviation of these errors. In order to investigate the processing of afferent information, the directional error as defined as the deviation from the longitudinal axis at 25%, 50%, 75% and 100% of the distance from the home position to the target, was recorded on each trial (Khan et al., 2003) (see Figure 14). Directional variability (mm) (i.e., within-participant standard deviation of directional error) was then calculated at each longitudinal distance.

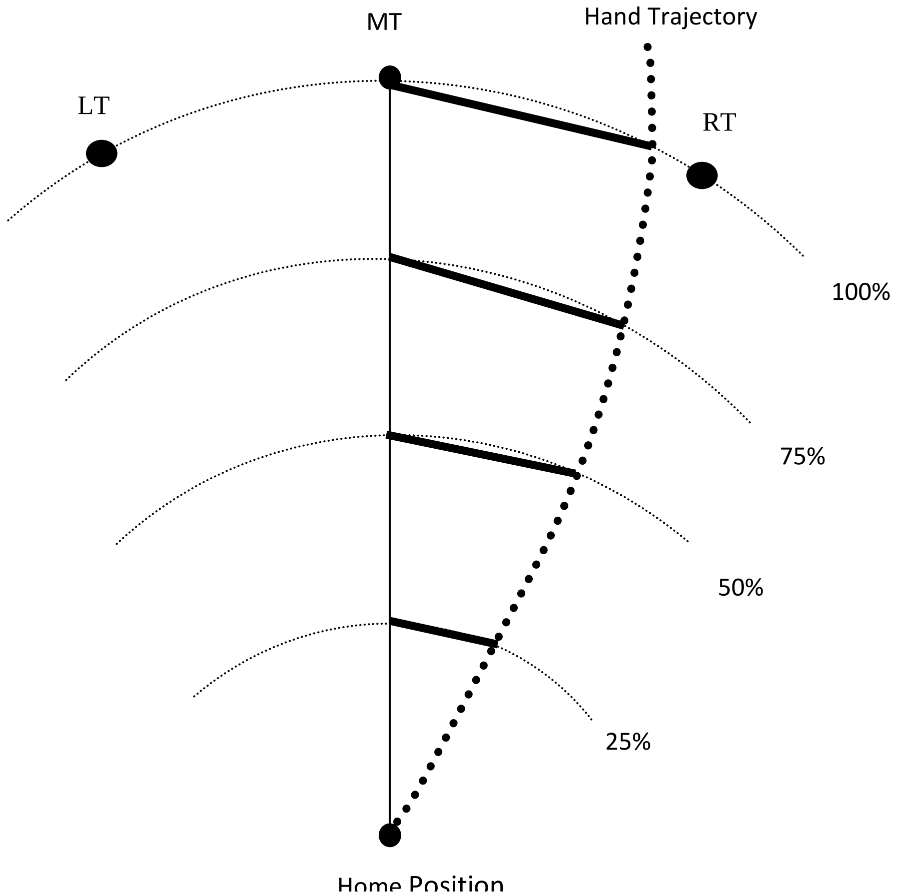

Figure 12. A schematic of a limb trajectory on the middle target (MT) illustrating the calculation of directional errors at 25, 50, 75 and 100 % of the longitudinal distance from the home position to the target. Figure includes left target (LT), middle target (MT), and right target (RT). Calculations of directional error is calculated as illustrated dependent on which target is in play.

Statistical Analysis

Psychological Measures

The anxiety (worry and tense), confidence, and effort data were all assessed separately by a 4 (group: NVCA; NVAC; FVCA; FVAC) x 4 (block: block 1; block 2; block 3; block 4) ANOVA with repeated measure on the second factor.

Performance Measures; Acquisition

To investigate task acquisition, MT, CE and VE were submitted to separate 4 (group: NVCA; NVAC; FVCA; FVAC) x 3 (block: block 1; block 2; block 3) x 3 (target: left; middle; right) ANOVA with repeated measure on the second factor and a further, 4 (group: NVCA; NVAC; FVCA; FVAC) x 3 (block: block 1; block 2; block 3) ANOVA with repeated measures on the second factor.

Acquisition vs. Transfer

In order to assess the effect of the transfer tests (anxiety and normal conditions) on performance, MT, CE and VE were submitted to separate 4 (group: NVCA; NVAC; FVCA; FVAC) x 2 (block: block 3; block 4) x 3 (target: left; middle; right) ANOVA with repeated measure on the last two factors. The effects of anxiety on directional variability throughout the movement was analysed using a 4 (group: NVCA; NVAC; FVCA; FVAC) x 2 (block: block 3; block 4) x 4 (longitudinal distance: 25%; 50%; 75%; 100%), ANOVA with repeated measures on both factors. The last block of 30 trials (block 3) in acquisition phase were used in these analyses since this is when participants had experienced the most practice (see Khan et al., 1998; Proteau et al., 1987). In order to precisely investigate the effect of the transfer tests (anxiety and normal conditions) on performance, a further analysis at each individual longitudinal distance was conducted. This consisted of MT, CE and VE submitted to separate 4 (groups: NVCA; NVAC; FVCA; FVAC) x 2 (block: block 3; block 4) ANOVAs with repeated measure on the second factor. All significant effects were broken down using Tukey's HSD post hoc procedures ($p < .05$).

4.3. Results

Psychological Measures

All means and *SDs* for anxiety, confidence and effort are in Table 13, and statistical values are reported in Table 14.

		Experimental Phase			
Variable	**Group**	**1**	**2**	**3**	**4**
Anxiety	NVCA	6.60	5.50	5.60	11.3
		3.16	2.22	*2.45*	*3.02*
	NVAC	8.80	8.90	10.8	5.00
		3.55	*3.34*	*4.87*	*3.49*
	FVCA	4.30	3.80	3.30	9.80
		1.76	*1.68*	*1.49*	*2.61*
	FVAC	10.7	11.1	12.6	4.40
		4.29	*4.53*	*4.69*	*1.71*
TOTAL		8.77	7.32	8.07	7.47
		4.39	*4.17*	*5.20*	*3.96*
Confidence	NVCA	7.20	6.70	6.90	6.00
		2.09	*2.00*	*1.85*	*2.40*
	NVAC	6.80	6.30	5.80	6.50
		1.93	*1.56*	*2.44*	*2.79*
	FVCA	8.10	8.20	8.80	7.60
		1.59	*1.54*	*1.47*	*2.31*
	FVAC	5.00	5.60	5.70	7.20
		2.16	*2.31*	*2.26*	*2.14*
TOTAL		6.77	6.70	6.80	6.82
		2.20	*2.05*	*2.33*	*2.41*
Effort	NVCA	*62.4*	*72.9*	*81.9*	*93.2*
		17.4	*16.8*	*23.9*	*32.4*
	NVAC	*69.8*	*76.00*	*78.5*	*71.9*
		21.6	*23.1*	*28.3*	*32.6*
	FVCA	*73.5*	*90.00*	*88.2*	*91.8*
		30.2	*34.9*	*39.6*	*41.9*
	FVAC	*71.9*	*82.1*	*85.9*	*73.8*
		27.8	*24.1*	*32.3*	*32.9*
TOTAL		*69.4*	*80.2*	*83.6*	*82.6*
		24.2	*25.4*	*30.5*	*35.2*

Table 13. All means and *SDs* for anxiety, confidence and effort as a function of group (NVAC = No Vision Anxiety-Control; NVCA = No Vision Control-Anxiety; FVAC = Full Vision Anxiety-Control; FVCA = Full Vision Control-Anxiety).

		Statistical Value		
Variable	**Factor(s)**	**F**	**Df**	**P**
Anxiety	Block	1.09	3, 108	.344
	Group	4.82	3, 36	.006
	Block x Group	29.27	9, 108	< .001
Confidence	Block	0.63	3, 108	.964
	Group	3.29	3, 36	.031
	Block x Group	2.79	9, 108	.010

Effort	Block	8.10	3, 108	< .001
	Group	3.43	3, 36	.794
	Block x Group	2.05	9, 108	.061

Table 14. All statistical figures for anxiety, confidence and effort.

Anxiety

The ANOVA revealed a significant main effect of group and a significant block x group interaction. Breakdown of the interaction revealed that the anxiety manipulation was successful in acquisition and transfer phases where targeted, and that the anxiety levels experienced in both acquisition and transfer phase manipulations were not significantly different from one another. No significant main effect of block was observed.

Confidence

Similar to the anxiety data, the analysis revealed a significant main effect of group and an interaction between block and group. Further breakdown of the results revealed that the anxiety-control groups increased in confidence from block 3 (last block of acquisition) to block 4 (transfer) (i.e., confidence increased when anxiety was taken away) and the control-anxiety groups decreased in confidence from block 3 (last block of acquisition) to block 4 (transfer) (i.e., confidence decreased when anxiety was induced). No significant main effect of block was observed.

Effort

The ANOVA revealed only a significant main effect of block, with the first block of acquisition),having significantly lower levels of effort than all other blocks. Thus, effort was similar throughout all groups and did not differ between anxiety and low anxiety transfers (block 3 and block 4).

Performance Measures

All means and *SDs* for Constant Error (CE), Variable Error (VE) and Movement Time (MT) are reported in Table 15 and the statistical values for the analysis conducted on these measures are reported in Table 16.

		Experimental Phase											
Variable	**Group**	**B1L**	**B1M**	**B1R**	**B2L**	**B2M**	**B2R**	**B3L**	**B3M**	**B3R**	**B4L**	**B4M**	**B4R**
CE	NVCA	-23.7	-1.89	12.7	-12.3	-1.37	2.93	-8.54	.689	2.79	-8.20	1.28	4.84
		13.6	*11.0*	*9.95*	*14.8*	*11.9*	*14.3*	*12.1*	*10.1*	*10.3*	*15.9*	*10.9*	*9.72*
	NVAC	-24.2	.201	21.3	-14.3	-.440	11.9	-13.7	-2.93	6.90	-5.15	-.603	6.61
		1.21	*8.47*	*13.5*	*14.0*	*7.83*	*14.1*	*10.5*	*4.12*	*10.5*	*11.1*	*5.15*	*10.3*
	FVCA	-4.92	-.652	2.90	-1.57	.333	1.08	-.588	.146	.508	.042	-.073	.829
		7.15	*2.86*	*6.34*	*3.02*	*1.95*	*3.66*	*2.90*	*1.70*	*2.32*	*3.26*	*1.76*	*2.77*
	FVAC	-1.78	1.47	4.87	-.714	1.14	1.52	-1.02	1.50	2.40	.809	.944	1.27
		4.38	*3.81*	*5.55*	*1.94*	*1.95*	*3.56*	*2.24*	*2.50*	*3.23*	*2.00*	*2.42*	*3.08*
TOTAL		-13.6	-.218	10.4	-7.24	-.084	4.38	-5.98	-.148	3.15	-3.12	.389	3.39
		16.5	*7.19*	*11.6*	*11.7*	*7.06*	*10.9*	*9.69*	*5.73*	*7.71*	*10.2*	*6.02*	*7.53*
VE	NVCA	14.6	6.74	13.3	11.5	6.35	9.16	9.27	6.94	9.12	9.43	6.29	9.42
		5.48	*2.01*	*4.03*	*3.08*	*2.61*	*1.66*	*3.65*	*1.99*	*2.84*	*2.00*	*1.86*	*3.06*
	NVAC	13.2	8.63	12.5	13.9	8.37	11.0	11.5	7.55	11.1	12.6	7.84	11.4
		3.85	*2.44*	*2.76*	*5.39*	*3.66*	*2.87*	*2.62*	*1.14*	*3.11*	*5.33*	*2.66*	*2.65*
	FVCA	6.39	4.80	5.13	5.19	3.81	4.29	4.26	3.26	4.01	3.91	3.37	3.69
		3.15	*2.73*	*3.00*	*2.75*	*.998*	*1.35*	*1.87*	*.864*	*1.45*	*2.00*	*.734*	*1.08*
	FVAC	5.84	4.77	6.51	5.03	4.38	5.52	4.26	4.20	4.74	5.31	4.81	4.93
		3.56	*1.28*	*1.72*	*1.76*	*1.08*	*1.83*	*1.19*	*1.91*	*1.51*	*1.49*	*1.38*	*1.82*
TOTAL		*10.0*	6.24	9.39	8.93	5.73	7.51	7.34	5.49	7.24	7.83	5.58	7.37
		5.63	*2.65*	*4.65*	*5.21*	*2.91*	*3.36*	*4.02*	*2.35*	*3.76*	*4.60*	*2.41*	*3.89*
MT	NVCA	454.2	452.0	450.6	447.6	453.2	447.4	452.3	447.3	445.7	455.3	453.9	447.9
		13.6	*7.28*	*12.0*	*14.7*	*15.1*	*13.0*	*12.0*	*13.2*	*10.8*	*8.32*	*11.0*	*9.42*
	NVAC	450.7	448.8	443.2	450.0	449.2	444.5	448.4	448.1	447.1	447.2	450.8	443.0
		11.8	*10.7*	*11.2*	*14.6*	*12.7*	*10.6*	*10.9*	*8.14*	*7.59*	*15.8*	*7.32*	*12.1*
	FVCA	452.8	444.3	448.0	453.4	447.0	443.9	458.0	447.4	445.1	452.1	448.3	443.6
		9.07	*6.51*	*9.17*	*7.28*	*8.84*	*7.27*	*9.08*	*8.80*	*9.77*	*7.46*	*9.67*	*12.0*
	FVAC	452.2	450.0	442.3	454.4	447.2	440.2	446.0	449.8	440.3	451.9	448.9	448.1
		12.4	*9.30*	*12.0*	*9.91*	*6.31*	*6.88*	*21.8*	*11.0*	*6.39*	*10.4*	*8.01*	*9.20*
TOTAL		452.5	448.8	446.0	451.4	449.1	444.0	451.2	448.1	444.6	451.6	450.5	445.6
		11.4	*8.78*	*11.2*	*11.9*	*11.1*	*9.77*	*14.5*	*10.1*	*8.87*	*10.9*	*9.03*	*10.6*

Table 15; including target. All means and *SDs* for CE (constant error), VE (variable error) and MT (movement time), as a function of group (NVAC = No Vision Anxiety-Control; NVCA = No Vision Control-Anxiety; FVAC = Full Vision Anxiety-Control; FVCA = Full Vision Control-Anxiety), experimental phase and target (L = left; M = middle; R = right).

		Statistical Value					
		Acquisition			**Acquisition vs. Transfer**		
Variable	**Factor(s)**	**F**	**Df**	**P**	**F**	**Df**	**P**
CE	Group	.488	3, 36	.826	.432	3, 36	.731
	Block	.976	2, 72	.024	4.512	1, 36	.041
	Target	< .001	2, 72	56.144	20.380	2, 72	< .001
	Block x Group	.313	6, 72	1.206	2.004	3, 36	.131
	Target x Group	< .001	6, 72	11.124	5.012	6,72	.002
	Block x Target	< .001	4, 144	32.772	3.438	2, 72	.058
	Block x Target x Group	< .001	12, 144	4.787	2.270	6, 72	.076
VE	Group	< .001	3, 36	44.826	64.531	3, 36	< .001
	Block	< .001	2, 72	17.930	.494	1, 36	.487
	Target	< .001	2, 72	37.421	18.608	2, 72	< .001
	Block x Group	.194	6, 72	1.488	.392	3, 36	.760

	Target x Group	< .001	6, 72	5.876	3.967	6,72	.002
	Block x Target	.025	4, 144	2.886	.329	2, 72	.721
	Block x Target x Group	.284	12, 144	1.206	.293	6, 72	.938
MT	Group	.605	3, 36	.616	.458	3, 36	.713
	Block	.357	2, 72	.701	1.023	1, 36	.028
	Target	9.790	2, 72	< .001	7.707	2, 72	.176
	Block x Group	.470	6, 72	.828	1.647	3, 36	.121
	Target x Group	1.174	6, 72	.330	.883	6,72	.069
	Block x Target	.198	4, 144	.939	.275	2, 72	.008
	Block x Target x Group	1.019	12, 144	.435	1.073	6, 72	.082

Table 16; including target. All statistical figures for all performance dependent variables for acquisition phase (block 1, block 2, block 3) and acquisition phase (block 3) vs. transfer phase (block 4).

Acquisition

CE

The results revealed a significant main effect for target, but no significant main effects for block or group. More interestingly, target x group, block x target, and block x target x group interactions were found. Similar to previous research (Lawrence, Khan, Mourton & Bernier, 201l; Lawrence et al., 2012), breakdown of the interactions revealed that participants in all groups and at all blocks overestimated the eccentricity of targets. That is, movement biases were to the left of the left target, to the right of the right target, and greater at both the left and right targets when compared to the middle target. Furthermore, the bias's observed at the left and right targets significantly decreased as a function of practice (block). Finally, these biases were greater in the NV compared to the FV groups.

VE

Results revealed a significant main effect of block, group and target. Specifically, variable error decreased as a function of practice, was greater in the left and right targets compared to that of the middle target, and was greater in the NV compared to the FV groups. In addition to the main effects, the analysis revealed significant target x group and block x target interactions. Breakdown of the interactions indicated that the effect of target reduced as a function of practice block and that the FVCA group and both the NV groups had significantly greater error on the left target compared to the middle and right targets. Additionally, both NV groups also performed significantly better on the middle target than the right target.

MT

Results revealed only a significant main effect of target with movements to the right target being significantly faster than those performed to either middle or left target (no differences between the middle or left targets was observed).

Acquisition vs. Transfer

CE

The results revealed significant main effects for target and block, together with a significant target x group interaction. Whilst movements were both bias to the direction of the target (i.e., left of the left target and right of the right target) and decreased as a function of practice, breakdown of the interaction revealed that these biases were greater in the NV compared to FV groups.

VE

Results revealed significant main effects for group and target. Specifically, the NV groups had significantly greater error than the FV groups and movements to the left and right targets had significantly greater error than movements to the middle target. Furthermore, the analysis also revealed a target x group interaction with the target effect being significantly greater in the NV groups compared to the FV groups and significantly greater in the NVAC group compared to the NVCA group.

MT

Results revealed only a significant main effect of target with participants moving significantly faster to the right target compared to both the middle and left target.

Directional Variability

All means and *SDs* for Constant Error (CE), Variable Error (VE) and Movement Time (MT) as a function of longitudinal distance and block are reported in Table 17 (acquisition; block 1, 2 and 3) and Table 18 (transfer; block4), and all statistical values are reported in Table 19.

		Acquisition Phase											
Variable	**Group**	**B125%**	**B150%**	**B175%**	**B1100%**	**B225%**	**B250%**	**B275%**	**B2100%**	**B325%**	**B350%**	**B375%**	**B3100%**
CE	NVCA	-1.76	-3.32	-4.27	-4.29	-1.52	-2.64	-3.45	-3.58	-.767	-1.44	-1.76	-1.68
		4.01	*6.98*	*9.22*	*10.58*	*4.40*	*8.01*	*10.9*	*12.9*	*3.49*	*5.95*	*8.03*	*9.41*
	NVAC	-.848	-1.39	-1.56	-.861	-.935	-1.66	-2.03	-.943	-.990	-2.08	-2.96	-3.26
		2.88	*5.56*	*7.68*	*9.64*	*3.11*	*5.68*	*7.35*	*7.97*	*2.74*	*4.66*	*5.58*	*5.43*
	FVCA	-2.71	-3.53	-3.45	-.888	-2.74	-3.35	-2.71	*-.052*	-2.91	-3.12	-2.46	.022
		2.03	*2.72*	*2.45*	*1.46*	*2.37*	*2.96*	*2.57*	*.956*	*2.28*	*32.80*	*2.34*	*.864*
	FVAC	-1.48	-1.66	-.782	1.51	-1.95	-2.12	-1.23	.653	-2.25	-2.42	-1.31	.961
		1.83	*2.21*	*2.55*	*2.56*	*1.77*	*1.85*	*1.82*	*1.40*	*1.71*	*1.68*	*1.88*	*1.64*
TOTAL		-1.72	-2.48	-2.51	-1.13	-1.78	-2.45	-2.35	-.982	-1.73	-2.26	*-2.12*	-.992
		2.79	*4.71*	*6.17*	*7.33*	*3.02*	*5.05*	*6.55*	*7.54*	*2.69*	*4.00*	*4.95*	*5.54*
VE	NVCA	3.64	6.38	8.89	11.5	3.03	5.11	6.99	9.00	2.96	4.18	6.49	8.44
		.674	*1.00*	*1.71*	*2.81*	*.481*	*.840*	*1.08*	*1.38*	*.628*	*1.15*	*1.67*	*2.09*
	NVAC	3.96	6.49	9.08	11.4	3.68	6.11	8.58	11.1	3.61	5.55	7.58	10.0
		.574	*1.13*	*1.59*	*2.30*	*1.06*	*1.64*	*2.36*	*3.22*	*.586*	*.538*	*.799*	*1.01*
	FVCA	2.99	4.61	5.48	5.44	2.62	3.81	4..51	4.43	2.46	3.44	3.90	3.84
		.733	*1.29*	*1.89*	*2.13*	*.739*	*.734*	*.933*	*1.24*	*.477*	*.699*	*.807*	*1.02*
	FVAC	3.11	4.58	5.42	5.71	2.69	3.96	4.71	4..98	2.74	3.74	4.33	4.40
		.792	*1.13*	*1.39*	*1.77*	*.724*	*.728*	*.620*	*.986*	*.557*	*.703*	*.951*	*1.12*
TOTAL		3.43	5.51	7.20	8.55	3.00	4.75	6.20	7.39	2.94	4.39	5.57	6.69
		.780	*1.44*	*2.38*	*3.73*	*.861*	*1.38*	*2.18*	*3.38*	*.693*	*1.15*	*1.87*	*2.98*
MT	NVCA	188.4	279.1	360.1	452.3	189.4	280.0	359.1	449.4	190.7	281.7	361.5	448.4
		17.4	*20.7*	*19.4*	*7.17*	*18.7*	*22.62*	*21.9*	*9.58*	*19.5*	*22.7*	*20.9*	*7.78*
	NVAC	182.0	272.1	352.0	447.6	183.2	272.9	352.2	447.9	185.0	274.3	353.2	447.8
		18.9	*19.8*	*17.0*	*8.49*	*14.7*	*17.9*	*17.7*	*9.59*	*21.1*	*23.8*	*22.6*	*5.88*
	FVCA	165.6	257.6	347.6	448.4	165.4	257.8	345.5	448.1	166.9	258.7	347.6	450.2
		15.8	*16.6*	*15.0*	*5.55*	*13.4*	*13.4*	*11.1*	*5.79*	*18.2*	*16.3*	*12.6*	*7.26*
	FVAC	172.1	262.6	347.4	448.2	173.2	262.0	354.0	447.3	171.5	259.8	342.2	445.4
		13.3	*18.4*	*19.2*	*7.76*	*13.9*	*15.6*	*15.0*	*5.46*	*16.5*	*20.2*	*20.7*	*8.93*
TOTAL		177.0	267.8	351.8	449.1	177.8	268.2	350.7	448.2	178.5	268.6	351.1	448.0
		18.1	*20.1*	*17.8*	*7.28*	*17.4*	*19.2*	*17.2*	*7.59*	*20.6*	*22.4*	*20.1*	*7.45*

Table 17.All means and *SDs* for CE (constant error), VE (variable error) and MT (movement time), as a function of group (NVAC = No Vision Anxiety-Control; NVCA = No Vision Control-Anxiety; FVAC = Full Vision Anxiety-Control; FVCA = Full Vision Control-Anxiety), experimental phase and longitudinal distance (25%, 50%, 75%, 100%).

		Transfer Phase			
Variable	**Group**	**B425%**	**B450%**	**B475%**	**B4100%**
CE	NVCA	-.294	-.549	-.908	-.689
		3.73	*6.84*	*9.08*	*10.86*
	NVAC	-.888	-1.16	-.848	.286
		2.42	*4.20*	*5.14*	*5.40*
	FVCA	-2.73	-2.78	-1.90	.266
		2.75	*3.60*	*3.16*	*1.52*
	FVAC	-2.28	-2.52	-1.17	1.00
		1.94	*1.62*	*1.88*	*1.72*
TOTAL		-1.55	-1.75	-1.20	.218
		2.86	*4.40*	*5.33*	*5.96*
VE	NVCA	2.94	4.83	6.49	8.38
		.736	*1.07*	*1.14*	*1.08*
	NVAC	3.71	6.07	8.39	10.6
		.944	*1.68*	*2.41*	*3.07*
	FVCA	2.24	3.30	3.79	3.66
		.427	*.552*	*.755*	*1.11*
	FVAC	2.65	3.87	4.71	5.02
		.538	*.808*	*.940*	*1.18*
TOTAL		2.89	4.52	5.85	6.93
		.857	*1.50*	*2.27*	*3.29*
MT	NVCA	190.2	281.9	363.0	452..3
		15.7	*18.8*	*17.1*	*6.61*
	NVAC	188.0	278.5	357.2	447.0
		20.9	*24.3*	*21.8*	*9.10*
	FVCA	164.1	255.1	343.8	448.0
		18.3	*17.8*	*15.7*	*7.88*
	FVAC	177.2	265.8	348.0	449.7
		16.1	*19.8*	*20.7*	*8.05*
TOTAL		179.9	270.3	353.0	449.2
		20.1	*22.3*	*19.8*	*7.92*

Table 18.All means and *SDs* for CE (constant error), VE (variable error) and MT (movement time), as a function of group (NVAC = No Vision Anxiety-Control; NVCA = No Vision Control-Anxiety; FVAC = Full Vision Anxiety-Control; FVCA = Full Vision Control-Anxiety), experimental phase and longitudinal distance (25%, 50%, 75%, 100%).

		Statistical Value					
		Acquisition			Acquisition vs. Transfer		
Variable	**Factor(s)**	**F**	**Df**	**P**	**F**	**Df**	**P**
CE	Group	.223	3, 36	.880	.093	3, 36	.964
	Block	.079	2, 72	.924	3.803	1, 36	.059
	Longitudinal Distance	3.763	3, 108	.050	4.902	3, 108	.022
	Block x Group	1.280	6, 72	.277	1.000	3, 36	.404
	Longitudinal Distance x Group	2.583	9, 108	.054	2.274	9, 108	.073
	Block x Longitudinal Distance	.219	6, 216	.829	4.677	3, 108	.031
	Block x Longitudinal Distance x Group	1.062	18, 216	.395	2.901	9, 108	.039
VE	Group	29.898	3, 36	< .001	39.785	3, 36	< .001
	Block	23.926	2, 72	< .001	.516	1, 36	.477
	Longitudinal Distance	495.152	3, 108	< .001	489.178	3, 108	< .001
	Block x Group	1.245	6, 72	.294	.523	3, 36	.669
	Longitudinal Distance x Group	49.662	9, 108	< .001	54.958	9, 108	< .001
	Block x Longitudinal Distance	9.729	6, 216	< .001	1.119	3, 108	.308
	Block x Longitudinal Distance x Group	1.095	18, 216	.374	.426	9, 108	.770
MT	Group	2.846	3, 36	.051	2.820	3, 36	.053
	Block	.028	2, 72	.972	2.607	1, 36	.115
	Longitudinal Distance	7223.11	3, 108	< .001	5636.73	3, 108	< .001
	Block x Group	.304	6, 72	.933	3.377	3, 36	.029
	Longitudinal Distance x	3.173	9, 108	.018	3.157	9, 108	.020

Group						
Block x Longitudinal Distance	1.217	6, 216	.305	.206	3, 108	.757
Block x Longitudinal Distance x Group	.551	18, 216	.795	2.409	9, 108	.052

Table 19. All statistical figures for all performance dependent variables for acquisition phase (block 3) vs. transfer phase (block 4).

Acquisition

CE

Analysis revealed only a significant main effect of longitudinal distance with movement bias being significantly less at the 100% longitudinal distance compared to the 25% and 50% distances.

VE

The analysis of variable error revealed a significant main effect of block, group and longitudinal distance together with longitudinal distance x group and block x longitudinal distance interactions. Specifically, whilst the NV groups demonstrated significant increases in VE as the movement progressed, the FV groups increased in error up to 75% of the longitudinal distance than then decreased in error from 75% to movement end. Furthermore, whilst this pattern of results was consistent for each block, error was significantly less during practice block 3 compared to practice block 1.

MT

Results revealed only a significant main effect of longitudinal distance together with a longitudinal distance x group interaction. Specifically, whilst movement time increased as a function of longitudinal distance, participants in the FV groups were faster at reaching the earlier longitudinal distances compared to the NV groups.

Acquisition vs. Transfer

CE

The results revealed a significant main effect of longitudinal distance together with significant block x longitudinal distance, and block x longitudinal distance x group interactions. Breakdown of the 3-way interaction revealed that both of the NV groups revealed less movement bias in transfer compared to acquisition. Furthermore, in the NVCA group movement bias significantly increased during acquisition up to 50% of the movement trajectory before then levelling off between 50% and 100%. Whereas, in transfer the same group revealed no significant differences in movement bias at any of the longitudinal distances. In the acquisition phase, the NVAC group increased in movement bias up to 75% of the movement trajectory before levelling off, whereas movement bias only significantly levelled off between 50% and 75% in the transfer phase. For both the FV groups, movement bias was greater in transfer compared to acquisition. Furthermore, both the FVCA and the FVAC groups demonstrated significant decreases in movement bias between 50% and 100% of the movement trajectory in acquisition. Whilst significant decreases in movement bias were only present between 50% and 75% of the movement distance in these groups at transfer (see Figure 13).

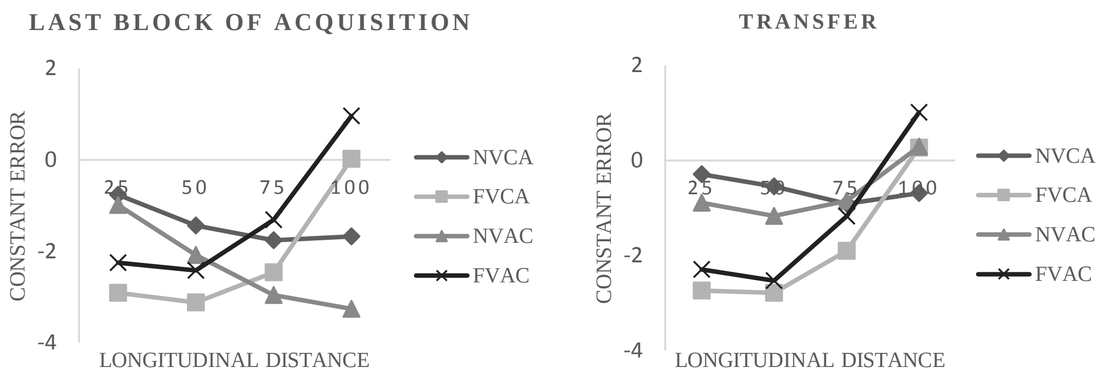

Figure 13. Constant Error (mm) at each longitudinal distance for all groups at the block 3 (last block of acquisition) and block 4 (transfer).

VE

Results revealed no significant main effect of interactions involving block. However, significant main effects for group and longitudinal distance, together with a longitudinal distance x group interaction were observed. Breakdown of the interaction revealed that the FV groups significantly increased in error between 25% and 75% of the movement trajectory before levelling off from 75% to 100%. However, in the NV groups variability significantly increased throughout the entire movement trajectory. Additionally, the NV groups made significantly more error than the FV groups and the NVAC group had the greatest overall variability (see Figure 14).

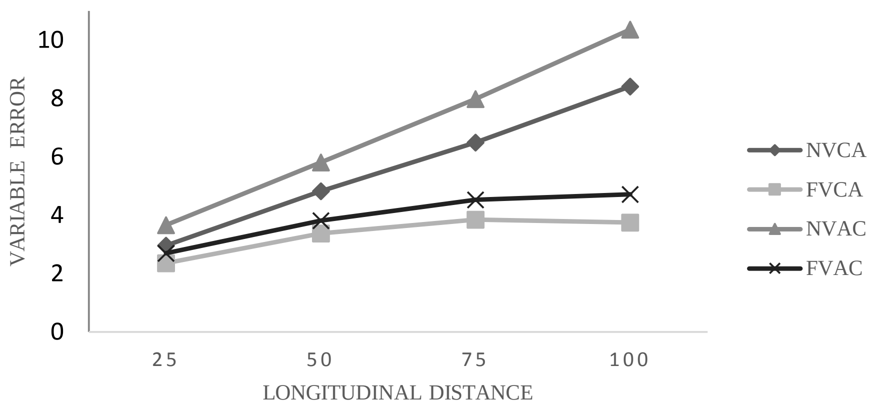

Figure 14. Variability Error for all groups at each longitudinal distance.

MT

Analysis revealed a significant main effect of longitudinal distance together with significant longitudinal distance x group, and block x group interactions. Breakdown of these interactions revealed that whilst all groups movement time increased as the movement trajectory unfolded, the FV groups reached the early distances (25% and 50%) quicker than the NV groups. In addition, the FVAC and NVAC group were significantly slower in transfer compared to acquisition (i.e., movement time was slower when anxiety was removed from practice). Whereas the FVCA group was significantly faster in transfer compared to acquisition.

4.4. Discussion

Recent research has revealed that both final outcome and the parameters of movements required to achieve the outcome are affected by the presence of pressure (Lawrence et al., 2012b). An important issue regarding the control of aiming movement tasks is the extent to which accuracy is determined offline by planning processes prior to movement initiation, verses online via adaptations to the limb trajectory during movement execution. The present experiment aimed to investigate the interaction between the offline process and the online process involved in motor control. More precisely, the experiment set out to identify any specificity effects within the two processes as a result of exposure too, and training with anxiety. Research has examined the curvature of trajectories to determine the extent to which trajectories are modified during movement execution (e.g., Beiere & Proteau, 2011). However, it is often difficult to distinguish whether curved trajectories are the result of online adjustments or directional differences in limb inertia (Ghez, Gordon, Ghilardi, & Sainburg, 1995). Therefore, in order to investigate the process involved in offline and online control, the current experiment analysed the variability in limb trajectories at various stages throughout the movement (e.g., 25% 50%, 75%, & 100%). The rational here being that any differences in the form of variability profiles in the later stages of the trajectory between acquisition and transfer would imply that compensatory adjustments occurred online during movement execution, whereas for offline processes involved in the planning of a movement, differences would be expected to occur early in the limb trajectory (see Khan et al., 2006 for a review).

Consistent with past research (Gordon, Ghilardi, & Ghez, 1994; Khan et al., 2003; Messier & Kalaska, 1997; 1999), examination of the variability (VE) profiles revealed that VE increased linearly throughout movement in the no vision groups. This finding indicates that the VE in the no vision groups was determined prior to movement execution (i.e., planned in advance) and not subject to online movement adjustment during the actual movement trajectory. Contrary to the NV groups, the VE profiles for participants who received full vision afferent information increased throughout movement until 75% of the trajectory distance before levelling off between 75% and movement end. This is consistent with past research (Khan et al., 2003; Lawrence et al., 2012b) and reveals that the planned trajectories of the FV groups were open to error detection and subsequent adjustment during movement execution (i.e., online).

Surprisingly, comparisons of the VE profiles between acquisition and transfer did not differ in form in any of the groups. This suggests that; (a) training with anxiety had no effect on VE whether you had vision or no vision, (b) transferring to anxiety conditions had no effect on VE whether you had vision or no vision, and (c) specificity of practice did not affect VE whether you have vision or no vision. These findings are contradictory to that of Lawrence et al. (2012b), where movement variability was greater at the latter stages of the trajectory under the high anxiety condition compared to the low anxiety condition. This may indicate that the processing of afferent information for online trajectory corrections was reduced as a result of anxiety. From the current experiment, neither the vision nor the no vision groups can support this notion by looking at the VE profiles alone. However, the nature of aiming movements are multidimensional both in terms of the planning and execution, but also the measurement facets that researchers utilise in order to investigate these processes. That is, movement time, movement consistency (variable error), and movement bias (constant error) are all possible performance indicators at both an individual level and at a holistic (interaction) level. Furthermore, research has revealed that some and/or all of these measures can differ between groups (no vision and full vision) at both the end of the movement and during different percentages of the movement trajectory (see Elliott et al., 2001, 2010 for reviews). Thus, it is important that the current research investigates all dependent variables at all of the different portions of movement trajectory before drawing any conclusions about differences between groups or between the acquisition and transfer experimental phases. Indeed, although VE is not significantly different between groups or the acquisition and transfer experimental phases within the groups, the strategies adopted in order to ensure the accuracy of movements could be very different between the different groups and between the different phases of the experiment. That is, the time spent on the different portions (25%, 50%, 75%, and 100%) of the movement trajectory and/or the choice of movement pathway (i.e., movement bias's at 25%, 50%, 75% and 100%) adopted to reach the target could be very different and thus, reflect specificity effects and adaption's to movement strategies as a result of the addition or removal of anxiety.

When examining the performance variables of movement time (MT) and constant error (CE), differences between acquisition and transfer conditions were revealed. Specifically, although the end point MT was not significantly different either between groups or between the acquisition and transfer phases of movement, the strategies that participants adopted to reach this final MT were significantly different. That is, MT was slower at 25%, 50% and 75% of the movement under the control conditions compared to anxiety conditions for the FVAC, NVAC and FVCA groups. Thus, when conditions changed from anxiety to control conditions participants disproportionally spent more time up to 75% of the limb trajectory in the control compared to the anxiety conditions. These findings are reflective of participants adopting movement planning strategies to reach the earlier parts of the movement trajectory at a slower rate in the control compared to anxiety conditions. Differences in the time spent reaching the distinct longitudinal distances of movement trajectories, has been reported to reflect strategies of online and offline motor control processes (Elliott et al., 1995, 2001, 2010; Khan et al., 1998, 2006). That is, when afferent information is both available and able to be used to adjust limb trajectories during movement (i.e., online), participants often choose to slow down movements and/or distribute the time spent at longitudinal distances differently in comparison to situations where afferent information cannot be utilised to adjust movements online (Elliott et al., 1995; Elliott, Lyons, & Dyson, 1997; Khan & Franks, 2000; Khan et al., 2003a, 2004; Lawrence et al., 2011). It has been suggested that this is a strategy adopted by participants to allow themselves greater time to process the afferent information to both detect errors in the initial movement plan and then attempt to correct these planning errors by making adjustments to the original movement plan during movement execution. For example, participants may choose to spend more time up to 75% of the movement distance in order to ensure they have sufficient time to detect and process discrepancies between the position of the travelling limb and the position of the to-be-reached target (Woodworth, 1899; for a recent review see Elliott et al., 2010). Therefore, in control conditions (i.e., without anxiety) participants likely adopted a strategy whereby they slowed down their MT early within limb trajectory to generate associative comparisons between the dynamic information from the limb (i.e., velocity and direction) and target location. This then permitted the creation of an internal representation of the expected sensory consequences of the movement that was used to regulate the movement online and to update the planning of the subsequent trial; something that was not possible under the anxiety conditions. Here, similar to previous research (Khan et al., 1998) where afferent visual information is not available during execution (i.e., NV conditions), participants distributed movement times more consistently during limb trajectories whilst also adopting strategies of reaching the latter parts of the trajectory faster when compared to the control conditions.

Thus, it is likely that the presence of anxiety prevented effective utilisation of afferent information online and that participants adopted planning strategies similar to those typical of the NV conditions of past research in order to combat these effects i.e., performers were more reliant on effective movement planning in an attempt to minimize the need for online error corrections to achieve optimal accuracy (Khan & Franks, 2000). Furthermore, it appears that this careful planning strategy allowed performance to be maintained between control and anxiety conditions as both VE and CE profiles were not significantly different between acquisition and transfer.

Further support that participants were able to utilise afferent information to make alterations to limb trajectories during movement execution in the control but not anxious conditions is evident from the CE data. Here when vision was available under control conditions both the FVAC and the FVCA groups changed trajectory pathways (movement bias) by reducing constant error between 50 % and the end of the movement. The reduction in movement bias in the NV groups when under control conditions was significantly less than that of the FV groups. These results indicate that movement bias becomes more consistent under situations where planned trajectories are open to error detection and subsequent adjustments during movement execution as a result of the availability of visual afferent information. These results are as expected given the findings of the previous goal directed aiming studies investigating the utilisation of afferent information under vision and no vision conditions (Elliott et al., 1995; Khan et al., 1998, 2003, 2004, 2006; Khan & Franks, 2000; Lawrence et al., 2011; 2012b). However, of more central interest to the current investigation was how the movement bias' of the FV and NV groups changed between the control and anxiety conditions. Here, in both the NV groups movement bias was significantly less under anxious compared to control conditions. However, similar to control conditions, the NV groups had a significant increase in movement bias as the limb trajectories progressed under anxious conditions. These findings suggest participants did not change the utilisation of the limited afferent information for online movement adjustment as a result of the introduction of anxiety. For the FV groups, the movement bias was significantly greater under anxious compared to control conditions and the reductions in movement bias during the limb trajectory were reduced in comparison to the control conditions. This pattern of results indicate that participants were less effective at using visual feedback online under anxious compared to control conditions since any alterations made during movement execution were less effective at reducing overall movement bias.

To summarise, throughout the groups there were two common trends found in the results; (1) alterations of movement parameters had no effect on movement accuracy at end point (i.e., no group's end point error was significantly different between acquisition and transfer) and, (2) the variability in early limb trajectories were altered in all groups. This experiment has given an insight into issues regarding the control of aiming movement tasks concerning which accuracy is determined by offline verses online processes in vision and no vision conditions. In line with previous research (Gordon, Ghilardi & Ghez, 1994; Khan et al., 2003a; Khan & Franks, 2003; Lawrence et al., 2012; Messier & Kalaska, 1997; 1999) variability profiles show that NV groups increase linearly throughout movement on a planned process that is determined prior to movement execution. Whereas, the FV groups increase linearly in movement variability up to 75% which demonstrates adjustments been made during movement execution. That is, NV groups rely on an offline process involved in movement planning in an attempt to minimise the need for discrete error correction, whilst the FV groups are open to more online processes involved with error detection in movement execution. Anxiety was predicted to affect online control processes involved with the error correction phase of movement execution; therefore, it is not surprising that performance outcome was not altered by a change in conditions (i.e., the removal or addition of anxiety) within the NV groups. More specifically, the strategy deemed most useful under no vision conditions (offline control) is not affected by anxiety hence, the strategy developed during acquisition did not differ during transfer. Thus, supporting SPH as acquisition and transfer phases were similarly relative to the sensory information available (Proteau, 1992).

Whilst end point accuracy did not differ between acquisition and transfer for the vision groups, support for specificity is evident in that when there is a change in mood kinematic measures are altered as a consequence. The more prominent findings within the current investigations comprises of the time spent on the different portions (25%, 50%, 75%, and 100%) of the movement trajectory and the choice of movement pathway (i.e., movement bias's at 25%, 50%, 75% and 100%) that revealed different strategies to reach the target in control verse anxiety conditions. Whereby the reason for no performance decrements (which contradicts that of SPH; SPH assumes performance decrements to occur) is due to combat mechanisms involved in the distribution of online and offline control processes. That is specificity within the psychological construct of anxiety may be counterbalanced by adopted strategies in the time spent on the different portions of movement trajectories and the choice of movement pathways. Whereby, strategies developed under one condition will differ from that of the other condition hence, alterations within the strategies will help maintain overall performance. It is proposed that participants are able to utilise afferent information to make alterations to limb trajectory during movement execution in the control but not the anxious conditions. Whereby, the strategy that is deemed most useful for success under the presence of anxiety is that of enhanced planning (i.e., offline processes). This strategy is likely adopted to combat the effects of anxiety disrupting the automatic processes associated with the use of online control.

CHAPTER 5

GENERAL DISCUSSION

5.1. Overview

The relationship between anxiety and performance has been investigated for over a hundred years within the social psychology domain (Yerkes & Dodson, 1908), but it wasn't until the 1960's where researchers from motor learning examined the anxiety-performance relationship (Cratty, 1967; Oxendine, 1968; Singer, 1968). Two main empirical standpoints have emerged within the sport psychology literature quantifying the effects of anxiety on performance. Both distraction theory (see Eysenck et al., 2007 for review; Ansari & Derakshan, 2011b; Hardy, Beattie, & Woodman, 2007) and self-focus theory researchers (Baumeister, 1984; Beilock & Carr, 2001; Lewis & Linder, 1997; Masters, 1992; see Maxwell & Masters, 2008 for a review) have contributed to developing training strategies in order to combat the negative effects associated with anxiety (Beliock & Carr, 2001; Wulf et al., 2001), with Oudejans and collegues (e.g., Oudejans, 2008; Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010) recently examining the introduction of anxiety within the training environment as an alternative training strategy.

In all of Oudejans experiments, results revealed that training with anxiety protected performance against the negative effects typically associated with the presence of anxiety in subsequent conditions. In relation to introducing anxiety within the training environment, it is important to acknowledge literature within the motor control domain and the framework of specificity (see below). The framework of specificity explains why retention and transfer performance tend to be better when the practice and test contexts are similar relative to (a) the sensory/perceptual information available, (b) the environmental context in which the skill is performed, and (c) the emotion experienced during performance.

Where literature has primarily focused on manipulation of sensory information to investigate specificity of practice, this thesis investigated specificity of practice within the construct of anxiety in all 3 empirical chapters. In addition, during chapters 3 and 4 movement parameters were investigated with the aim being to further understand specificity in relation to the utilisation of offline and online control processes involved in the planning and execution of movement. Finally, since previous literature has primarily focused on movement outcome and not movement production when measuring performance (nor has any work to date examined the effects of specificity or/and anxiety on proprioception), chapter 4 aimed to fill this research void. That is, chapter 4 examined additional measures to precisely quantify the effects of specificity within the construct of anxiety in relation to offline and online control within both vision and no vision groups.

5.2. Specificity within the Construct of Anxiety

Within the specificity framework there are three major theories; the first concept proposes that learning is best when environments most closely approximate the movements of the skill and the environment conditions of the skill in which the skill is performed. This formulates Specificity of Learning (SOL; Henry, 1968). Here it is specified that performance in one skill does not predict performance in another related skill (i.e., learning from one skill to another related skill is not transferrable). This is because the transfer from a practiced movement to another is very specific. The second concept is the Specificity of Practice Hypothesis (SPH; Proteau, 1992) which states, practice is specific to the source of afferent information available during acquisition, and that the specificity effect enhances as practice increases. SPH assumes that, in order to execute successful performance, performers develop motor control strategies specific to the afferent information available during acquisition. Therefore, if a source of afferent information that was available during practice changes (e.g., removal or addition), the motor control strategies that were developed in acquisition are no longer suited to the source of afferent information in transition, resulting in a decrease in performance.

Similar to SPH, Gilligan and Bower's (1983) network theory of affect, relates the acquisition stage and the transfer stage by predicting that learning is enhanced when there is high congruity between a learner's mood state during acquisition and subsequent recall. This is because emotions can be regarded as units within a semantic network that connects related events, ideas, and muscular patterns. Therefore, when mood matches that of acquisition, associations of connect events, ideas, and muscular patters are activated simultaneously. This creates the third concept Specificity of Mood (SOM; Gilligan & Bower, 1983). Although all three notions of specificity have received substantial support (Adams, Goetz, and Marshal, 1972; Alexander & Guenther, 1986; Bower, 1981; Bower, Monterio, & Gilligan 1978; Khan et al.,1998; Mackrous & Proteau, 2007; Natale & Hantas, 1982; Proteau, 1992, 1998, 2001; Proteau & Cournoyer, 1990; Proteau, Marteniuk, Girouard, & Dugas, 1987; Schare, Lisman, & Spear, 1984; Snyder & White, 1982; Teasdale & Fogarty, 1979; Teasdale & Taylor, 1981; Teasdale, Taylor, & Fogarty, 1980; Tremblay & Proteau, 1998), very few researchers have sought to investigate the principles of specificity within the construct of anxiety. In perspective to the assumptions concerning specificity, it is plausible that if anxiety is experienced in transfer then anxiety should also be incorporated within training; this will enhance recall and more importantly, protect against performance decrements typically associated with anxiety.

This thesis tested the principles of SPH (Proteau, 1992) and SOM (Gilligan & Bower, 1983) in association with anxiety and performance where significant support for both were found. That is, practicing with anxiety conforms to specificity effects where the strategy that is deemed most useful for success under the presence of anxiety is to enhance planning. This strategy appears to be due to anxiety disrupting the automatic processes associated with the use of online control.

5.3. Support for the Specificity Framework

In all chapters results revealed that when participants learnt with anxiety and were then transferred to subsequent anxiety conditions, participants were able to maintain or even improve performance therefore, providing evidence that learning with anxiety does in fact eliminate choking. These results provide support for both mood and condition-congruent learning theories. That is, when there are congruent conditions between learning and transfer, the transfer condition activates the emotions associated with this mood state that was also present during learning. Which in turn results in the activation and subsequent recall of the muscular patterns required during transfer. As such, those participants who created a network during acquisition between the emotions of anxiety and the movements of the to-be-learned skill (i.e., those who experienced anxiety while practicing), were better able to recall the required action during the subsequent anxiety transfer test. Further support for the mood congruent learning effects can be found from the results of the control (low anxiety) transfer phase. Here, participants who had received all practice under anxiety significantly increased climbing times in experiment 2, increased reaction times in experiment 3, or altered offline control in experiment 4, from that of acquisition to the non-anxiety transfer tests. Thus, when the transfer test resulted in a change in the conditions under which the skill had been learned (i.e., the absence of anxiety), a decrement in performance was observed.

Henry (1968) proposed that the best learning experiences are those that most closely approximate the movements of the target skill and the environmental conditions of the target content. As such, a change in the conditions under which the skill had been learnt results in these movement plans no longer being appropriate for successful performance. This may explain a common theme in all experiments in the current investigation concerning a decrement in performance during transfer to an anxious condition within the control groups, and for the groups transferring to control condition from anxious conditions. The movements developed by the participants in these group were likely adapted to the conditions experienced during learning (i.e., the absence of anxiety or the addition of anxiety) and thus, a change in the conditions experienced between learning and transfer resulted in the movement no longer being effective for accurate performance. Findings support the fundamental principles of the specificity framework and give evidence of specificity within the construct of anxiety.

5.4. Timing and Amount of Exposure to Anxiety

The assumption regarding the exposure effect to specificity assumes that the specificity relationship increases with an increase of practice (i.e., the more exposure you experience under a particular learning condition the greater effect specificity will have on performance; Proteau, 1992). From the results of chapter 2 and results from the anxiety-control group only in chapter 3, the current investigation can support the exposure effect when one considers the analyses of the early and late transfer phases. Specifically, we compared the change in performance of the control-anxiety group in chapter 2, at the midpoint of acquisition (i.e., the last block of control conditions to the introduction of anxiety) to the change in performance of the control group between the end of acquisition and the anxiety transfer test. Since, the change from control conditions to anxiety conditions occurred at the midpoint of practice (early transfer) in the control-anxiety group and at the end of practice (late transfer) for the control group, greater performance decrements in late transfer compared to the early transfer would demonstrate the exposure effect in SPH. The results of the analyses revealed that the decrement in performance were greater in late transfer for all 3 experiments (e.g., golf-putting, climbing and pattern sequence). These findings offer support for the specificity exposure effects reported in the previous motor control literature (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau, Marteniuk, Girouard, & Dugas, 1987; Tremblay & Proteau, 1998, 2001) and thus, lend further support for considering SPH when attempting to explain the choking phenomenon.

With regards to the control-anxiety group in chapter 3, where performance decrement were greater in early transfer, it is proposed that the results were due to method protocols from an added information diagram. As the added information diagram (detailing the movement patterns of each task) that was presented in the first block of acquisition trials (e.g., trials 1-27) was removed before the start of the early transfer phase (i.e., trials 28-45). Therefore, possibly creating a higher anxiety condition in early transfer than later transfer manipulations i.e., the removal of the visual aid designed to aid understanding of the experimental tasks between block 1 and early transfer acted as another increase to anxiety in addition to those that were specific to the anxiety manipulation protocols. Results from the anxiety data for the control-anxiety group did in fact reveal that anxiety levels were greater in early (10.2) compared to late transfer (9.2). However, this difference was not significant and thus represents only a trend in the data. Whilst speculative, this trend may have led to the greater decrement in planning performance in the early compared to late transfer phase of the control-anxiety group. It is worth noting that within SOM, it is assumed that the more intense the emotion the stronger the activation of recall will be in subsequent congruent emotion environments. Therefore, the intense relationship could relate to none congruent emotions (e.g., control to anxiety), consequently leading to larger negative effects and give reason to the results found. This lends itself to further investigation in opposing emotions with diverse levels of intensity in order to fully understand the intensity emotional relationship.

The current thesis aimed to extend principles of SPH by investigating the effects of introducing anxiety at different stages in the learning process. Findings in chapter 2 revealed that, those participants in the anxiety-control group (i.e., those who practiced with anxiety in the first half of acquisition and practiced in control conditions in the second half of acquisition), significantly increased performance following the switch in acquisition conditions, whereas those in the control-anxiety group (i.e., those who practiced in control conditions in the first half of acquisition and practiced with anxiety in the second half of acquisition), decreased performance. Furthermore, the performance (for all dependent variables) in both the anxiety and low anxiety transfer tests in the climbing study were greater in the control-anxiety group compared to anxiety-control group. These findings suggest that training with anxiety from the start of learning may actually be detrimental to skill learning. It is likely that the presence of anxiety at this cognitive stage of learning increases the task demands to a level that reduces the efficiency of the learner, by negatively influencing the updating part of the working memory system (Eysenck et al., 2007). Thus, the effectiveness of the performer's learning strategies are negatively impacted. However, this notion is task dependent, since the performance differences between the anxiety-control and control-anxiety groups seen at the mid-point of acquisition were only present at transfer in the more complex climbing task. As such, introducing anxiety from the beginning of acquisition disrupts the learning process to such a degree that it reduces the benefits of training with anxiety from the start of learning, only in the more complex task. Consequently, learning was at a much slower rate or none existent in the first half of acquisition compared to the second half of acquisition in the more complex task. Therefore, the skill itself may have been developed under controlled conditions instead of anxiety conditions hence, it would be expected when transfer to anxiety a decrease in performance would be experienced as the learning and transfer conditions are non-congruent. Additionally, with regards to the exposure effect, only 50 acquisition trials were therefore experienced in learning, which would account for relatively low exposure. Thus, the specificity effect when transferred back to control conditions would also be low, as specificity is thought to increase with an increase in exposure to acquisition conditions. Since this group was only exposed to the 'learning' condition (e.g., control condition) for 50 trials, it is not surprising that the effects of specificity were lower than other groups who experienced 100 trials in acquisition in the same condition, further supporting the principles of SPH.

In keeping with the exposure effects, it is also important to note that in chapter 2 and 3 there were no benefits in being exposed to anxiety throughout acquisition when transferring to further anxiety induced conditions. This finding is represented when comparing performance at the anxiety transfer stages between the anxiety throughout groups, the groups who experience anxiety for half the acquisition trials in the golf-putting task, and the control–anxiety group in the climbing task. Results revealed that performance at transfer was not significantly different from each other and hence there were no benefit of inducing anxiety throughout all trials in acquisition. Although what is not clear from this investigation is the exact quantity of exposure to anxiety that would benefit from specificity effects and crucially protect against choking. Further research should aim to manipulate the exposure to anxiety within the learning stages in order to maximise the anxiety-specificity relationship in order to provide training protocols for both athletes and coaches.

5.5. Specificity of Movement Parameters

Participants develop a movement plan to optimize the sensory information present during acquisition, and this movement plan is specific to the information available during practice (Elliott, Chua, Pollock, & Lyons, 1995; Khan & Franks, 2000; Khan, Franks & Goodman, 1998; Mackrous & Proteau, 2007). That is, when participants practice in specific conditions (e.g., anxiety) movement plans are developed specific to the sensory information available during that condition (e.g., anxiety). Thus, when participants are transferred to the same condition (e.g., anxiety) movement plans developed during acquisition are applicable to the transfer conditions. To extend the novel anxiety and specificity findings of the first experimental chapter, chapters 3 and 4 sought to examine *what* aspects of movement parameters involved in motor control develop specificity. The objective of the experiments were to examine not only the planning of movements (i.e., offline control) seen by reaction times in the pattern movement task (chapter 3) and early trajectory in the directional aiming task (chapter 4), but also the adjustment to movement parameters during execution (i.e., online control) seen by pause times and movement times in the pattern movement task (chapter 3) and late trajectory adjustments in the directional aiming task (chapter 4).

To date, there have been two distinctive investigations that have sought to examine the effects of anxiety on movement parameters. However, the findings from these two investigations result in opposing conclusions. First, Coombes et al. (2009) investigated the effects of anxiety on motor processes, but only motor planning. Researchers utilised a target force contraction task (e.g., a pinch action with the index and thumb digits of the right hand without concurrent visual feedback) which was adapted to measure planning efficiency (reaction time and rate of force change) and performance efficiency (RMSE of actual production) in both high and low anxious individuals. Results revealed that movement planning was only compromised by anxiety in the more difficult task (reproducing 10% of maximal voluntary force production) i.e., the task requiring greater working memory. Coombes et al. (2009) applied ACT (Eysneck et al., 2007) to interpret their findings by suggesting that the results were due to reduced inhibition in the high anxiety group therefore, leading to a decrease in the goal-driven system and specifically a reduction in the planning efficiency. However, their research design only allowed anxiety effects on movement planning efficiency to be investigated and therefore cannot specify that anxiety does not affect movement execution. The second investigation by Lawrence et al. (2012b) precisely sought to measure the effects of anxiety on both movement planning (i.e., offline) and movement control (i.e., online). They examined the relationship of afferent information processing with a directional aiming task (experiment 1) or an amplitude task (experiment 2). Participants practiced the experiments under controlled conditions before being transferred to anxiety conditions, where differences were observed. In both experiments, results revealed that anxiety negatively impacted on performance. Furthermore, the use of afferent information to adjust movement trajectories online were disrupted when movements were performed with anxiety, whereas there were no differences in the offline processing of afferent information between the control condition and anxiety condition. Lawrence et al. (2012b) further suggest that it is the automatic process involved in the use of information to control and adjust movement during execution that is negatively impacted under conditions of anxiety, rather than the more conscious processes involved in the use of information for offline purposes. The results were related to the principles of CPH (Masters, 1992), as anxiety led to outcome performance decrements by reducing the effectiveness of using afferent information to correct movement planning errors during movement execution. Both the investigation by Coombes et al. (2009) and Lawrence et al. (2012b) found alterations in the breakdown of movement parameters that decreased overall performance. The same cannot be said for results in chapter 3 (the pattern movement task) in the current thesis (as no outcome measure was examined) and chapter 4 (the directional aiming task), where results revealed consistent overall performance between acquisition and transfer.

Performance in chapters 3 and 4 were broken down into micro measures and related to movement parameters. Movement initiation time and the characteristics in early trajectory are assumed to reflect the movement planning process related to offline control. Whereas, later portions of the movement trajectory, discontinues in the trajectory, movement times and pause times, are more often associated with movement execution processes related to online control (Henry & Rogers, 1960; Khan et al., 2002; Khan & Franks, 2002; Klapp et al., 1974). In order to investigate the process involved in offline and online control, chapter 3 measured reaction times (RT) which is consistently demonstrated of a strategy involving pre-programming (Coombes et al., 2009; Henry & Rogers, 1960; Klapp et al., 1974), and online control via movement times (MT's) and pause times (PT's) since these have been suggested to represent adjustments being made during movement execution (Khan et al., 2006). Chapter 4 analysed the variability in early limb trajectories and late limb trajectories. The rational here was that any differences in the form of variability profiles for offline processes (involved in the planning of a movement) would be expected to occur early in limb trajectories. Whereas, any differences occurring during the later stages of the trajectory would imply that compensatory adjustments occurred online during movement execution (Khan & Franks 2003; Khan et al., 2003a; Lawrence et al., 2012b). The findings in both chapters 3 and 4 when analysing data between acquisition and transfer revealed that RT in movement pattern task (chapter 3) and early limb trajectory in the directional aiming task (chapter 4), were both altered during transfer for all groups experiencing a change in conditions (e.g., with the addition or removal of anxiety). These results indicate that participants are altering offline process involved with movement planning when a change in condition occurs. Thus, it could be that participants develop a movement plan to optimize the sensory information present during acquisition and this plan is specific to the information that is available during practice (e.g. learning in anxiety conditions or learning in control conditions likely created movement plans during acquisition with the emotions specific to the learning condition). Consequently when information present during acquisition was removed or added (e.g., anxiety), the movement plan that was once developed was no longer adequate, therefore alterations in performance were experienced (i.e., increase in RT in chapter 3 and an increase or decrease in MT early in limb trajectory in chapter 4). These finding are consistent with evidence from manual aiming studies in which performance decrements have been observed following both the withdrawal (Khan et al., 1998; Proteau et al., 1987) and the addition of visual feedback (Proteau et al., 1992). However, the alterations observed in chapter 4 did not lead to an overall performance decrement as seen by end point error. Furthermore, chapter 3 was unable to identify if the alterations within RTs were detrimental to overall performance as no overall performance measure was taken. Nonetheless this alteration found within these experiments support SPH.

The consistent discovery within chapters 3 and 4 is the finding of alterations occurring during offline process when being transferred to an incongruent condition from that of acquisition. The offline process is characterised as an effortful, none automatic and conscious process involved in a limited capacity working memory system (Eysenck et al., 2007), where anxiety has been shown to impair the efficiency of the central executive by consuming resources in the processing and storage of the working memory system (Baddeley, 1986). Therefore, it would be expected for those groups who practice under control and transfer to anxiety conditions to experience a decrease in performance unless an increase in invested effort occurred, lending itself to the principles of ACT (Eysenck et al., 2007). According to ACT, impairment within processing efficiency would not necessarily lead to decrements in performance, provided that anxious individuals respond to processing inefficiency by using compensatory strategies such as enhanced effort and additional use of processing resources. From the analysis of the effort data, the experimental chapters can confirm that effort scores were consistent throughout the experiments and thus any performance results were not dependant on effort. Therefore, the alterations observed within the offline process may not be due to principles of ACT due to overall performance outcome results.

An important issue regarding movement tasks is the extent to which accuracy is determined offline by planning processes prior to movement initiation, verses online via adaptations to the limb trajectory during movement execution. Chapter 4 precisely set out to identify any specificity effects within the two processes as a result of exposure too, and training with anxiety but also whether any effects of specificity differ, depending on the afferent information available to perform planning and corrective processes (e.g., vision and /or proprioceptive feedback). In line with previous research (Gordon, Ghilardi & Ghez, 1994; Khan et al., 2003a; Khan & Franks, 2003; Lawrence et al., 2012; Messier & Kalaska, 1997; 1999) variability profiles showed that no vision (NV) groups increased linearly throughout movement on a planned process that is determined prior to movement execution. Whereas, the full vision (FV) groups increase linearly in movement variability up to 75% which demonstrates adjustments been made during movement execution. That is, NV groups rely on an offline process involved in movement planning in an attempt to minimise the need for discrete error correction, whilst the FV groups are open to more online processes involved with error detection in movement execution. The more prominent findings within chapter 4 comprised of the time spent on the different portion of the movement trajectory and the choice of movement pathway that revealed different strategies to reach the target in control verse anxiety conditions. Support for specificity is evident in that when there is a change in mood kinematic measures were altered as a consequence. The alterations observed during offline processes are proposed to be deemed most useful for success under the presence of anxiety. Although online processes are deemed most useful to enable participants to utilise afferent information to make alterations to limb trajectory during movement execution in the control but not the anxious conditions.

5.6. Distraction and Self-focus Based Theories

Within ACT assumptions are made that anxiety impairs attentional control by increasing the influence of the stimulus-driven attentional system (e.g., threat related). The task in chapter 3 involved a three element sequence (e.g., target 1 to target 2 to target 3) with a choice of three sequences (e.g., sequence 1, 2 and 3), which would be expected to consume resources within the working memory, especially if programming all three elements of the sequence occurs before any movement initiation. It has been suggested that responses may not be programmed in their entirety and that it is possible that programming can persist during movement execution online (Glencross, 1980; Smiley-Oyen & Warringham, 1996). If this were the case an expected result would be an increase in PT's on targets indicating that participants could be planning the next element of the sequence. However, PT's revealed no interactions between acquisition to transfer, hence movement strategies between conditions for PT's were the same for all groups and further support that RT's involved pre-planning of the whole sequence. Thus, consuming greater resources within the working memory system. Anxiety also consumes resources within the working memory system, and one general assumption within ACT (Eysneck et al., 2007) is that anxiety impairs attentional control, whether the control is unable to inhibit distractors (e.g., inhibition function) or unable to shift between relevant stimuli (e.g., shifting function). With this assumption in mind, a consequence is that any adverse effects of worry (e.g., addition of anxiety) on task performance should be greater on tasks that exert large demands on the capacity of the working memory system. Therefore, decreasing processing efficiency (as seen by a decrease in RT in chapter 3 and alterations in early trajectory in chapter 4), supporting the principles of ACT (Eysneck et al., 2007). That is, anxiety impairs attentional control without causing decrements in performance (as seen by MT's in chapter 3 and end point accuracy in chapter 4). The assumption is due to the recruitment of additional resources (e.g., effort) which cannot be support from the results within the current thesis, as effort ratings remained constant throughout. Nonetheless, these findings are still an important factor to consider within decision-making tasks that rely on a fast effective response and provide further considerations to interpret the results.

A further consideration when considering the results is that of CPH which predicts that, an increase in state anxiety leads performers to direct their attention inward in an attempt to control their performed skill by using task relevant explicit knowledge. Explicit attention to a step-by-step skill process is thought to disrupt well-learned performance processes that normally run largely outside of conscious awareness (Beilock, Bertenthal, McCoy & Carr, 2004). The mechanism governed by explicit knowledge is that of 'dechunking' that breaks down movement into individual units, which then have to be both activated and run separately. This creates room for error and slows down movement which could account for the increase in PTs seen in chapter 3 and the increase in MTs in chapter 4 however, the alterations within PT's and MT's did not decrease overall performance. It can therefore, not be ruled out that these alterations within movement are made to maintain performance and protect against a decrease in performance.

In addition not all experiments within the current thesis exert large demands on the capacity of the working memory system. Chapter 4, the directional aiming task was simple in nature and held trivial threat related stimuli. Therefore, the experiment did not lend itself to exhausting extensive resources of the working memory. Nevertheless, all groups experience alterations involved in offline process (e.g., early trajectory) but maintained overall performance when conditions altered from acquisition to transfer (i.e., with the addition or removal of anxiety). Furthermore, effort remained constant throughout the task. As a result it is reasonable to suggest that these alterations could provide alternative explanation not due to inefficient processing but actually due to strategies to protect against a decrease in performance, hence why performance was maintained in transfer. Importantly, results from chapter 3 and 4 conclude that anxiety was not specifically causing a reduction in planning efficiency as suggested by Coombes et al. (2009), but rather that anxiety effects the error detection phase within movement execution (Lawrence et al., 2012) and to maintain performance participants enhance planning efficiency. This contradicts the assumption of ACT (Eysneck et al., 2007) and relates more to the principles of CPH when trying to explain the anxiety-performance relationship.

Through the findings in chapter 3 and 4 there were a common trend found, that offline control was altered when there was a change in conditions from acquisition to transfer. Not only this but these alterations were not negative to overall performance (i.e., no group's performance outcome decreased in transition when acquisition and transfer phases were incongruent). It is thought that during transfer (i.e., change in sensory information) participants altered RT in chapter 3 and early limb trajectory in chapter 4 to keep attentional focus to that of acquisition. For groups that have the use of full vision, the predominant useful source of information to execute successful performance is that of online control. Whereas, the opposite has been shown for participants with no vision, in that offline control is the predominate source of information (Gordon, Ghilardi, & Ghez, 1994; 1999; Khan et al., 2003; Lawrence et al., 2012b; Messier & Kalaska, 1997). Lawrence et al. (2012b) support findings that the processing of afferent information for online trajectory corrections are reduced as a result of anxiety, this could give evidence to the switching of attentional focus. It is rational to assume that attention can shift to other sensory cues, on the basis that shifts in attention significantly affect performance (Wulf & Prinz, 2001). ACT suggests that attention shifting slows down under anxiety conditions and/or that one cannot shift attention away from threat efficiently. This shifting is assumed to be maladaptive to performance, because ones ability to inhibit the shifting process (from source of threat to the goal of the task) is reduced under pressure. However, this mechanism has never been assumed to be adopted in an adaptive way as a coping mechanism for overall performance. For example, the full vision groups would predominately focus on online afferent information, but when anxiety is present attentional focus is switched to the afferent information most likely to achieve successful performance (i.e., offline). Therefore, the full vision group practicing with anxiety predominately focus on offline processes and the full vision practicing in control conditions predominately focus on online processes. Hence, when there is a switch is attentional focus (i.e., removal or addition of anxiety) performance strategies alter in order to combat the shift in attention. The alterations in offline processes observed in the current thesis have been linked to combating strategies occurring from a shift in attention as an adaptive strategic mechanism rather than maladaptive. That is, by implementing planning strategies as a tactic to combat the disruptive nature on the automatic process that anxiety appears to have associated with the use of online control. Consequently it is possible that results apply more to the principles of CPH (Masters, 1992). That is, the presence of anxiety results in explicit monitoring of task execution, which leads to a breakdown in the processes involved in online control because these processes are automatic or reflex in nature (Beiere & Proteau, 2011; Franklin & Wolpert 2008; Lawrence et al., 2012b; Proteau et al., 2009). This conscious processing effect on the online control system, results in a subsequent adjustment in the effortful and non-automatic parameter programming of movements (i.e., offline control).

5.7. Future Directions

The results from the current thesis are consistent with previous literature with regards to vision (Khan et al., 1998; Proteau, 1992), manipulation with knowledge of results (Adams et al., 1972), emotional transfers (Bower et al., 1978), sources of afferent information

(Tremblay & Proteau, 1998), and focus of attention (Coull, Tremblay, and Elliott, 2001). Whilst the present investigation demonstrated specificity effects and supports SPH (Proteau, 1992), all experiments adopted short delays between the completion of acquisition and the start of the transfer test (15 minutes in the golf-putting task, 1 hour in climbing task, 5 minutes in the pattern movement task and directional aiming task). Future research should investigate the anxiety specificity effect with greater time intervals between the completion of training and the start of transfer to see if the specificity effects reported are more permanent in nature. In addition to the time interval another possible avenue for future research could examine the exposure effects of specificity in relation to the ratio between anxiety and control within the learning phase. The anxiety and control manipulations in the current thesis were based on either a 100% or 50% frequency. Although in chapter 2 anxiety at the beginning of learning was of no benefit compared to anxiety being induced half way through acquisition, it is not clear what ratio within acquisition is required to achieve the most efficacious learning under both conditions (i.e., 20:80, 35:65 etc.), in order to maximise the specificity performance relationship. The intensity of moods (e.g., anxiety) should also be investigated within the exposure investigation. That is, does specificity intensify as anxiety heightens?

The findings from chapters 3 and 4 that predict offline control alterations are adopted as a combat mechanism. That is, movement planning is adopted as a mechanism to combat the effects of anxiety on online processes and thus maintain overall performance. Future research would serve to investigate and design interventions that aid movement planning, in order to provide a further theoretical and applied application within the specificity framework. This kind of research would supplement work from the current thesis and deliver practical examples by providing coaches and athletes with interventions in order to obtain an optimal training environment. Furthermore, the variability methods used in chapter 4 in the directional aiming task could be developed to investigate anxiety specificity effects on the strategy of online and offline control during a gross body skill. Chapter 2 in the climbing experiment was crudely attempted by investigating explored and ventured movements, which could both be explained by movement pathways and/or as a result of changes to the planning of movements. Thus, future research may wish to replicate the golf-putting action and/or climbing traverse adopting variability methods in order to investigate the specificity online/offline control relationship.

Finally, for future research investigating the anxiety performance relationship, SPH should also be considered as an alternative explanation within the sport psychology domain, but also within the motor control literature when attempting to provide training techniques and environments to obtain optimal performance. The present thesis experiments and research from the motor control domain tends to employ some variation on a pretest-posttest paradigm (i.e., pretest to transfer) that attributes any differences in the posttest (i.e., transfer) performance relative to the pretest as a result of the intervening practice session (i.e., acquisition). Often, two (or more) practiced variations of the goal movement, or different practice schedules (e.g., anxiety and control conditions) using the goal movement, are compared as to their benefits on subsequent performance (i.e., transfer) of the goal movement. For example, Goode and Magill (1986) trained novices three badminton serves using one of three different training schedules, blocked, serial, or random practice. After the training session, ability to serve and the usefulness of the different training schedules were evaluated in a retention test (-24 hours after the final training session). This retention test was comprised of the three serves that had been practiced being performed randomly. The group that practiced the serves under a random schedule performed the best in the retention test and the blocked group performed the worst. Considering SPH it is difficult to attribute the retention-training schedule for best performance when the experimental paradigm used to evaluate the schedules worked in favor of those that had the random practice. This difficulty in the experimental paradigms used and the conclusions drawn from them need to be considered with knowledge of SPH. The important consideration is the goal of the training. That is, practice sessions/schedules must be created to allow not just the facilitation of the learning of the movement, but also the high similarity between the practice and goal situations.

In summary this thesis supports SPH as a theoretical standpoint when considering the anxiety-performance relationship, and therefore highlights some practical implications that need further attention in order to provide athletes and coaches with strategies to obtain an optimal training environment. For this to be achieved attentions needs to be paid to the following areas within the specificity framework; greater time intervals between the completion of training and the start of transfer to see if the specificity effects reported are more permanent in nature; the exposure effects of specificity in relation to the ratio between anxiety and control within the learning phase i.e., what ratio within acquisition is required to achieve the most efficacious learning under both conditions (i.e., 20:80, 35:65 etc.); intensity of moods (e.g., anxiety) that is, does specificity intensify as anxiety heightens?; and finally investigate and design interventions that aid movement planning which has been deemed the most useful strategy when under anxiety conditions.

5.7. Conclusion

In conclusion, practicing with anxiety conforms to specificity effects and the strategy that is deemed most useful for success under anxiety conditions is to enhance movement planning. This strategy appears to be due to anxiety disrupting the automatic processes associated with the use of online control. SPH also offers an alternative explanation for choking. That is, performance decrements occur due to a change in the conditions under which the task is practiced, both when conditions change from control to anxiety and anxiety to control. Whilst the findings are primarily interpreted through SPH, alternative ACT and CPH explanations cannot always be ruled out. As such, the specificity principle should be considered in future research investigating the choking phenomenon in conjunction with, CPH (Masters, 1992) and ACT (Eysneck et al., 2007). In addition, results revealed that training under anxiety should be adopted as a process for eliminating choking. When introducing anxiety into the learning environment it is important to consider the task complexity. The significantly greater performance of the control-anxiety group compared to the anxiety-control group in both the anxiety and low anxiety transfer tests of the climbing task, indicate that for more complex skills, one should avoid introducing anxiety into training until later in the learning process. These findings highlight that introducing anxiety from the start of acquisition disrupts the learning strategies and results in less than optimum performance both in subsequent anxious and non-anxious situations. More specifically, it is believed that sensory information plays a part in which control of movement (e.g., online or offline) becomes specific during practice. Since the thesis was investigating specificity within the construct of anxiety this in itself results in a change of sensory information and a manipulation of performer's focus of attention. Coull, Tremblay, and Elliott (2001), who manipulated the focus of attention found support for SPH; when there was a change in condition (e.g., withdrawal of auditory or withdrawal of vision) a decrement in performance was experienced however, with a bigger decrement in performance experienced from the group who received no instructions within the acquisition stage. This supports that focus of attention on a particular sensory mode (i.e., auditory or visual) can influence the effects of vision withdrawal on motor performance. Hence, if participants can develop a strategy to focus attention on a particular control of movement (online or offline) performance decrements may not occur as observed in the directional aiming task. With regards to vision and no vision, it is proposed that offline control becomes specific for no vision groups and online control becomes specific for full vision groups. Furthermore, online control is interrupted through anxiety but if focus of attention can be maintained through an adopted strategy when sensory information is altered during transfer, performance can also be maintained. It is therefore important when using a specificity framework to take into consideration the sources of afferent information available to the performer when it matters, in order to match the information during acquisition.

The current research therefore provides further support for the SPH (Proteau, 1992), supporting both an alternative explanation for choking and an alternative training strategy by enhancing planning mechanisms. In summary, specificity of practice raises important theoretical and practical issues within both the motor control domain and the sport psychology domain that is, experimental paradigms used and the conclusions drawn from them need to be considered with knowledge of the SPH in order to provide athletes and coaches with the best training protocols to achieve best performance.

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