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State anxiety, conscious processing and motor performance.

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STATE ANXIETY, CONSCIOUS PROCESSING
AND MOTOR PERFORMANCE

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Richard Hugh Mullen

Thesis submitted to the University of Wales in fulfilment of the requirements for the degree of Doctor of Philosophy at the School of Sport, Health, and Physical Education Sciences, University of Wales, Bangor.

September, 2000



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Summary

This thesis examined the conscious processing hypothesis as a potential explanation for the way in which anxiety affects motor performance. The thesis is written as a series of research papers (studies). The five papers are preceded by a general introduction and followed by a general discussion. The first study replicated and extended previous research in the area of conscious processing. Participants acquired the skill of golf putting explicitly and implicitly across 400 trials. During a high anxiety transfer test, the performance of participants who learned explicitly was less robust than that of participants who learned implicitly, supporting the conscious processing hypothesis. Study 2 tested the conscious processing hypothesis using a performance rather than learning paradigm to control for possible desensitisation effects identified as a possible alternative explanation for the results of study 1. Results supported the conscious processing hypothesis, but an alternative attentional explanation was identified. Study 3 examined the conscious processing hypothesis while controlling for both desensitisation and attentional effects. Kinematic measures were also adopted to examine the golf putting task *in vivo*. Performance results partially supported the conscious processing hypothesis. Study 4 replicated and extended the design adopted in study 3. Study 4 also examined processing efficiency theory as a plausible alternative to the conscious processing hypothesis. Kinematic and cardiovascular measures were incorporated into the design. Performance scores suggested a processing efficiency interpretation. However, conscious processing effects could not be totally discounted. The fifth study examined the suggestion that the use of process goals by skilled but anxious performers might actively encourage lapses into conscious processing. Increases in state anxiety did not produce performance decrements. A lack of training in the use of goals was identified as an explanation for the absence of performance impairment. Implications for future research and applied practice are derived from the five studies.

Chapter 1

Introduction

One of the key challenges faced by sport psychology is to ensure that the interventions provided for athletes have a sound theoretical underpinning. In this respect, the success of applied consultancy work depends upon the development and availability of a sound knowledge base founded upon theory and research (Jones, 1995). A problem frequently encountered by the consulting sport psychologist is the inability of some performers to deal with the stress and anxiety that characterise both preparation and performance at the highest levels of sport (Orlick & Partington, 1988). As a result, the sport psychology literature is replete with articles, books, manuals, and tapes devoted to helping athletes deal with anxiety.

Sport psychologists have also generated a large amount of empirical research addressing a variety of aspects associated with anxiety and sports performance. These have included issues surrounding the measurement of anxiety in sport (Burton, 1998) and various theories, hypotheses and models of anxiety and sports performance. The theoretical relationship between anxiety and performance has produced a large body of research adopting a variety of approaches including drive theory (Hull, 1943; Spence & Spence, 1966), the inverted-U hypothesis (Yerkes & Dodson, 1908), individual zones of optimal functioning (Hanin, 1997), multidimensional anxiety theory (Martens, Vealey, & Burton, 1990) and catastrophe models (Hardy & Fazey, 1987). A comprehensive review is beyond the scope of this chapter and the reader is directed to Hardy, Jones and Gould (1996) and Jones (1995). Recently, researchers have also begun to examine performers' interpretations of their anxiety states. Specifically, researchers have begun to acknowledge that performers may interpret their anxiety in different ways (Jones, Swain, & Hardy, 1993; Mahoney & Avenier, 1977) and that cognitive anxiety may not always be detrimental to performance (Hardy & Fazey, 1987; Hardy & Parfitt, 1991). Hanin (2000) has applauded this move away from a narrow, negatively oriented focus on anxiety-performance relationships.

Despite an abundance of theoretical advances, researchers have still been unable to identify the exact mechanisms via which anxiety actually affects performance.

Theoretical developments such as catastrophe models (Hardy, 1990; Hardy, 1996b; Hardy & Fazey, 1987) may enable researchers to better predict the exact combination of circumstances that result in a negative relationship between anxiety and performance. However, models that explain the processes that mediate the effects of anxiety upon motor skills are comparatively under-researched.

The main purpose of this introduction is to briefly review some of the theories that purport to explain how anxiety affects performance. However, before doing so, the next section attempts to address some conceptual problems that have clouded the use of terms such as stress, anxiety, arousal, and activation in stress and anxiety research. In so doing, this section draws heavily on the work of Hardy, Jones and Gould (1996).

Definition of key terms

Stress

Stress can be regarded as a state in which some demand is placed upon an individual who is then required to react in some way in order to be able to cope with the situation (Jones, 1990). As a result, depending upon the individual's perception of their ability to cope with the demands of the stressor in question, stress may or may not impose a "strain" upon the individual (Jick & Payne, 1980; Lazarus, 1966). Thus, it is the individual's perception or cognitive appraisal of the situation that is the crucial factor in the stress process. Where an individual perceives that they do not possess the resources or capabilities to cope with the perceived demand placed upon them by a stressor, it is likely that feelings of anxiety will ensue (Jones & Hardy, 1989).

Anxiety

It is generally accepted that anxiety is an unpleasant emotional response. Although there are different perspectives on just how emotions are generated (e.g. Lazarus, 1982; Zajonc, 1984), the dominant view is that, even in their most implicit form, emotions are the result of cognitive processing (Eysenck, 1992; Lazarus, 1991). Thus, to fully understand anxiety as an emotional response it would appear necessary to consider the cognitive processes that trigger such a response. It is important to distinguish between anxiety as a transitory emotional state and anxiety as an individual difference personality variable (Smith, Smoll, & Wiechman, 1998).

Spielberger (1966) differentiated between the momentary level of anxiety experienced by individuals (state anxiety) and the relatively stable personality disposition (trait anxiety). Individuals high in trait anxiety are more prone to view a variety of situations as threatening and respond with high levels of state anxiety. The interactional perspective allowed anxiety researchers to move away from the more traditional trait paradigm prominent during the 1950s and early 1960s (Sarason, Davidson, Lighthall, Waite, & Ruebush, 1960; Taylor, 1953). Researchers in educational psychology also identified two subcomponents of the anxiety response, a cognitive component, termed worry, and a physiological component, termed emotionality (Liebert & Morris, 1967). Sport psychologists responded to these developments and constructed measurement instruments to assess the multidimensional nature of the state anxiety response (Martens, Burton, Vealey, Bump, & Smith, 1990). In the development of the Competitive State Anxiety Inventory-2 (CSAI-2), Martens, Burton, et al. adopted the definitions of worry or cognitive anxiety, and emotionality or somatic anxiety, used by Morris, Davis and Hutchings (1981). According to Morris et al., cognitive anxiety refers to “negative expectations and cognitive concerns about oneself, the situation at hand, and potential consequences” (p. 541). Morris et al. defined somatic anxiety as “one’s perception of the physiological-affective elements of the anxiety experience, that is, indications of autonomic arousal and unpleasant feeling states such as nervousness and tension” (p. 541). It is also generally accepted that in the context of sport, cognitive anxiety is manifested by negative expectations of success and the resultant negative self-evaluation that may trigger several types of negative mental consequences. According to Burton (1998), these include (a) negative thoughts such as worry, (b) images of failure and other disturbing evaluation-related imagery, (c) distraction preventing appropriate attentional focus, and (d) control problems ranging from feeling totally overwhelmed to slight feelings of loss of control (p. 131). According to Burton, somatic anxiety reflects perceptions about the physiological and affective elements of the anxiety response emanating from the autonomic arousal process. This definition contrasts with that offered by Martens, Burton, et al., in which somatic anxiety refers to the physiological symptoms themselves. Burton’s definition would appear to be the more logical of the two as perceptions of physiological symptoms afford the opportunity of measurement using self-report instruments, such as the CSAI-2.

Arousal and activation

Most sport psychology textbooks refer to arousal or activation as a single unitary construct that incorporates physiological and psychological aspects of behaviour. Furthermore, adding to the conceptual ambiguity, the terms arousal and activation are often used synonymously. Duffy (1962) defined arousal as “the extent of release of potential energy, stored in the tissues of the organism, as this is shown in activity or response” (p. 179). Unidimensional conceptualisations of arousal and activation responses were called into question by Lacey (1967), who presented evidence for multidimensional responses. As a result, a number of researchers suggested that it is necessary to view arousal and activation in more detail by examining the different systems involved in performance (Hockey & Hamilton, 1983; Näätänen, 1973; Neiss, 1988). Adopting a multidimensional approach to the study of arousal and activation, Pribram and McGuiness (1975) identified three distinct but interacting neurophysiological systems involved in the control of attention. The three energetical components of Pribram and McGuiness’ model were arousal, defined as the organism’s immediate response to some new input; activation, defined as the organism’s readiness to respond; and effort, responsible for co-ordinating the arousal and activation resource pools. Using Pribram and McGuiness’ model, Hardy, Jones, et al. (1996) have advocated a clearer distinction between arousal and activation in the sport psychology literature. Hardy, Jones, et al. distinguished between activation, referring to the cognitive and physiological activity geared towards the preparation of a planned response to an anticipated situation, and arousal, referring to the cognitive and physiological activity that takes place in response to some new input. For example, picture a golfer preparing to attempt a potentially match-winning putt. If the golfer is highly skilled, they probably possess the appropriate activation state for performing the putt successfully. If, however, a spectator suddenly shouts out at the very moment the golfer starts the backswing of the putt, the golfer may experience an involuntary startle (arousal) response, leading to a disruption of the practised activation pattern. The different activation pattern may cause the golfer to miss the putt. The various distinctions made above are important in terms of theory, research design and applied implications.

Potential Explanations of how Anxiety Affects Performance

Traditional approaches to explaining the anxiety-performance relationship have relied upon attentional mechanisms (Easterbrook, 1959; Wine, 1980). These early theories will be addressed briefly before examining contemporary work based upon more sophisticated attentional explanations (Eysenck & Calvo, 1992; Humphreys & Revelle, 1984) and alternative explanations for anxiety effects, grounded in self-focus mechanisms (Masters, 1992b; Wegner, 1994).

Easterbrook's Cue Utilisation Theory

Easterbrook (1959) reviewed a large body of literature concerning the effects of emotional arousal on perceptual selectivity. Easterbrook concluded that increases in emotional arousal consistently narrowed the range of cue utilisation in task performance. Easterbrook used a very broad definition of arousal, describing it as,

The innate response to a state of biological deprivation or noxious stimulation, which underlies or occurs simultaneously with overt action and affects its strength and course. This emotional arousal is greater in neurotic than in normal subjects, greater than usual in subjects under stress or threat or in frustration, and in general greater in animals that have been motivated by any of the usual deprivations, noxious stimulations or other incentives than it is in unmotivated or resting animals of the same species. (p. 184)

Anxiety appears to be one aspect of this emotional arousal dimension. In the context of the competitive anxiety response, the emotional arousal described above presumably refers to the physiological arousal that underpins the somatic anxiety response. According to Eysenck (1982; 1992), Easterbrook argued that high emotionality, arousal and anxiety all produced comparable effects upon cue utilisation. Easterbrook noted that individuals detect visual information from a variety of sources, some of which are relevant, and others that are not. In sports, for example, the relative positioning of opponents is a relevant cue, while the movement of the crowd would be irrelevant to task performance. Easterbrook claimed that the range of cues used by individuals reduces as anxiety, and therefore emotional arousal, increases. At low levels of anxiety a wide range of cues are detected, including irrelevant cues, and this lack of selectivity results in relatively poor performance (Figure 1, below). At moderate levels of arousal or anxiety, the range of

cues available to the performers is reduced and performance is subsequently maximised. At higher levels of anxiety or arousal, continued narrowing of the attentional field leads to the exclusion of task-relevant cues and performance deteriorates.

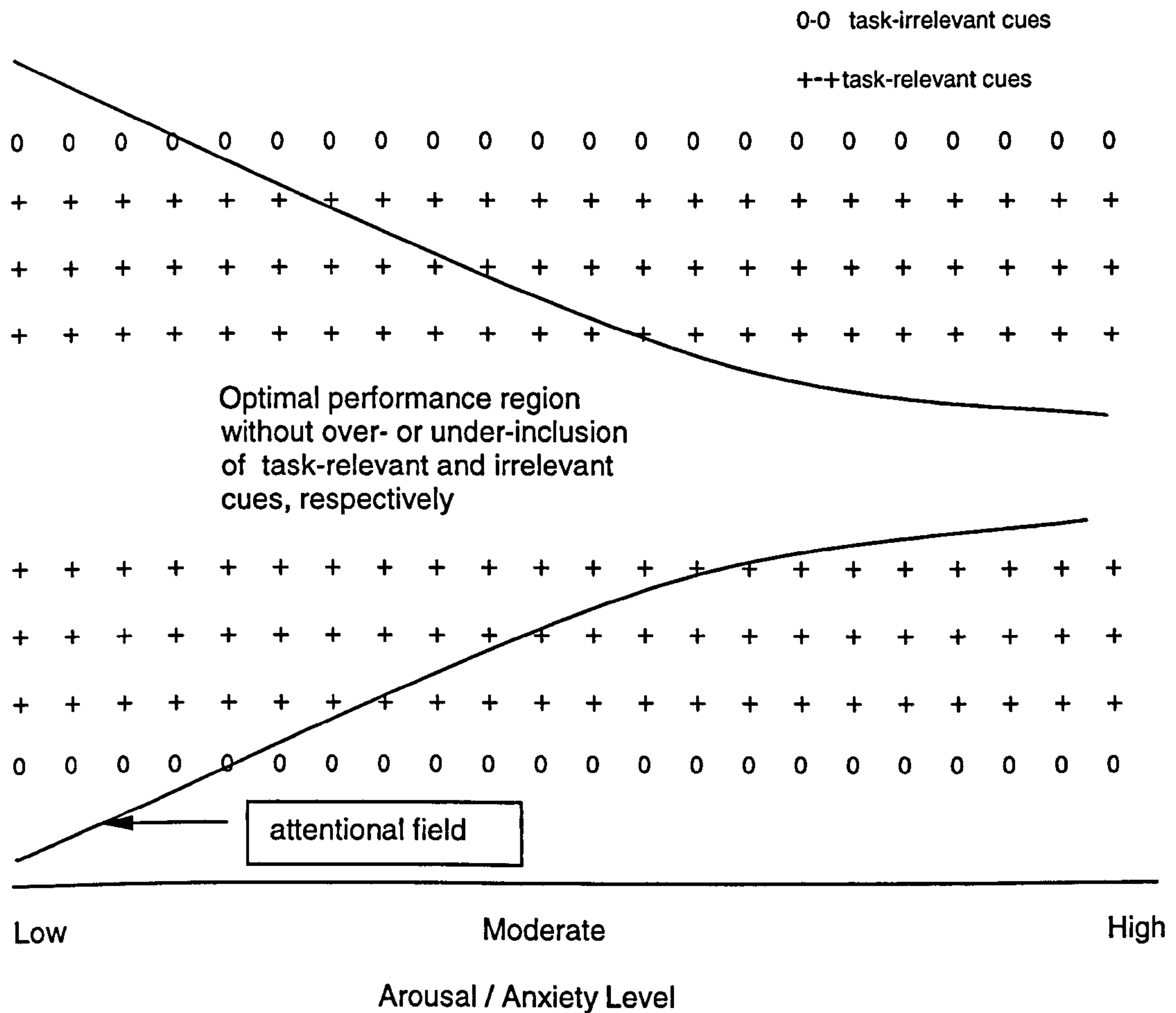


Figure 1. Peripheral narrowing as a potential explanation of the arousal/anxiety-relationship (Source: Abernethy, 1993, p. 134).

Despite the intuitive appeal of Easterbrook's theory, Eysenck (1982) suggested that tests of the theory provide less than convincing support, claiming that the dual task paradigm commonly employed to test the theory was biased. As Eysenck pointed out, "There are nine possible combinations of main-task and subsidiary task performance, only three of which are clearly incompatible with Easterbrook's hypothesis." (p. 50). Furthermore, Easterbrook claimed that the attentional

narrowing associated with high anxiety was a passive and automatic process. Eysenck (1992) questioned the automaticity of this response, suggesting that any narrowing may be an active-coping response. In their attempts to cope, anxious individuals may strategically attempt to ensure task success by restricting their limited processing resources to a small proportion of the information available. In a similar vein, Hockey and Hamilton (1983) supported Easterbrook's view that high arousal produces a "monotonic increase in the selectivity of attention" (p. 339). However, Hockey and Hamilton suggested that increases in selectivity are more likely to be associated with a bias in the intake of information from dominant or high priority sources.

In the context of anxiety, Eysenck (1982) highlighted two further questionable aspects of Easterbrook's hypothesis. Firstly, Eysenck noted that elevated anxiety results in a lack of ability to concentrate on the task at hand, rather than the intense concentration implied by cue utilisation theory. This is reflected in anxious individuals' tendency to appear to spend more time engaged in off-task glancing. Secondly, Eysenck questioned Easterbrook's implicit assumption that anxious individuals should be less distractible than non-anxious individuals. Eysenck (1992) reviewed a large body of literature supporting the notion that anxiety can lead to increased rather than decreased distractibility.

Despite these criticisms, Landers, Wang, and Courtet (1985) found partial support for attentional narrowing with rifle shooters. More recently, however, Janelle, Singer and Williams (1999) specifically addressed the selectivity – distractibility question using a dual-task motor racing simulation. Participants performed a central driving task under conditions of low and high anxiety, while responding to peripheral cues. Janelle et al. found evidence to support both attentional narrowing and distraction. Williams and Elliott (1999) found improvements in the performance of cognitively anxious participants engaged in a simulated karate task. Visual search data collected under high and low anxiety conditions indicated that anxious participants increased their search rate and the amount of time spent fixating on peripheral display areas. The data could be explained using either attentional narrowing or distractibility. It appears from the recent evidence that an increase in attentional selectivity is unable to provide a complete picture of how anxiety affects performance. As Hockey and Hamilton (1983) noted, however, researchers should not be misled into believing that

selectivity is the key to arousal / anxiety effects. Rather, attentional selectivity might be better considered as part of a more complex puzzle.

Easterbrook's theory has several practical implications. According to Eysenck (1992), Easterbrook claimed that arousal, anxiety and emotionality all produce comparable effects upon cue utilisation. This suggests that performers require strategies to enable them to deal with these effects, which cause "tunnel vision". However, as Hockey and Hamilton (1983) and Eysenck (1992) have suggested, the tunnel vision caused by responses to stressors may be a strategic response used by performers to focus upon the perceptual cues they perceive to be important. As such, coaches and sport psychologists might attempt to identify which cues performers perceive to be important. Hardy, Jones, et al. (1996) use the example of a soccer player who fails to mark opponents consistently "when 'psyched up' in 'big games' because he 'ball watches', i.e. focuses all his attention on the ball, instead of the players he is supposed to mark" (p. 120). Hardy, Jones, et al. suggest that the player might be re-educated by helping him to understand the spatial relationship between himself, the ball, and the opponents he is supposed to mark. Performers might also be taught quick relaxation strategies that can be used during performance to lower arousal levels. Hardy, Jones, et al. also suggest that performers might learn task-specific cues that help to maintain an appropriate focus of attention when they become highly aroused.

In summary, Easterbrook's cue utilisation theory predicts that an increase in emotional arousal impairs performance by narrowing the range of task-specific cue utilisation. Low levels of arousal result in reduced selectivity and a wide range of cues, including task-irrelevant cues, are detected, impairing performance. Moderate levels of arousal facilitate performance by limiting the range of cue utilisation to optimal levels, such that only task-relevant cues are detected. Further increases in arousal impair performance by further reducing the range of cues detected, such that some task-relevant cues remain undetected. Despite limitations with Easterbrook's theory (Eysenck, 1982, 1992), it does appear that attentional selectivity might have a role to play in explaining how arousal and anxiety affect performance.

Cognitive Interference Theory

Like Easterbrook (1959), Wine (1971; 1980) and Sarason (1984; 1988) also suggested that attentional processes mediate the effects of anxiety upon task

performance. Rather than emphasise a peripheral narrowing of attention, cognitive interference models of anxiety-related performance impairment focus upon the possibility that the critical restriction in information processing capacity occurs centrally within the cognitive system. Such accounts typically attribute this reduction in central cognitive capacity to the effects of task-irrelevant processing. According to cognitive interference theory, task irrelevant processing is hypothesised to consist of worry and self-preoccupation, which serve to divert attention away from task-relevant thoughts. For example, thoughts such as “I’m bound to fail, I’m not as good as the others”. Wine (1980) cites several further examples of ways in which high anxious individuals tend to be negatively self-preoccupied in comparison with low anxious individuals. High anxious individuals report a higher frequency of task-irrelevant thoughts, are more likely to self-attribute task failure, to set lower levels of aspiration, even when actual performance does not differ, and to have less confidence in perceptual judgements. This type of self-preoccupation is attributed to the construct of worry, rather than to emotionality. Kroll (1982) produced evidence that task-irrelevant thoughts were associated with competitive athletic situations. Such thoughts interfere with attention to current tasks, and it therefore follows that anxiety has larger adverse effects upon tasks requiring most attention.

Empirical research has generally supported the hypothesis that cognitive anxiety is strongly negatively related to performance in both academic (Deffenbacher, 1980; Morris et al., 1981) and sport (Burton, 1998) domains. Researchers have concluded that reducing cognitive anxiety can effectively enhance performance. Martens, Vealey, et al. (1990), Morris et al., and Wine (1980) proposed that cognitive anxiety can be reduced in several ways: (a) by creating positive expectations of success, (b) by eliminating distracting negative thoughts and self-rumination, and (c) by preventing excessive analysis and evaluation that inhibit flow. However, Burton (1990) has suggested that reducing cognitive anxiety may not be sufficient to improve performance. Burton suggested that it might also be necessary to reduce somatic anxiety in order for cognitive interventions to work effectively. More recent evidence presented by Hardy and Parfitt (1991) and Hardy, Parfitt, and Pates (1994) has also indicated that high levels of cognitive anxiety are not always detrimental to performance.

Eysenck (1992) has criticised Wine and Sarason’s theoretical approach in several ways. Firstly, according to Eysenck, cognitively anxious individuals do not always

suffer performance impairment in comparison with their low-anxious counterparts (Calvo, Alamo, & Ramos, 1990; Calvo & Ramos, 1989). Secondly, Eysenck contends that both Wine and Sarason have over-simplified their accounts of the interaction between task difficulty and anxiety. Specifically, Eysenck noted that “task difficulty appears to be equated with the amount of attentional resources required by a task. This has the undesirable consequence that transformational and storage processes are ignored” (p. 127).

In summary, cognitive interference theory proposes that performance impairment in anxious performers is caused by task-irrelevant processing hypothesised to consist of worry and self-preoccupation that diverts attention away from task-relevant cues. As with Easterbrook’s cue utilisation theory, however, the effects of distraction upon performance appear to provide only a partial account of the effects of anxiety upon performance.

Humphreys and Revelle’s Information Processing Model

Humphreys and Revelle (1984) proposed a theory that considered the effects of anxiety upon performance in information processing terms. The advantage of the model proposed by Humphreys and Revelle over cognitive interference theories is that tasks can be categorised in terms of sustained information transfer and short-term memory. Sustained information transfer (SIT) involves an individual processing a stimulus, associating a response to the stimulus, and executing a response. Furthermore, there is no attempt at retaining this information in memory. For example, a soccer goalkeeper making a reaction save. Short-term memory (STM) tasks are those tasks where information is maintained in an available state or retrieved when it has not been attended to for a while. For example, deciding where to deliver the next corner kick in a soccer match.

A further advantage of Humphreys and Revelle’s (1984) model over cue utilisation and cognitive interference theories is that performance, at the level of information processing, can be predicted by the combined effects of: selected personality dimensions (achievement motivation, trait anxiety, impulsivity); motivational states (approach motivation, avoidance motivation); and situational moderators (stressors). The relationship between these mechanisms and two further key systems, arousal and on-task effort is depicted in Figure 2 (below). Arousal was defined by Humphreys and Revelle as “that factor common to various indicants of

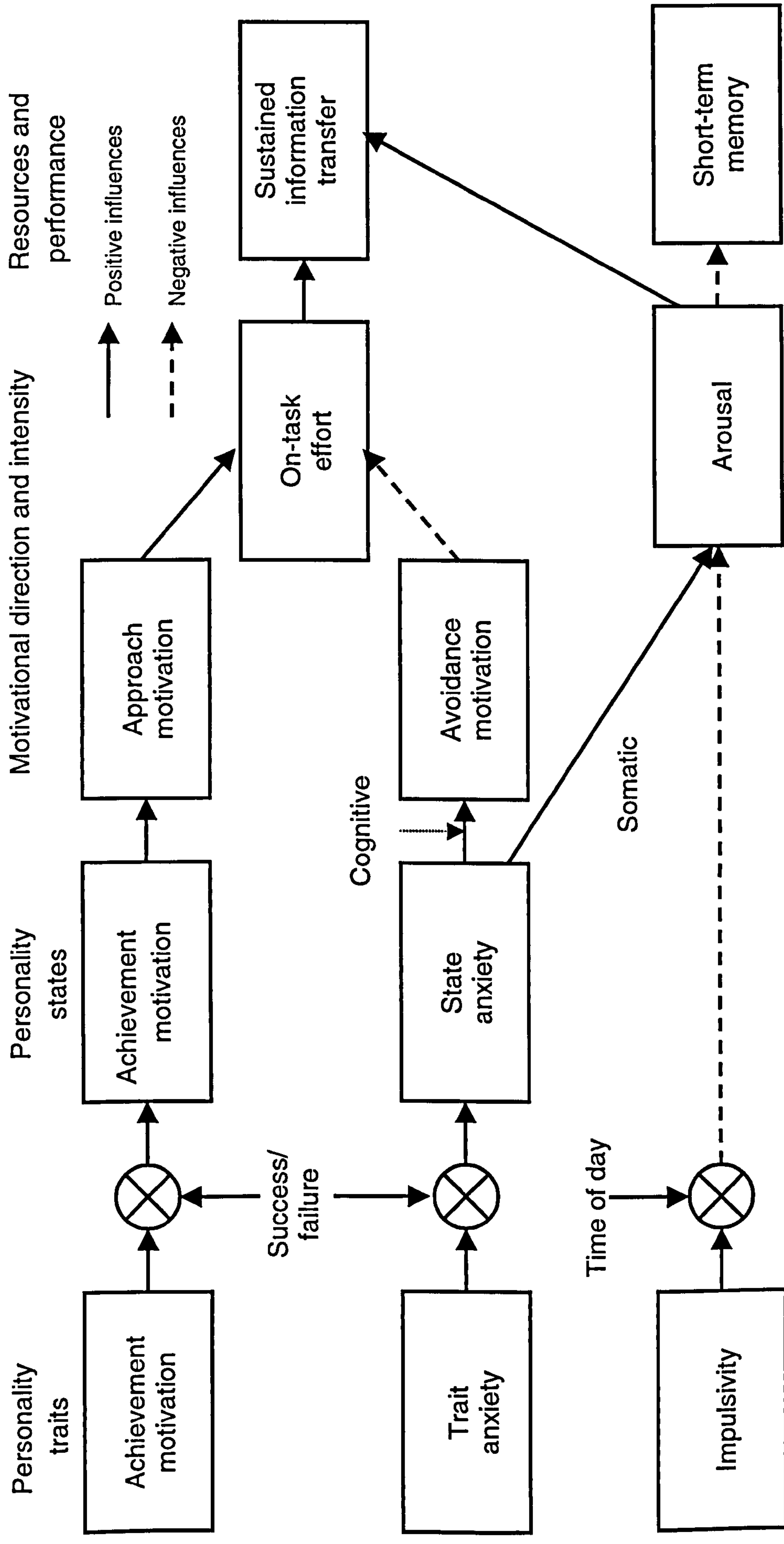


Figure 2. Conceptual structural model of the effects of personality, situational moderators, and motivational states on information processing and cognitive performance (Source: Hardy, Jones & Gould, 1996, p. 123 [Modified from Humphreys & Revelle, 1984, p. 155]).

alertness” (p. 158). This conceptualisation is unidimensional in nature and clearly a major drawback with Humphreys and Revelle’s model. On-task effort is defined by Humphreys and Revelle as “the motivational state commonly understood to mean trying hard . . . (and) is increased when the subject tries harder, when there are incentives to perform well, or when the task is important or difficult” (p. 158). As noted by Jones (1990), the notion of “on-task effort” is more specific than the general feeling of trying hard as it refers to the allocation resources to the task at hand.

A key feature of the model proposed by Humphreys and Revelle (1984) is the suggestion that the SIT and STM tasks outlined above are differentially affected by arousal and on-task effort. For SIT tasks, increases in arousal and on-task effort produce an increase in the number of resources available to sustain skills. As Humphreys and Revelle also proposed that performance increases monotonically as a function of the number of resources applied, increases in both arousal and on-task effort should therefore improve SIT performance. STM tasks, on the other hand, are adversely affected by increases in arousal.

Humphreys and Revelle’s (1984) model also includes predictions concerning the interactions between the three personality dimensions (Figure 2, above), on-task effort, and arousal and specific task requirements. In terms of explaining how anxiety affects performance, Humphreys and Revelle suggest that state anxiety has a cognitive component, worry, which is equated with avoidance motivation. According to the authors, avoidance motivation produces a subsequent decrease in allocated task resources, or on-task effort. Tasks with a high short-term memory component are therefore more adversely affected by high state anxiety. As a result, high levels of state anxiety, with the associated worry component, interfere with attention and reduce on-task effort, impairing performance on both SIT and STM tasks.

Despite the advantages of looking at the effects of different stressors upon specific components of performance, Eysenck (1992) notes several limitations of Humphreys and Revelle’s (1984) model. The first of Eysenck’s major criticisms concerns the unidimensional conceptualisation of arousal proposed by Humphreys and Revelle. A unidimensional view of arousal is in conflict with the notion of

multidimensional activation states and arousal espoused earlier. However, in spite of these criticisms, the differential performance effects predicted by Humphreys and Revelle's model are an advance on unidimensional theorists' conceptualisation of a single arousal system that affects general performance in a curvilinear fashion. Eysenck also criticises Humphreys and Revelle's failure to include a control system within their model. According to Eysenck, a control system should be responsible for monitoring and adjusting the functioning of the information processing system. Eysenck suggests that a control system would be responsible for initially recognising and subsequently compensating for specified effects upon information processing. Eysenck's third major criticism concerns the hypothesis that state anxiety promotes avoidance motivation, which reduces on-task effort, "overestimates the negative motivational influence of anxiety" (Eysenck & Calvo, 1992, p. 412). Eysenck and Calvo expand on this criticism by noting that both Calvo (1985) and Eysenck (1985) have produced empirical evidence supporting the contention that performance is not always impaired on tasks with substantial short-term memory demands. Eysenck also criticises the short-term storage system incorporated within the model. According to Eysenck, the short-term memory system proposed by Humphreys and Revelle is inadequate and inconsistent with the more complex multi-component system proposed by Baddeley (1986) and Baddeley and Hitch (1974).

In terms of practical implications for coaches and performers, Humphreys and Revelle's model suggests that the same psychological skills are unlikely to be appropriate for all individuals. As the model predicts different responses by individuals to specific situations and also differential performance on different types of skills, psychological skills training should be sensitive to such differences. Multimodal stress management strategies (Burton, 1990; Meichenbaum, 1977) may be appropriate in this context.

In summary, Humphreys and Revelle's model attempts to predict the combined effects of personality and motivational variables upon SIT and STM components of performance. Humphreys and Revelle predict that high arousal enhances SIT performance but impairs STM performance. Elevated anxiety is predicted to negatively influence both SIT and STM. Humphreys and Revelle's dual-system approach, while extending the theoretical scope of earlier theories, is hindered by a number of limitations, not least of which is the lack of empirical evidence upon

which the theory is based.

Eysenck and Calvo's Processing Efficiency Theory

Eysenck and Calvo's (1992) cognitively derived processing efficiency theory might have important implications for sport psychology. Central to Eysenck and Calvo's theory is the relationship between cognitive anxiety and performance. Cognitive anxiety is hypothesised to affect performance by demanding cognitive resources, which are located within a multidimensional working memory system (Baddeley, 1986; Baddeley & Hitch, 1974). As cognitive anxiety is predicted to affect the working memory system, tasks with little or no working memory component should not be affected by increases in cognitive anxiety. Processing efficiency theory thus accounts for the Anxiety x Task Difficulty interaction (Eysenck & Calvo, 1992). Processing efficiency theory also predicts that cognitively anxious individuals can maintain the quality of task performance. According to Eysenck and Calvo, high cognitive anxiety can serve a motivational function. Eysenck and Calvo proposed a monitoring or control system that reacts to feedback indicating that performance is falling below the level desired by the individual. The monitoring system reacts to poor performance by allocating extra resources to the task at hand, thus maintaining performance at an acceptable level. In this respect, Eysenck and Calvo's distinction between performance effectiveness and processing efficiency is important. Performance effectiveness simply refers to the quality of task performance. Processing efficiency refers to the "relationship between the effectiveness of performance and the effort or amount of processing resources invested" (Eysenck & Calvo, 1992, p. 417). The distinction is important in explaining the maintenance of task performance under stress. Processing efficiency theory predicts differential effects upon processing efficiency and performance effectiveness as anxious individuals generally make more use of the control system and so exert more effort. According to Eysenck and Calvo, anxiety therefore affects processing efficiency more than performance effectiveness. Eysenck (1992) has reviewed a large number of studies that support the predictions outlined above. The empirical evidence reviewed by Eysenck was largely based upon cognitive tasks such as letter transformation and reading, and as Eysenck (1996) has noted, it is not clear how important worry is in influencing performance on motor tasks. As such, it may be

unreasonable to expect the findings from test anxiety research to be applied en bloc to competitive sport contexts. However, Hardy and Jackson (1996) examined the performance of experienced rock climbers who led and seconded high and low anxiety rock climbs. Climbers performed better and exerted more cognitive and physiological effort when they were cognitively anxious (leading) compared to when they were not cognitively anxious (seconding). Sport tasks similar to rock climbing that tax working memory, may be more susceptible to the effects predicted by Eysenck and Calvo. Hatzigeorgiadis and Biddle (1998) also found moderate support for processing efficiency theory. Using seven point scales, University volleyball players who reported performance worries were asked to rate how frequently the worries were reported, the degree to which these thoughts disrupted concentration (“distraction”), and the degree to which these thoughts influenced subsequent effort (“effort”). Using path analysis, the authors found support for the contention that the “frequency” of cognitive interference was negatively associated with performance, which was also measured using a seven point rating scale. Hatzigeorgiadis and Biddle found that the frequency of negative thoughts might lead participants to increase the amount of effort invested in the task. However, multi-sample analysis also revealed that the level of expectancy moderated the effect of worry upon performance. Favourable expectancies might result in extra resources being applied to the task, whereas worry and low expectancy “might discourage individuals, resulting in withdrawal of effort” (p. 127).

Hatzigeorgiadis and Biddle (1998) included expectancy in their test of processing efficiency theory based upon suggestions made by Carver and Scheier (1988) who suggested that the key to whether or not an individual persisted with, or disengaged from, a task was their confidence about achieving their goals. Although Eysenck and Calvo (1992) say little about the exact circumstances under which anxious individuals will invest more effort, Eysenck (1982) had previously suggested that the amount of effort expended by an individual was an evaluation of task demands. According to Eysenck, “if an anxious person believes that the probability of reducing anxiety through successful task performance is very low, then anxiety will lead to a low investment of effort in the task” (p.109). Eysenck cited the work of Revelle and Michaels (1976), who hypothesised that motivation is affected by the subjective probability of task success, proposing the following

relationship between the two variables: “Moderately difficult problems or situations . . . should be extremely motivating (‘When the going gets tough, the tough get going’). On the other hand, very difficult or impossible tasks . . . should lead to extremely low levels of motivation (‘Wise people do not beat their heads against brick walls’)” (Revelle & Michaels, 1976, p. 402). Additionally, Hardy (1990; 1996b) suggested that the construct of self-confidence may be an important variable that might “protect” against the debilitating effects of high state anxiety. Hardy (1990; 1996b) also hypothesised that processing efficiency theory might dovetail with the predictions of catastrophe models of anxiety and performance (for a full consideration, see Hardy, 1990, 1996). The role of expectancies and self-confidence in facilitating the allocation of extra resources to the task at hand could help clarify the compensatory role of effort in processing efficiency theory.

In summary, processing efficiency theory distinguishes between performance effectiveness and processing efficiency. Performance effectiveness may be impaired under high anxiety by worry consuming attentional resources located in the working memory system. The main advantage of processing efficiency theory over other theories is the inclusion of a control system that allows anxious performers to offset the negative effects of high anxiety by applying extra resources to tasks, thus impairing processing efficiency. The exact circumstances under which anxious individuals apply extra resources require further clarification. Further research examining processing efficiency theory remains a priority within sport psychology.

Wegner’s Theory of Ironic Processes of Mental Control

Wegner (1989; 1994) developed the theory of ironic processes of mental control from the observation that the mind wanders because we try to control it. Wegner (1989) cites Dostoyevsky’s example of trying, and failing, to suppress a thought of a white polar bear as an example of an ironic process. Wegner suggested that mental control results from the interaction of two processes, an intentional operating process, and an ironic monitoring process. The intentional operating process searches for mental contents that will result in the desired mental state. The intentional operating process is effortful, conscious, effective, and interruptible. The ironic monitoring process searches for mental contents that signal the failure to achieve the desired state and is usually unconscious, less demanding of mental

effort, and uninterruptible. For example, prior to taking a penalty kick in soccer, the operating process might look for any signs that will allow the player to successfully take the penalty kick. Such signs might include picking a target area in the goal, reminding oneself that the goalkeeper has a weaker left-hand side, or remembering the last successful penalty kick. At the same time the ironic monitoring process might look for signs that will result in an unsuccessful kick. These might include recalling where the ball went the last time one missed the goal, or remembering that the goalkeeper has a good track record saving penalties.

The monitoring process is functionally adaptive in that it normally ensures that any threat to the operating system is registered and dealt with appropriately. In the example of a penalty kick, the monitoring process might register that the goalkeeper is stronger to his or her right side and, normally, the penalty-taker should be able to direct the penalty to the goalkeeper's left side. Unfortunately, ironic control problems may arise under conditions of mental load. Normally, the operating process functions effectively by consuming attentional resources (assumed to be of limited capacity, cf. Kahneman, 1973), while the monitoring process functions at a subconscious level and, as such, is less effortful than the conscious operating system. Under increased mental load, for example, when an individual is cognitively anxious, interference at the cognitive level consumes attentional resources being used by the operating process. As a result the monitoring process becomes more dominant and mental control paradoxically works against itself by attending to those thoughts that are least desirable (the contents of the monitoring system). In the case of the penalty-taker, the last missed penalty becomes the fixated thought. "Don't hit the ball too close to the 'keeper" results in the player mis-cueing his kick, which goes straight at the goalkeeper.

Research into ironic effects is sparse within sport psychology. Wegner, Ansfield, and Pilloff (1998) examined golf putting performance under conditions of mental load. Wegner et al. found that players who were instructed not to hit the ball past the hole were more likely to do so. The central tenets of Wegner's theory were also supported by Wegner, Broome and Blumberg (1997), who found that people who attempted to relax under conditions of mental load demonstrated an increase in symptoms of anxiety and physiological arousal.

In terms of applied implications, little has been written about preventing or

changing ironic processes within sport psychology. In the field of clinical psychology, Wegner (1997) and Shoham and Rohrbaugh (1997) suggested that paradoxical interventions might provide a means of interrupting ironic processes. Janelle (1999) provides some detail on how paradoxical interventions might function in a sporting environment. According to Janelle, asking athletes to focus on their anxious competitive feelings should trigger the monitoring process to initiate a search for signs that are incompatible with the anxious state. Janelle suggests that in this manner, relaxation can be induced through ironic identification of relaxation strategies by the monitoring process. However, as Hall, Hardy, and Gammage (1999) point out, paradoxical interventions should probably be viewed with caution in view of their counterintuitive quality and the lack of empirical evidence that supports them.

In summary, Wegner's theory of ironic processes suggests that mental control is achieved via the interaction of an intentional operating process and an ironic monitoring process. Under conditions of high cognitive load, the monitoring process supersedes the operating process and leads individuals to focus on the aspect of behaviour they have been seeking to avoid.

Masters' Conscious Processing Hypothesis

According to Baumeister (1984), paradoxical performance effects, or "the occurrence of inferior performance despite incentives and striving for superior performance" (Baumeister & Showers, 1986, p. 361), are a common result of competition. The concept of paradoxical performance is not new. The Bliss-Boder hypothesis, derived from early work by Bliss (1893) and Boder (1935), suggested that performance impairment is caused by competition which leads individuals to consciously monitor performance. Deikman (1966) termed this effect "deautomatisation", which involves the undoing of automatisation by reinvesting actions with attention. Eysenck (1982) believed that deautomatisation could occur even in everyday skills: "For example, if you think too deeply about the leg movements involved in walking down a flight of stairs, you may well finish up in a heap at the bottom of those stairs!" (p.13).

Empirical evidence for the deleterious effect of task-focus upon the performance of well-learned or "overlearned" skills has been provided by Kimble and Perlmutter

(1970) and Langer and Imber (1979). Vallacher (1993) believed that self-focus causes an exaggerated concern with the mechanics underlying task execution, disrupting fluidity and rhythm. Reason (1984) suggested that such task disruption was the result of being in the wrong control mode with respect to current task demands. Reason claimed that errors often occur as a result of “going closed loop during the execution of a highly automated sequence of actions for which intervention by the intention system is both unnecessary and undesirable” (p. 536).

Masters (1992b) sought to explain the effects of anxiety upon motor performance from the premise that “failure of expert motor skill is common in cases where performers are highly motivated to succeed and that one cause of this can be an inward focus of attention in which an attempt is made to perform the skill by *consciously processing* explicit knowledge of how it works” (p. 14, emphasis added). Central to this “conscious processing hypothesis” is a distinction between expert and novice task control. Where individuals are highly skilled, a concern for the mechanics of a particular motor skill is largely redundant for successful performance. As Vallacher (1993) noted, “Consciousness can be overdone, functioning to subvert as well as facilitate effective action.” (p. 140). The theoretical basis for making such claims lies in the notion of stages of learning, central to cognitive (Fitts & Posner, 1967) and ecological (Newell, 1985) approaches to motor learning. One of the central features of cognitive theories of motor learning is the role of attention in task control. Conscious attentional processes are thought to guide performance early in learning. As a result, performance is inconsistent, slow, erratic and jerky.

One of the reasons for the deliberate performance of the novice might be that verbal information, typically provided by coaches, has to be “translated” into the “language” of the action processes responsible for task performance. Annett (1991) suggests that such translation is achieved via “action and language” bridges. Figure 3 (below) illustrates Annett’s ideas. The top of the diagram shows different kinds of input, words and actions. The central section (the four boxes) represents internal processes, while the bottom represents output as actions or words. The left-hand side represents the non-verbal domain of action, while the right-hand side represents the verbal domain. The upper pair of the four areas in the centre represents receptive and interpretive processes, while the bottom pair represents productive processes. Annett

describes a number of routes through the diagram; the most typical of which is from the top straight down in the conventional direction of perception to action. Other routes involve crossover between the verbal and non-verbal routes. In particular, a novice learning a motor skill has to transform verbal instruction from coaches into a language that can be used by motor processes and also translate the internal coding of the movement that may initially be verbally coded.

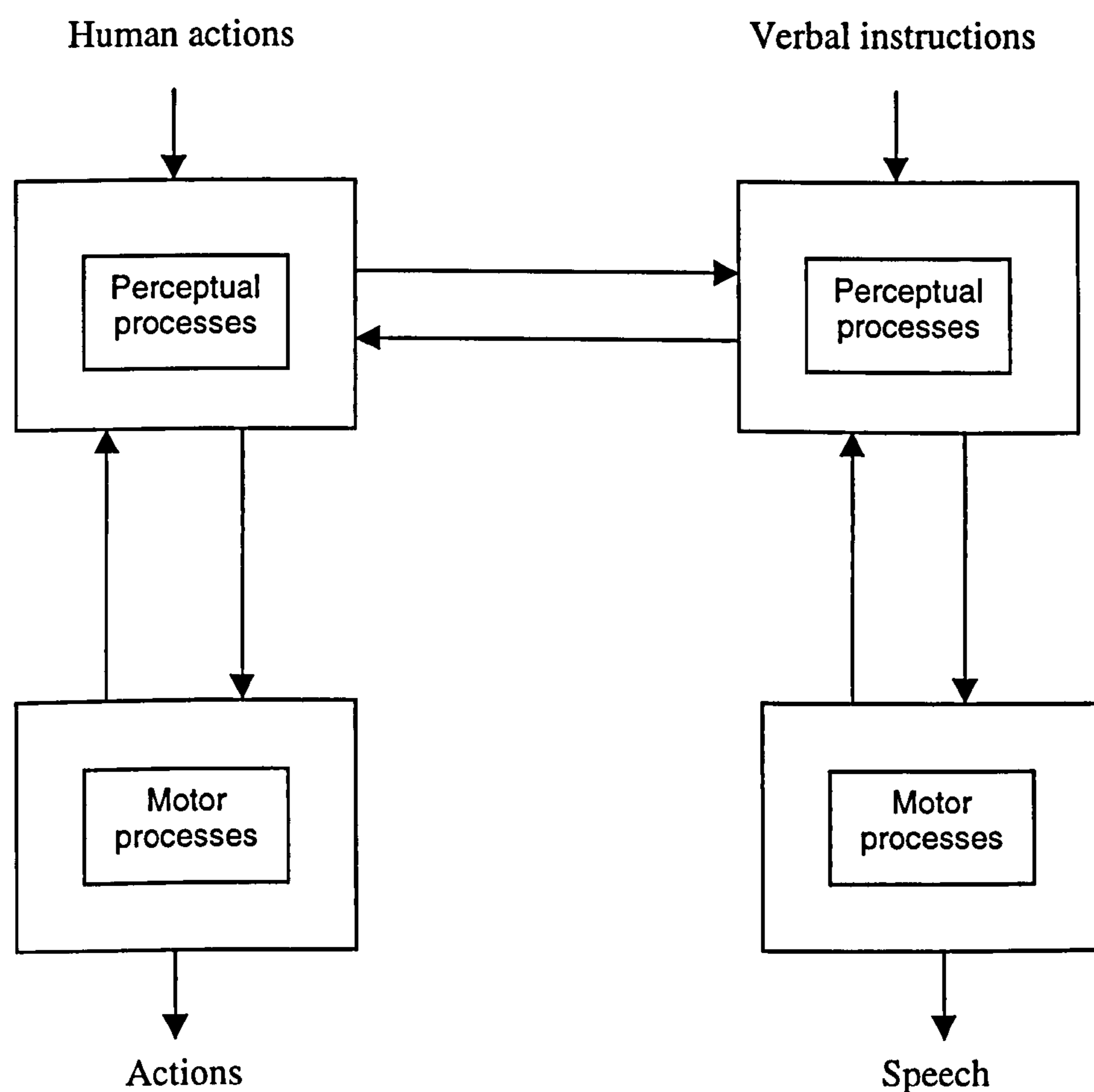


Figure 3. Annett's (1991) hypothetical relationships between motor and verbal systems.

By way of contrast, the performance of the expert is largely thought to be automatic or unconscious. In the context of Annett's framework, the expert is relatively free from the problem of finding crossover links between language and action. Hours of practice lead to a state where performance is relatively automatic, taking place with little conscious attention or mental effort. As a result, in describing the final stage of learning, Fitts and Posner used the label "autonomous" to describe the relatively attention-free functioning of the expert. Once again, this idea is not new, with James (1890) noting that "Habit diminishes the conscious attention with which our acts are performed." (p. 114). The sport psychology literature is replete with anecdotal examples and empirical evidence for the automatic, effortlessly processed performance of experts. For example, Tony Meola, an international soccer goalkeeper, claimed that "When I'm really concentrating, I would say it's almost like I'm playing unconscious." (Newman, 1992, p. 95). The late Ayrton Senna, describing an experience that occurred during practice for the Monaco grand prix in 1988, provided an extreme example of automatic functioning:

Monte Carlo '88, the last qualifying session. I was already on pole and I was going faster and faster . . . Suddenly I was nearly two seconds faster than anybody else, including my team-mate with the same car. And suddenly I realised that I was no longer driving the car consciously. I was driving it by a kind of instinct, only I was in a different dimension. It was like I was in a tunnel . . . I was way over the limit but still able to find even more. Then suddenly something just kicked me . . . my immediate reaction was to back off, slow down. I drove slowly back to the pits and I didn't want to go out anymore that day. (Williams, 1995, pp. 98-99)

Sport psychologists have also collected empirical data supporting such anecdotes (Csikszentmihalyi, 1975; Jackson, 1992).

The distinction between automatic and controlled processing (Schneider, Dumais, & Shiffrin, 1984; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) is fundamental to the conscious processing hypothesis. Controlled processes are thought to underlie the inconsistent performance of the novice. Controlled processing is attention demanding and effortful, serial in nature, slow, and can be subject to conscious modification (Abernethy, 1993). Automatic processing on the other hand appears to be largely without conscious demand or effort, parallel in

nature, fast, and difficult to modify once initiated (Abernethy, 1993). This distinction is popularly used in the sport psychology literature to describe the apparent release from effortful processing that accompanies motor learning.

A further feature of skill acquisition central to Masters' (1992b) conscious processing hypothesis is the change in knowledge structures thought to underpin performance at early and late stages of learning. According to Anderson's (1982) Active Control of Thought (ACT) theory, expertise is developed by a transition from control by declarative knowledge to control by procedural knowledge. Declarative, or explicit knowledge, is thought to underpin the conscious control of the novice. Explicit knowledge refers to knowledge of facts, that is knowing "what to do" in a specific situation. Explicit knowledge is rule-based, available to consciousness, and verbalisable (Reber, 1993). Procedural knowledge is hypothesised to be used later in learning. Procedural knowledge is concerned with "how to do" something and is abstract, unavailable to consciousness, and nonverbalisable (Reber, 1993). Central to Anderson's theory, which it must be noted concerns the acquisition of cognitive rather than motor skills, is the premise that all incoming knowledge is coded explicitly or declaratively. The declarative codings are accessed step-by-step by a procedure subject to capacity limits and under conscious control. With practice, a production system develops that replaces the interpretive application with productions that perform behaviours quickly and directly without conscious awareness. The shift from declarative to procedural knowledge and the concomitant "dropping out" of consciousness is consistent with the view of automaticity developed earlier. The interpretive application of declarative knowledge suggested by Anderson, occurs early in learning and might be illustrated by the crossover links from verbal to action processes in Figure 3. Furthermore, Anderson's theory also appears to fit in well with Annett's ideas on action-language bridges. A further key mechanism that might help explain the attention-free performance of the expert is "chunking". According to Neves and Anderson (1981), the development of expertise is the result of a gradual chunking of independent components of a task. Through practice, the individual task components are incorporated into larger chunks, which can be handled as a single representation of the task. The chunking process may help explain how expert task performance appears smooth and efficient, whereas that of the novice appears jerky and segmented.

The notions of automatic and controlled processing, “chunking”, and Anderson’s ACT theory of learning are all central to Masters’ (1992b) conscious processing hypothesis. According to Masters, increased state anxiety leads performers to focus their attention inwards in an attempt to control movement using explicit or declarative knowledge about the skill. Masters termed this process “reinvestment” of explicit knowledge. By reinvesting in their explicit knowledge base, performers are relying upon knowledge used to guide performance during the early stages of learning. As a result, the conscious processing hypothesis suggests that the underlying mechanisms used to guide performance also shift from the smooth, unconscious, automatic processing of the expert, to the erratic, deliberate, controlled processing of the novice. Referring to Figure 3, the direct path through the left-hand side of the model via action-oriented receptive and interpretive processes and productive processes is disrupted by state anxiety. The conscious processing hypothesis suggests that anxious performers might revert to using conscious verbal receptive and interpretive processes to generate action-oriented productive processes via the action-language bridge. Thus, referring to Figure 3, anxious performers might attempt to use the cognitively oriented perceptual processes on the right-hand side of the model to guide the motor processes found on the other side of the “bridge”. Automatic processing thus becomes subverted by the conscious mechanisms associated with the performance of the novice, typically with disastrous consequences.

Masters’ (1992b) ideas regarding conscious processing also dovetail neatly with Fitts, Bahrck, Noble and Briggs’ (1961) progression-regression hypothesis which suggested that learning produces a progression to complex control strategies that are underpinned by higher-order kinematic derivatives. During the “regression” phase of the progression-regression hypothesis, individuals under stress are hypothesised to regress to using more basic task control strategies centred upon lower-order kinematic parameters, that is, time-position information. More recently, Lee and Swinnen (1993) noted that the progression-regression hypothesis might be useful in describing the acquisition and breakdown of motor skills. MacMahon and Masters (1998) have produced empirical evidence supporting the progression and regression phases of Fitts et al’s. (1961) hypothesis using the notion of chunking discussed earlier. Using a serial reaction time task, MacMahon and Masters demonstrated that

learning resulted in chunking of separate task components into larger, functional units. In a subsequent high anxiety condition, performance regressed or “de-chunked” from the larger, functional units into the smaller, separate task components.

The role of self-focus as a dispositional variable has also received some attention in the conscious processing literature. Masters, Polman and Hammond (1993) examined the suggestion that reinvestment might be a dimension of personality, with some individuals more predisposed than others to reinvest actions with attention. Masters et al. devised the Reinvestment Scale to measure individuals’ predisposition to focus attention on the mechanics of movements. The Reinvestment Scale has been shown to be internally reliable with an alpha coefficient of 0.80 and a test-retest correlation coefficient of 0.74 (Masters et al., 1993). In terms of validity, however, the evidence presented by Masters et al. was not strong. Masters et al. were unable to find causal evidence supporting the notion that high reinvesters were more likely than low reinvesters to experience performance decrements under pressure. Despite this criticism, dispositional self-focus may still be important in the context of conscious processing. Baumeister (1984) suggested that individuals high in dispositional self-consciousness are not as prone to the negative effects of pressure because they are accustomed to performing under high self-awareness. Baumeister found that participants high in self-consciousness outperformed those low in self-consciousness. Lewis and Linder (1997) found evidence supporting Baumeister’s prediction. However, a recent study by Bawden, Maynard, Graydon, and Chell (2000) found that anxious and highly self-conscious participants performed significantly worse than non-anxious and low self-conscious participants on a golf-putting task. An explanation for the discrepant findings described above may lie in the measure of self-consciousness used by the researchers. All the studies described above used a score composed of private and public aspects of self-consciousness. As Baumeister pointed out, “increased self-awareness of one’s performance process seems to denote a private self-consciousness . . .” (p. 611). It might be that the construct of private self-consciousness is more relevant in terms of conscious processing than public self-consciousness. Hence, in this respect at least, the composite measure of self-awareness adopted by Baumeister, Lewis and Linder, and Bawden et al. may have been inappropriate.

Within sport and “mainstream” psychology, the ideas described above have typically been placed within a traditional, cognitive framework that emphasises centralised executive control mechanisms situated at the highest level of a hierarchical structure. Such notions are clearly at odds with ecological accounts of motor control and learning that emphasise a more distributed framework (Davids, Handford, & Williams, 1994). Adopting a hybrid model of human functioning, Annett (1991), suggested that automaticity could be better conceptualised in terms of levels of control. Annett’s proposals place human functioning within a heterarchical control structure. Such systems comprise higher-order strategic control mechanisms and lower-order operators. Annett suggested that the higher-order mechanisms direct the lower level mechanisms without conscious awareness of the operations performed at lower levels. Hardy, Jones and Gould (1996) put this simply, stating that “Elite performers may first ‘weigh up’ the alternatives that are available in any given situation and then set conscious goals about what needs to be done. However, having done this, they trust their motor system ‘to get on with the job’, and simply monitor progress to ensure that no major adjustments to the ‘game plan’ are necessary.” (pp. 179-180). Although evidence for heterarchical models of motor control is scarce (Rumelhart & Norman, 1982), such models may be important in the context of conscious processing in terms of understanding exactly how multidimensional state anxiety affects performance.

The heterarchical model of human functioning described above can be used to highlight a possible extension of Masters’ (1992a) ideas on conscious processing. Specifically, Masters hypothesised that the effects of the cognitive and somatic subcomponents of multidimensional state anxiety on the processing system were inseparable, claiming that they were “so intertwined that one will directly influence the other” (p. 13; cf. Borkovec, 1976). Such a position ignores important evidence indicating that the cognitive and somatic subcomponents of competitive state anxiety follow different time courses (Martens, Burton et al., 1990) and exert differential effects upon certain aspects of performance (Parfitt & Hardy, 1993; Parfitt & Pates, 1999). Heterarchical control systems allow for these differential effects. For example, increased somatic anxiety or physiological arousal may result in increased muscle tension that affects the operation of the lower level mechanisms, while cognitive anxiety may lead the performer to use the higher-level cognitive

mechanisms in an attempt to consciously control lower level automatic operations (Hardy, Jones & Gould, 1996). In terms of conscious processing, then, the suggestion is that the cognitive subcomponent of state anxiety may play the crucial role in impairing performance.

In summary, the conscious processing hypothesis predicts that the normal automatic functioning of skilled but anxious performers is disrupted by increases in cognitive state anxiety, resulting in performance impairment. Corroborating evidence is scarce, however, and there is a need for further research in laboratory and applied settings. The applied implications of the conscious processing hypothesis are discussed later.

Summary

This chapter has attempted to clarify some of the problems relating to terminology within the area of stress and anxiety in the sport psychology literature. The chapter also outlined several theories with the potential to explain how anxiety affects performance. These theories included Easterbrook's (1959) cue utilisation hypothesis, cognitive interference theory (Sarason, 1972; Wine, 1971), Humphreys and Revelle's (1984) information processing model, processing efficiency theory (Eysenck & Calvo, 1992), and Wegner's (1989; 1994) theory of ironic processes of mental control. The advantages and disadvantages of these approaches were briefly addressed before turning to examine Masters' (1992b) conscious processing hypothesis in more detail. Each of the theories examined has its own merits, and each probably warrants further investigation as it is possible that anxiety exerts its effect upon performance via more than one mechanism. In this respect both the conscious processing hypothesis and processing efficiency theory seem worthy of further empirical investigation.

Purpose of the Research Programme

The primary purpose of the present research programme was to examine the conscious processing hypothesis as a possible explanation for the effect of state anxiety upon motor performance. Specifically, the project attempts to replicate and extend the work of Masters (1992b), and then gradually moves toward an

interdisciplinary examination of some of the ideas generated by conscious processing effects and processing efficiency theory.

Structure of the Thesis

This thesis is presented as a collection of research papers. Each paper incorporates a synopsis of the literature relevant to that paper. The final chapter (7) then provides a general summary. Thus, the structure of the thesis is as follows:

Chapter 2 reports a study that replicates and extends Masters' (1992b) study, which examined the effect of high anxiety upon the performance of a golf putting task acquired using implicit and explicit learning strategies.

Chapter 3 reports a study that adopted a quasi-experimental performance paradigm to examine the effect of task-relevant, explicit knowledge upon the performance of skilled trampolinists under high and low anxiety conditions.

Chapter 4 describes a study designed to address alternative explanations of the findings from the studies outlined in chapters 2 and 3. Specifically, the study was designed to control for the desensitisation hypothesis identified in study 1, and Eysenck and Calvo's (1992) processing efficiency theory as a plausible alternative to the conscious processing hypothesis. An interdisciplinary focus was adopted incorporating behavioural and kinematic analyses of skilled golfers putting under low and high anxiety conditions while using task-relevant and task-irrelevant knowledge.

Chapter 5 reports a study incorporating a refinement of the research design used in chapter 4 and continued the examination of the conscious processing hypothesis and processing efficiency theory. The study also extended the interdisciplinary approach adopted in chapter 4 using three-dimensional kinematic analysis to examine movements and spectral analysis of heart rate variability as a cardiovascular index of effort.

The study detailed in chapter 6 adopts a more applied focus by examining the effects of different types of explicit knowledge upon performance. Specifically, explicit knowledge is manipulated using holistic and part process goals. The effect of the two different types of process goals upon the performance of skilled golfers putting in low and high anxiety conditions was examined.

The final chapter (7) summarises the research project as a whole. It also discusses the major theoretical issues addressed, explores the applied implications, identifies, the programme's strengths and limitations, as well as directions for future research.

Chapter 2

Knowledge and conscious control of motor actions under stress¹

(Study 1)

Abstract

Masters (1992b) investigated the effect of stress upon the performance of a well-learned golf putting skill, acquired under implicit and explicit learning conditions. Masters found that high anxiety had a detrimental effect on the performance of the explicit learning group but not the implicit learning group. However, the implicit learning group performed a random letter generation task during 400 learning trials but not during a high anxiety transfer test. It is possible that the participants in the implicit learning group continued to improve during the stress session simply because they were performing an easier task. The present study re-examines Masters' conclusions by replicating and extending his method. An additional implicit learning group was included which was required to carry out random letter generation during the learning trials and the high anxiety transfer test. It was hypothesised that this "new" implicit learning group would suffer the same disruption to performance as the explicit learning group, providing evidence contradicting Masters' explanation. Thirty-two subjects were allocated to one of four groups. Performance measures were analysed using mixed two-factor analysis of variance (4 x 5: Groups x Sessions). The main dependent variable was the number of putts successfully completed. The analysis revealed that both the implicit learning groups continued to improve their performance under stress whilst the explicit learning group did not. Despite limitations to both Masters and the present study, these results add support to Masters' conscious processing hypothesis.

¹ Based upon Hardy, L., Mullen, R., and Jones, G. (1996). Knowledge and conscious control of motor actions under stress. *British Journal of Psychology*, 87, 621-636.

Introduction

Recent studies of the anxiety-performance relationship have relied upon explanations of the anxiety response which are based upon resource allocation models of information processing (Jones, 1990). In such models, performance decrements are thought to be due to performers using up attentional resources by worrying (Eysenck, 1982; Sarason, 1972; Wine, 1971). Carver and Scheier (1981) suggested a similar, distraction-based theory involving negative self-awareness. Carver and Scheier hypothesised that by becoming more aware of oneself while performing, attention would be taken away from task-relevant cues, causing performance degradation. Baumeister (1984) offered an alternative explanation, claiming that in competitive situations performers are highly motivated to do well and this leads to a tendency to focus on the process of performing. Thus, performers who realise the importance of precise skill execution will attempt to ensure success by consciously monitoring their performance. This may disrupt the natural automatic processing of information, which should be taking place if the performer is not a novice. This suggestion is supported by research conducted by Keele (1973), who found that performers who focused attention on piano playing skills suffered from performance decrements; and Langer and Imber (1979), who showed that attempting to ensure accuracy by consciously monitoring finger movements during typing was also detrimental to performance. This evidence is also consistent with Fitts, Bahrck, Noble and Briggs' earlier (1961) progression-regression hypothesis which suggested that learning produces a progression to complex control strategies and that exposure to stress produces a regression to more simple levels.

The basis for Baumeister's explanation of the effects of competitive pressure upon performance may lie within theories of skill acquisition (cf. Anderson, 1982; Logan, 1988; Schmidt, 1988; Schneider & Shiffrin, 1977). One of the most fundamental ideas which characterises such theories is the suggestion that in acquiring a skill, a performer passes through several distinct developmental stages (Fitts & Posner, 1967). Two characteristics that can be used to distinguish between such phases are the type of knowledge (Anderson, 1982) or control (Schneider & Shiffrin, 1977) that guide performance. During the early stages of learning performance tends to be overtly processed and is also, typically, slow, effortful, and unrefined. The type of knowledge that guides performance during these early stages

is characterised as being “explicit” in nature (i.e., knowledge that is rule-based, available to consciousness and verbalisable: Reber, 1993). Subsequent practice results in a shift away from such overt processing to a stage where performance is fast, smooth, efficient, and subject to covert processing. Performance is now commonly characterised as being automatic in nature and the knowledge underpinning it could be described as being “implicit” (i.e., knowledge that is abstract, unavailable to consciousness and non-verbalisable; Reber, 1993). While implicit knowledge may be acquired without an initial base of explicit knowledge (Reber, 1993; Seger, 1994), expert performance can unquestionably be described as being automatic or implicit in nature. Indeed, this point is made by Reber (1993), who notes that the automatic processes described by contemporary learning theories are “classic examples of implicit systems” (p. 16).

Bearing these remarks in mind, one possible explanation for the performance decrements reported by Baumeister (1984) may be that performers, in attempting to consciously monitor their performance, are “reinvesting” in their explicit knowledge base. As a result, performance regresses to a conscious level associated with early stages of learning. There seems to be little empirical evidence that directly supports this phenomenon. However, Masters (1992b) found that the execution of a well-learned golf putting skill acquired using typical “explicit” procedures, reliant upon the provision of rules or guidelines to direct performance, was impaired when performers were anxious. Masters hypothesised that this was due to performers attempting to control action using task-relevant explicit knowledge. Participants who acquired the same skill implicitly, that is, without recourse to explicit instruction, suffered no performance degradation during a stress test. In fact, anxious performers actually improved their performance. Masters interpreted his results as providing empirical support for the conscious processing hypothesis.

The implicit learning condition was a key feature of Masters’ (1992b) study. Implicit learning has been demonstrated using several paradigms. These include the acquisition of artificial grammars, sequence learning and the control of complex systems (for reviews see Berry & Dienes, 1993; Reber, 1993; Seger, 1994). Empirical evidence also exists to support the notion of implicit learning in the context of motor learning (Green & Flowers, 1991). One of the central features of implicitly acquired knowledge that may be of interest to coaches and performers of

sports skills is the relative robustness of such knowledge “in the face of disorders and dysfunctions that compromise explicit knowledge” (Reber, 1993, p. 88). It may be that implicitly learned skills demonstrate greater resilience and stability under stress when compared to skills acquired explicitly. Reber cited an unpublished paper by Rathus, Reber and Kushner, who found evidence supporting this suggestion. Rathus et al. divided college undergraduates into two groups, depending on whether or not they scored above or below the median on Sarason’s (1978) Test Anxiety Scale. High anxious participants took longer to explicitly memorise letter strings than low-anxious participants. Subsequently, on a test to determine whether participants had acquired any implicit knowledge about an underlying grammar structure in the letter strings, the performance of the two groups was statistically indistinguishable, suggesting that the negative effects of anxiety were experienced only on the earlier explicit task. Masters’ results offered further support for this suggestion using a motor skill.

One of the main reasons for questioning Masters’ (1992b) interpretation of his results lies within current goal setting literature (Kingston & Hardy, 1994a; Orlick & Partington, 1988) which suggests that athletes should be encouraged to use process goals. Process goals commonly involve consciously attending to specific aspects of a movement in order to remain focused during performance. However, if Masters’ conscious processing hypothesis is correct, the use of process goals by skilled but anxious performers might increase the likelihood of performance failure.

There are more specific factors associated with Masters’ (1992b) methodology that could possibly confound his interpretation. Masters tested the explicit knowledge hypothesis by having participants acquire a golf-putting task under explicit and implicit learning conditions. Explicit learning was promoted by asking participants to use technical information on the “correct” way to putt during the practice sessions. Participants in the implicit learning groups were not given any explicit instructions. Implicit learning was promoted by requiring participants to perform a random letter generation task throughout the duration of their practice sessions. The purpose of the random letter generation task was to interfere with the functioning of the central executive of the working memory system (Baddeley, 1986; Baddeley & Hitch, 1974). Participants who putted while generating random letters were, therefore, denied the opportunity to self-generate explicit knowledge

about the task. Masters' study consisted of a learning phase of 400 trials, followed by a further 100 trials performed under high anxiety. Anxiety was elevated using a combination of social evaluation and financial incentive. The implicit learning group continued to improve during the high anxiety trial, while the explicit learning group did not. Masters interpreted these results as offering support for his conscious processing hypothesis. However, in the high anxiety condition, the implicit learning group was not asked to continue generating random letters. As such, the results could be attributed to a reduction in task difficulty. The aim of the present study was to address this task difficulty explanation by replicating and extending Masters' method. To address this problem an additional implicit learning group was included. Participants in this new group were required to continue to generate random letters during the stress condition as well as during the skill acquisition sessions. By generating random letters during the stress test, the "new" implicit learning group would be performing at a level of task difficulty equivalent to that experienced during the four skill acquisition sessions. It was hypothesised that the new implicit learning group would experience the same disruption to performance under stress as the explicit learning group.

Method

Participants

Thirty-two paid volunteers (16 male and 16 female, mean age = 21.13 years) were assigned to one of four conditions: implicit learning without random letter generation in the stress test (IL), implicit learning with random letter generation in the stress test (ILRLG), explicit learning (EL) and a non-stressed control group (NSC). Groups were assigned using stratified random sampling so that each group consisted of 4 male and 4 female participants. The participants, all right-handed, first year students at Cardiff Institute of Higher Education, had no experience of psychology courses.

Apparatus

The putting surface used in the present study was constructed according to criteria laid down by Masters (1992b). An identical "Astroturf" putting surface was used. Participants putted at a hole 10.8 cm in diameter, the size enforced by the United

States Professional Golf Association, from a distance of 150 cm. Task difficulty was increased by requiring participants to putt up a 25 per cent incline. All participants used standard size (4.27 cm in diameter) white golf balls and a standard sized golf putter (88.9 cm in length with a standard angle of lie and loft). Heart rate was measured using a Polar Electro Sport Tester PE³⁰⁰⁰ heart rate monitor, comprising a transmitter, strapped around the participant's chest, and a receiver worn on the wrist. Participants' heart rates were recorded at 5 second intervals. An electronic metronome was used to emit "clicks" at regular intervals of 1.5 or 1.0 seconds in the RLG condition.

Learning conditions

Participants performed according to instructions that were tailored specifically to each group.

Explicit learning (EL) group. Masters (1992a; 1992b) developed a set of specific instructions on how to putt a golf ball for use by the explicit learning group in his experiment. He compiled the instructions using two "reputable coaching sources" (Saunders & Clark, 1977; Stirling, 1985). The instructions used in the present study were identical to those used by Masters. These were presented to participants in the EL group in each of the first four sessions during the 5-minute resting phase prior to heart rate measurement. It was impressed upon participants that they should read the instructions carefully and follow them as closely as possible. The instructions were not presented during the final stress test.

Implicit learning (IL) and implicit learning RLG (ILRLG) groups. In these conditions, participants received no instruction on how to putt, but were required to generate random letters while putting. To ensure replication, the task used mirrored that used by Masters (1992b), who had based his random letter generation on procedures outlined by Baddeley (1966). Participants were required to call out a random letter each time an electronic metronome "clicked". In the initial two sessions, clicks sounded every 1.5 seconds. In the two later sessions, clicks sounded every 1-second. The reduction in the time interval between clicks was designed to maintain the difficulty of the random letter generation, ensuring continued suppression of explicit knowledge throughout the learning phase. Participants were asked not to stop generating letters at any stage of the putting session and to give

priority to maintaining the randomness of the letters. Inter-click intervals of 1.0 - 1.5 seconds were assumed to be too short to enable participants to divert their attention to the putting task. The IL and ILRLG groups differed in that the IL group did not generate random letters during the high anxiety test phase whilst the ILRLG group were instructed to continue with the secondary task. Both groups were placed under stress in the final test phase.

Non-stressed control (NSC) group. Participants in the NSC group received no instruction in the task of golf putting and were not required to generate random letters. The group was instructed to improve as much as possible. The control group remained unstressed in order to determine whether performance continued to improve in session 5 or had reached asymptote.

Design

The experiment had two distinct phases: a skill acquisition phase followed by a test phase. In the skill acquisition phase, consisting of four sessions of 100 putts, participants acquired the motor skill of golf putting implicitly, explicitly, or in a control condition. In the test phase, taking place over one session of 100 putts, participants in the EL, IL and ILRLG groups were subjected to stress while they performed, whereas those in the NSC condition were not. The five sessions took place on consecutive days at approximately the same time of day.

Procedure

All participants attended individually and were informed that the purpose of the experiment was to examine how well a skill could be acquired under different learning conditions. At the beginning of the sessions, participants were required to sit quietly for a period of 5 minutes to allow their heart rates to return to baseline. During the five minutes, all participants read a standard statement explaining that they would earn £12.00, and requesting that they not think about, rehearse or practise putting while away from the experiment. Immediately following the five-minute rest period, participants' heart rates were monitored for a period of three minutes. The first set of fifty putts began at the end of the three-minute period. In each session, participants made two sets of 50 putts separated by an interval of five minutes. A global performance measure, the number of successful putts made in

each session, was used as the primary dependent variable. No time constraints were imposed on participants. On completion of the task, it was impressed upon each participant that the study was ongoing, and that it was imperative that they did not discuss the experimental procedures with anyone.

Stress measures

Three stress indices were used to check the effectiveness of the stress intervention.

Performance Anxiety. The Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump & Smith, 1990) measured participants' performance anxiety. The CSAI-2 was administered pre- and post-stress intervention, to assess each participant's levels of cognitive and somatic anxiety. This was an extension of Masters' (1992b) study, which relied upon the state scale of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970) to provide only a unidimensional, non-situation specific measure of state anxiety. The use of the CSAI-2 is in line with recent sport-specific studies that have utilised this scale (for reviews see Jones, 1995; Jones & Hardy, 1990) and represents a response to the need for greater conceptual specificity. The CSAI-2 was used in the present study, as it offers more worthwhile information regarding the competitive anxiety response than the state scale of the STAI. The CSAI-2 is a sport-specific questionnaire that assesses the cognitive and somatic sub-components of state anxiety. A third sub-component, self-confidence is also measured by the CSAI-2, although this measure was not used in the present study. The scale comprises 27 items, with nine items in each of the three subscales of cognitive anxiety, somatic anxiety and self-confidence. Examples of cognitive anxiety items include "I am concerned about performing poorly" and "I am concerned about this competition", while somatic anxiety items include "I feel nervous" and "My body feels tense". Responses to each item are scored on a Likert scale ranging from 1 (*not at all*) to 4 (*very much so*). The psychometric properties of the CSAI-2 have been well established. Internal consistency has been deemed to be adequate with Cronbach's alpha coefficients ranging from 0.70 to 0.90 (Gould, Petlichkoff, & Weinberg, 1987). Martens, Burton, et al. (1990) reported that concurrent validity had been confirmed by studies which had obtained the predicted relationships between the CSAI-2 and an assortment of

trait measures. The CSAI-2 was administered during the inter-trial interval in the third and fifth sessions.

Heart Rate. Heart rate was monitored under stressed and unstressed conditions to obtain a direct physiological indication of stress, supporting the somatic sub-component of the CSAI-2. Heart rate was monitored at the beginning of each session for a period of three minutes. Before heart rate was measured, participants were required to sit quietly for five minutes to allow their heart rate to return to baseline.

Task completion time. To ensure full replication, task completion time was recorded to examine Masters' suggestion that, under stress, the time taken to prepare for each putt would increase in order to ensure accuracy. The total time taken to complete the two sets of 50 putts was recorded each day in order to provide information regarding this expected slowing of performance in the stressed groups during the test phase.

Stress intervention

During the final test session the IL, ILRLG and EL groups were placed under stress. Following Masters (1992b), stress was induced by a combination of social evaluation and financial incentives. As in previous sessions, participants from the three stressed groups were asked to sit quietly for 5 minutes prior to heart rate measurement. However, during the middle 60 seconds of the 180 second heart rate monitoring period they were required to read a standard statement which explained that the original payment of £12.00 could increase to £15.00 or decrease to as little as £1.00, subject to evaluation of their putting performance by an "expert" in golf.

As in Masters' (1992b) study, the suggestion that the sum of £12.00 could increase to £15.00 was introduced as a defensive measure against participants feeling that their performance was so poor it would be pointless to continue making an effort. It was thought that motivation would remain high if the participants believed there was a chance of winning their money back. Ten seconds after presentation of the statement the golf expert arrived and was introduced to the participant before retiring to an adjacent room where the participant's performance was to be viewed using a one-way mirror. The expert's fictitious status as a golf professional was emphasised by reference to past achievements, which included competing in "The Open" at St. Andrews. "Kitting out" the expert in a lambswool sweater and golf slacks completed the effect. As heart rate was still being monitored,

it was possible to obtain an indication of the participant's physiological response to the prospect of evaluation, and to the threat of losing almost all of the £12.00. The response elicited was measured by comparing the initial 60 seconds of the 180-second monitoring period with the final 60 seconds. A significant increase in heart rate was accepted as indicating an increase in performance apprehension. The final session of 100 putts then began.

No actual evaluation was made. The expert was free to leave once he had entered the viewing room. Evaluation apprehension was maintained throughout the test conditions using pre-recorded coughing, which occurred at intermittent intervals. All participants received a lump sum payment of £12.00.

Verbal protocols

Verbal protocols were used to assess the amount of explicit knowledge generated by each individual. These tested the prediction that individuals learning implicitly would accumulate less explicit knowledge than those learning using either explicit rules or discovery learning. After completing the final 50 putts of the fifth session all participants were asked to write down all the factors that they felt were important in making a successful putt. The participants were asked to use information that they had become aware of over the five putting sessions. As admitted by Masters, this was a "primitive" way of measuring explicit knowledge. However, the same procedures were used in order to fulfil the criteria of replication. Summing the number of explicit rules each participant wrote down scored the written protocols. An explicit rule was understood to be any rule drawn from the explicit written instructions received or specifically relating to the technical and mechanical aspects of holing a putt. Statements not referring to the technical and mechanical aspects of putting were excluded. "Investigator triangulation" (Lincoln & Guba, 1985) was used to check the credibility of the explicit rules elicited from the written protocols. This method involved the use of an additional researcher who was trained in qualitative analysis techniques. Both researchers analysed the protocols independently using the same criteria. Checking one list against the other then corroborated the explicit rules elicited.

Results

The data were subjected to several different analyses. The verbal protocols were examined to establish whether the acquisition of explicit knowledge had been successfully suppressed by the secondary task. The effectiveness of the stress intervention was tested by analysing the cognitive and somatic anxiety components of the CSAI-2 scores, heart rate, and task completion times. Finally, the performance scores were analysed to ascertain the extent of learning over the four skill acquisition sessions and any performance changes during the final stress test. All measures were tested using analyses of variance (ANOVA) and a priori contrasts. Tests of simple main effects and Newman-Keuls tests followed up significant effects in ANOVA models.

Verbal Protocols

It was predicted that the EL and NSC groups together would have a significantly larger pool of explicit knowledge than the IL and ILRLG groups together (Table 1, below). One-way ANOVA showed a significant main effect for the four learning conditions, $F(3, 28) = 5.69, p < 0.01$. The above prediction was confirmed using an a priori contrast, $t(28) = 3.34, p < 0.01$. However, it is perhaps worth noting two points. Firstly, the NSC group actually acquired more rules than any other group, despite having received no explicit instruction. Secondly, the ILRLG group scored higher than the IL group, despite having carried out the RLG throughout the entire experiment.

Table 1. Mean (*SD*) number of explicit rules reported after final stress test.

Group	Explicit rules
Implicit learning	2.75 (1.38)
Implicit learning RLG	4.88 (2.10)
Explicit learning	5.63 (1.51)
Non-stressed control	6.37 (2.26)

Stress intervention

The effectiveness of the stress intervention was analysed by testing four separate a priori contrasts. It was hypothesised that the three stressed groups would exhibit greater increases in anxiety than the unstressed control group on each of the stress indices. Analysis of the cognitive and somatic anxiety subcomponents of the CSAI-2 (Table 2, below) and heart rates (Table 3, below) confirmed these predictions, $t(21.8) = 2.2, p < 0.05$; $t(14.2) = 2.12, p < 0.05$; and $t(28) = 3.22, p < 0.01$, respectively. The contrast performed on the task completion times (Table 3, below), only approached significance, $t(28) = 1.88, p = 0.07$. Pooled variance estimates of “ t ” were used for the heart rate and task completion time contrasts. Separate variance estimates were used for the cognitive and somatic anxiety contrasts, as Cochran’s test for homogeneity of variance was significant in both cases. Taken together, these results suggest that the stress intervention was effective as the three stressed groups (EL, IL and ILRLG) experienced significant increases in performance anxiety pre- and post-stress intervention when compared to the unstressed group (NSC).

Table 2. Mean (*SD*) cognitive and somatic anxiety scores pre- (Pre-SI) and post-stress intervention (Post-SI).

Group	Cognitive anxiety		Somatic anxiety	
	Pre-SI	Post-SI	Pre-SI	Post-SI
IL	17.63 (4.03)	18.75 (4.71)	17.63 (6.65)	16.75 (8.41)
ILRLG	18.63 (6.61)	23.13 (6.08)	18.75 (7.32)	22.00 (7.41)
EL	14.25 (3.28)	16.63 (5.18)	12.13 (2.85)	15.13 (6.08)
NSC	16.38 (4.21)	16.88 (3.91)	15.87 (4.22)	14.25 (5.06)

Table 3. Mean (*SD*) heart rates (bpm) pre- (Pre-SI) and post-stress intervention (Post-SI) and task completion times in sessions 4 and 5.

Group	Heart rate		Task completion time	
	Pre-SI	Post-SI	Session 4	Session 5
IL	68.77 (10.46)	74.31 (14.14)	10.44 (2.60)	10.95 (2.74)
ILRLG	67.69 (11.37)	75.25 (13.46)	09.74 (1.22)	10.89 (1.83)
EL	72.19 (7.07)	79.15 (10.00)	12.09 (2.10)	12.24 (2.75)
NSC	70.95 (7.86)	68.59 (4.77)	12.43 (2.52)	12.18 (2.26)

Performance scores

As with Masters' (1992b) experiment it was not possible to match participants on the basis of skill level. As Masters explained, exposure to a pre-test would have meant that the implicit learning groups would have been given the opportunity to self-generate explicit knowledge. To ensure that the groups were indeed equivalent, a one-way analysis of variance was performed on the mean number of putts holed in the first five putts of session 1 by each group. As hypothesised by Masters, no differences were expected over such a small range of putts. No significant differences were found between the groups, $F(3, 28) = 0.37, p > 0.05$.

Figure 1 (below) displays the mean number of successful putts for each of the four groups over the five sessions. Mixed two-factor analysis of variance (4 x 5, Groups x Sessions, with repeated measures on the sessions factor) revealed a significant interaction, $F(12, 112) = 2.22, p < 0.05$. The main effect for sessions was also significant, $F(4, 112) = 41.18, p < 0.001$. No main effect for group was evident ($p > 0.70$). Newman-Keuls tests on the significant interaction indicated that none of the groups differed significantly at test 1. The IL group scored significantly lower than both the EL and ILRLG groups at test 2. During test 3, the IL group scored significantly lower than only the EL group; and during test 4 both the IL and ILRLG groups scored significantly lower than the EL group. No significant differences were found between the groups at test 5.

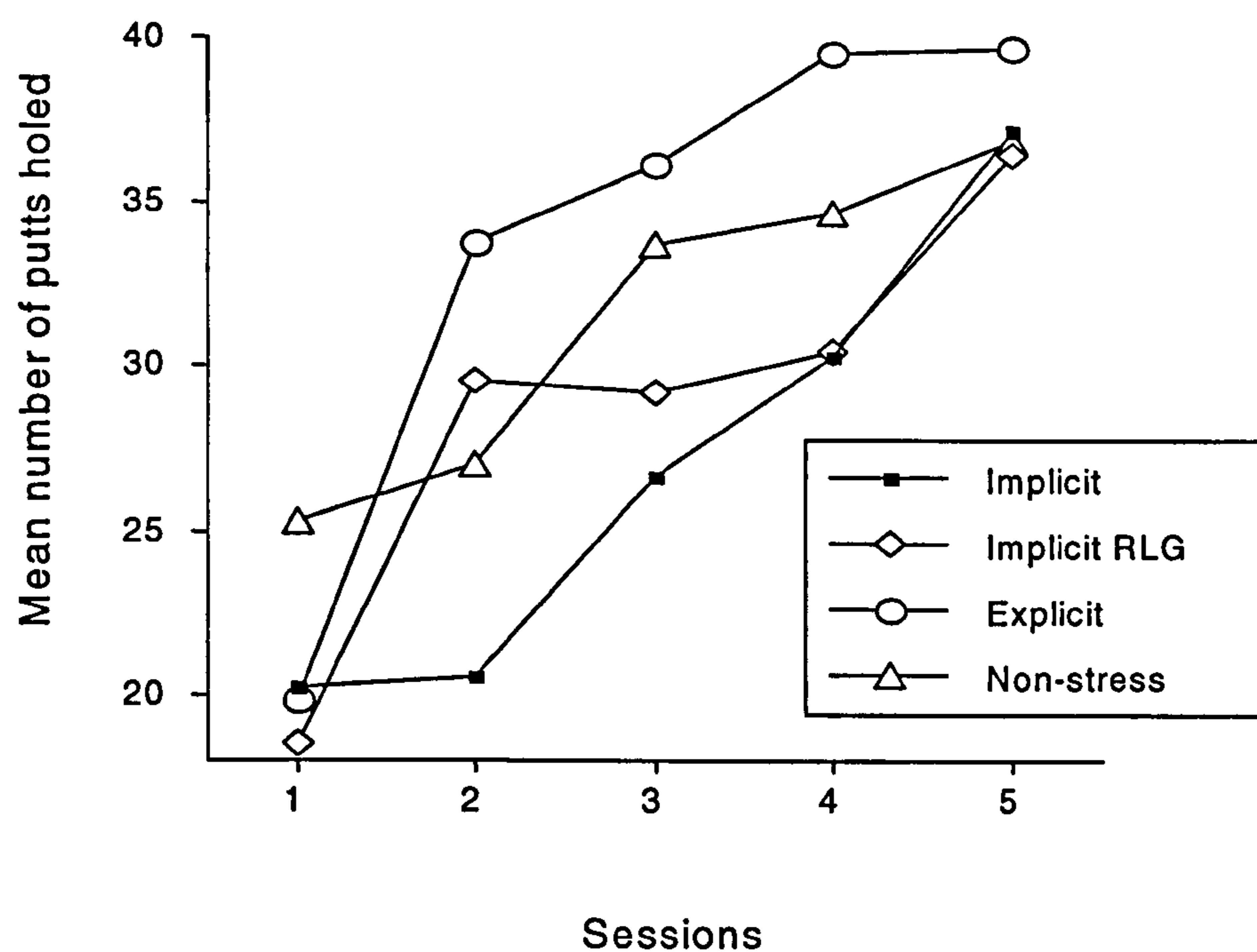


Figure 1. Mean number of putts holed as a function of sessions (1-5).

Newman-Keuls tests were also employed to examine differences for each group's performance over the five tests. Although these indicated that each group improved significantly at some point, they did not reveal significant improvements from test four to five for any of the groups. As shown in Figure 1 the IL, ILRLG and NSC groups improved considerably over these last two sessions. The failure of the Newman-Keuls test to detect any significant differences could have been due to the large number of cells involved in the analysis. Analyses of simple main effects were therefore conducted on each group's performance over the five tests. These analyses revealed significant differences for all groups across the five tests, $F(4, 112) = 13.07, p < 0.01$; $F(4, 112) = 17.28, p < 0.01$; $F(4, 112) = 10.83, p < 0.001$; and $F(4, 112) = 6.66, p < 0.01$ for the IL, EL, ILRLG, and NSC groups respectively. Newman-Keuls tests revealed that the IL group improved significantly from test 1 to test 4, and also from test 4 to test 5. The EL group improved significantly only from test 1 to test 2.

The performance of the ILRLG group also improved significantly from test 1 to test 2, and from test 3 to test 4. This group also made further significant improvements from test 4 to 5. The NSC group showed a significant improvement from test 1 to test 3, and from test 3 to test 4. These results reveal that both the implicit learning groups continued to make significant improvements when subjected to stress, whereas the performance of the EL group, that had acquired explicit knowledge, was severely retarded by the stress intervention.

Discussion

The results of the present study add support to Masters' (1992b) explicit knowledge hypothesis. The results of the stress intervention, when taken together, indicate that performance anxiety was successfully induced in the three stressed groups. As with Masters' experiment, the verbal protocols indicated that the two implicit learning groups had acquired significantly smaller pools of explicit knowledge than the explicit and control groups. However, it is worth noting that the control group reported a larger mean number of explicit rules than the explicit learning group, who were actually supplied with explicit instructions. This leads to the suggestion that, in the absence of explicit instruction, performers are capable of generating their own explicit knowledge base that they may use to guide performance during the early stages of learning.

The performance scores recorded during the present study were similar to those reported by Masters (1992b). Masters, however, reported significant differences between the groups at the end of the first session, whilst in the present study the performance of the groups remained evenly matched at that stage. This suggests that the groups in the present study were well matched on the basis of skill level for this golf putting task. The hypothesis that the "new" implicit learning group (ILRLG), who continued to generate random letters under stress, would suffer from the same disruption to performance as the explicit learning group was not supported by the results. The ILRLG group actually continued to improve their performance during the stress test, mirroring the performance of the IL group. However, the performance of the EL group was impaired in the stress condition.

Assuming that the results of both Masters' (1992) and the present study do support the conscious processing hypothesis, there are several theoretical implications to consider. In the first instance further validity research is required to explain *how* the regression process occurs. Of particular interest here is Eysenck and Calvo's (1992) processing efficiency theory. Eysenck and Calvo's theory has two main premises concerning anxiety effects upon performance. The first of these concerns the effect of worry or self-concern upon the working memory system. According to Eysenck and Calvo, worry affects tasks that impose demands on the capacity of working memory, mainly via the central executive, and, to a lesser degree, the articulatory loop. Anxiety affects the performance of such tasks by preempting some of the resources available to the working memory system; the more difficult the task, the greater the demands made upon the resources of working memory. The second premise concerns a distinction made by Eysenck and Calvo between processing efficiency and performance effectiveness. Performance effectiveness is outcome related and refers to the quality of task performance, while processing efficiency refers to "the relationship between the effectiveness of performance and the effort or processing resources invested in performance" (p. 132). This distinction is important as performance effectiveness and processing efficiency are affected differentially according to Eysenck and Calvo's model. Briefly, it is assumed that anxious individuals will make greater use of a control system which is thought to mediate the effects of anxiety on processing and performance (Hockey, 1986). According to Eysenck (1992), a major function of this control system in anxious performers is to exert more effort in order to maintain performance effectiveness at an "acceptable" level. As a result, anxiety is thought to affect processing efficiency more than performance effectiveness. The "Eysenckian" notion of anxious individuals expending more effort in an attempt to improve performance could dovetail nicely with the explicit knowledge hypothesis. According to processing efficiency theory, greater expenditure of effort is associated with the allocation of additional processing resources. It may be that in trying harder, anxious individuals transfer task control from lower order, automatic sub-systems to higher-order, controlled sub-systems. Eysenck suggests such a possibility, noting that:

While this quantitative shift in the use of processing resources may well be a common reaction to inadequate performance, it is improbable that it is the only reaction. In many cases, *there will be a qualitative shift from the current (and relatively unsuccessful) processing strategy to a different processing strategy.* (p.143, emphasis added)

This contention is supported by Borkovec and Inz (1990) who found that the induction of worry results in thought processes predominating over imagery-based processes, suggesting that worry is more likely to affect the explicitly-oriented articulatory loop than the more implicitly-oriented visuo-spatial sketch pad. As Eysenck admits, such a shift in processing emphasis may mean that worry has more extensive effects upon the working memory system than processing efficiency theory currently predicts. The present results seem to sit comfortably with such a suggestion.

Despite the intuitive appeal of such links, it seems unlikely that in their present forms, either processing efficiency theory or the conscious processing hypothesis can fully explain the behaviour of anxious performers under stress. For example, Eysenck (1992) does not address the issue of motivation (apart from effort). In the context of performance failures or “catastrophes” (Hardy & Parfitt, 1991), it becomes unclear to what extent the results of the present study can be attributed to anxiety effects or to the relative importance of the situation. Motivation may be an important mediating variable here.

Aside from Masters’ (1992b) conscious processing hypothesis, there are also several alternative explanations for the performance of the stressed groups. It may be that both the implicit learning groups continued to improve under stress because in generating random letters during the previous 400 skill acquisition trials they had become desensitised to self-generated verbal distractions. Thus, when exposed to the stress condition, participants in these groups may have become immune to the effects of performance anxiety. This seems to be the most pressing limitation to both Masters’ and the present study. Future studies should examine alternative ways of manipulating the use of explicit knowledge in order to explore this hypothesis.

It could also be argued that the performance disruption suffered by the EL group during the stress test was caused by a ceiling effect. In Masters’ (1992b) study the performance of the control group improved beyond that of the explicit learning

group during the final session. However, in the present study the performance of the NSC group remained below that of the EL group. It could therefore be argued that the EL group had simply “hit” a performance ceiling. However, the author would prefer to argue against such an interpretation on the following grounds. The mean accuracy of the EL group during the final stress test was 39 per cent. This is considerably below the mean accuracy percentage achieved by Masters’ non-stressed control group during their final session. Although Masters did not report the exact figure, examination of his graph reporting the mean number of putts holed reveals that this group approached 60 per cent during the final session. Indeed the performance of the EL group in the present study remained below the 42 per cent mean accuracy figure for all groups in Masters’ study at the corresponding stage. As such, it seems unlikely that the results can be attributed to a performance ceiling.

Applied implications

The results of the present study have several practical ramifications. One of the main reasons, stated earlier, for questioning Masters’ (1992b) interpretation of his results was the reported use of process goals by high level performers to keep them focused during performance. Support for the use of process oriented goals has been established by Orlick and Partington (1988); Kingston, Hardy and Markland (1992) and Kingston and Hardy (1994a; 1994b), with the latter studies by Kingston and associates endorsing the use of process goals over and above performance-related goals. As Masters’ interpretation was supported by the present results, it does appear that the use of process goals by skilled but anxious performers can be called into question. One way around this apparent contradiction may be to encourage the use of pre-performance routines (Boutcher & Zinsser, 1990) which incorporate holistic process goals that focus on global aspects of a skill, thus encouraging chunking and automaticity (Kingston & Hardy, 1994b).

Despite the success of the random letter generation task in suppressing explicit knowledge in the two implicit learning groups, it remains to be seen how this suppression can be transferred to the coaching environment, enabling performers to acquire skills implicitly. The instructions used by performers in the EL group were also successful in encouraging these subjects to rely upon explicit knowledge to guide their performance. However, the ecological validity of these instructions could

be called into question. Typically, coaches would administer such instructions one at a time. Coaches would also rely upon a far greater variety of coaching strategies, for example, demonstrations and augmented feedback, rather than just the written instructions provided in Masters' (1992b) and the present study. While discussing the ecological validity of the study, it seems appropriate to examine the method used to induce stress. The use of monetary incentives and social evaluation appear to be reasonable approximations of those experienced by performers. However, the provision of financial incentives can be questioned as Eysenck (1985) suggests that such incentives can act as a way of actually increasing motivation without generating an anxiety response. It may be that equivalent or greater levels of anxiety could have been achieved by relying upon social evaluation as the sole method of inducing anxiety in the three stressed groups (cf. Calvo, 1985; Calvo et al., 1990).

The results also suggest that coaching strategies that follow the accepted procedures of early reliance upon explicit knowledge to develop motor skills can be called into question. Tuition of this type could, potentially, lead to skill breaking down under conditions of high stress. Indeed, much of the current research examining optimal practice situations addresses problems such as varying the form and timing of different types of explicit information (Berry & Dienes, 1993). This suggests a need to examine the potential of implicitly oriented learning strategies in coaching and teaching environments.

The interaction of both explicit and implicit learning strategies in the context of motor skill acquisition also requires empirical analysis. It appears that different processes may underpin performance at different stages of learning and a variety of coaching and teaching strategies may be required to produce optimal results (Annett, 1991). Similarly, the role of explicit and implicit learning strategies probably varies as a function of task demands. One can imagine, for example, that explicit instruction probably plays a much more central role in strategic sports such as rock climbing, with implicit strategies possibly predominating in sports such as tennis.

A final practical implication concerns the use of modelling (Bandura, 1971) and imagery (Murphy & Jowdy, 1992) by performers. These techniques may enable performers to make better use of implicit rather than explicit knowledge. It may be that modelling and imagery techniques could enable learners to produce holistic conceptual representations of movements thus encouraging automatic functioning

and accelerating the learning process. In a similar manner, holistic imagery techniques could help elite athletes avoid the debilitating effects of anxiety.

Summary and conclusions

The preceding discussion has posed several questions and opened up a number of potential avenues of investigation that future researchers may wish to explore. The most pressing of these concerns is Masters' (1992b) conscious processing hypothesis explanation of anxiety effects upon performance. The role of implicit knowledge in motor skill acquisition also warrants further examination, especially as this study supports Masters' contention that such knowledge demonstrates robustness under conditions of high anxiety.

Chapter 3

Effect of Task-Relevant Cues and State Anxiety on Motor Performance¹

(Study 2)

Abstract

Twelve experienced, female trampolinists participated in a field study designed to test Masters' conscious processing hypothesis which predicts that the combination of task-relevant knowledge and high levels of state anxiety will impair motor performance. Participants performed their voluntary competition routines while shadowing task-relevant cues in training and pre-competition sessions. State anxiety increased from training to pre-competition sessions. Two-factor analysis of variance (2 x 2, Anxiety x Shadowing, with repeated measures on both factors) indicated that performance in the high anxiety shadowing condition was impaired, supporting the conscious processing hypothesis. However, an alternative attentional explanation of the data was identified.

¹ Currently accepted for publication as Hardy, L., Mullen, R., and Martin, N., Effect of task-relevant cues and state anxiety upon motor performance. *Perceptual and Motor Skills*. The data for this chapter was collected by Nikki Martin as part of an undergraduate research project at the University of Wales, Bangor. The study is included in this thesis more for the sake of completeness than originality.

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Chapter 4

State anxiety and motor performance:

Testing the conscious processing hypothesis¹

(Study 3)

Abstract

Previous research has argued that skills acquired explicitly are more likely to fail under stress than skills that have been learned implicitly. The present study addresses an alternative explanation for the robustness under stress of implicit task performance. As implicit learners acquired the skill of golf putting while generating random letters, it is possible that they had become desensitised to self-generated verbalisations and thus immune to the effects of competitive anxiety. The present study tested the conscious processing hypothesis, while controlling for desensitisation and a further rival attentional threshold hypothesis. The study also examined the effect of increased state anxiety upon the kinematic processes underlying performance breakdowns. For task performance, evidence was found that partially supported the conscious processing hypothesis, while the results of the kinematic analysis of the putting stroke were equivocal. Analysis of self-reported effort scores supported the predictions of processing efficiency theory.

¹ In press as Mullen, R. and Hardy, L., State anxiety and motor performance: Testing the conscious processing hypothesis. *Journal of Sports Sciences*, 18.

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Chapter 5

Conscious processing and motor performance: An interdisciplinary examination

(Study 4)

Abstract

The conscious processing hypothesis has recently emerged in the sport psychology literature as a viable explanation for the effect of anxiety upon motor performance. The study reported here aimed to examine the conscious processing hypothesis, while controlling for an alternative attentional explanation of anxiety effects. Twenty-four skilled, male golfers completed 10 putts in control, task-relevant shadowing, and task-irrelevant tone counting conditions, while stressed and unstressed. Two-factor ANOVA revealed that performance deteriorated in the high anxiety shadowing and tone counting conditions. Kinematic analysis of clubhead and joint dynamics produced evidence supportive of a refreezing of degrees of freedom of the left wrist. Spectral analysis of heart rate variability indicated that performance impairment was associated with an increase in the power of the high frequency component of the heart rate power spectrum.

Introduction

Despite recent advances in explanations of the anxiety-performance relationship (Hardy, 1996b; Jones & Hanton, 1996), existing models and theories fail to satisfactorily address *how* anxiety affects performance. Two plausible explanations have emerged with the potential to explain anxiety-induced performance impairment, Masters' (1992b) conscious processing hypothesis and Eysenck and Calvo's (1992) processing efficiency theory.

Masters' (1992b) conscious processing hypothesis predicts that increased state anxiety leads performers to focus attention inwards in an attempt to control motor skills using task-relevant, explicit knowledge. Baumeister (1984) had previously found that highly motivated performers in competitive situations had a tendency to focus on the process of performing. By consciously monitoring their performance in an attempt to ensure success, highly skilled performers are likely to interfere with normal automatic task processing and adopt inappropriate control strategies. As a result, performance suffers. More recent evidence has supported the notion of conscious control (Lewis & Linder, 1997).

Masters based his (1992b) conceptualisation of this phenomenon upon stages of learning (Fitts & Posner, 1967). Masters hypothesised that under stress, the smooth, unconscious, covertly controlled processes of the expert become destabilised as performers attempt to gain conscious control over actions and, in so doing, adopt a mode of control based upon explicit, or declarative, knowledge which is associated with early stages of learning. Masters and Hardy, Mullen and Jones (1996, Chapter 2 of this thesis) examined the conscious processing hypothesis using a learning paradigm, in which participants acquired the skill of golf putting over 400 trials using either an explicit or an implicit learning strategy. In a subsequent transfer test, in which state anxiety was elevated, participants who had learned using an explicit strategy suffered performance impairment, while those using an implicit strategy continued to improve. Hardy, Mullen et al. identified an alternative interpretation for their own and Masters' results. Participants who learnt implicitly did so while generating random letters to prevent the generation of explicit knowledge about the task. Over 400 trials, these participants may have become desensitised to self-generated verbal distractions and at least partially immune to the effects of state anxiety. Hardy, Mullen, and Martin (under review, Chapter 3 of this thesis) set out to test the conscious processing hypothesis using a design that was not confounded

by desensitisation effects. Hardy et al. used a performance paradigm in which anxious trampolinists performed their voluntary competition routines while shadowing task-relevant cues. Hardy et al. found support for the conscious processing hypothesis. In a further study, Mullen and Hardy (in press, Chapter 4 of this thesis) successfully controlled for the desensitisation hypothesis using the performance paradigm adopted by Hardy et al. Skilled golfers putted while using explicit instructions on how to putt in order to encourage lapses into conscious processing. In a separate condition, the golfers putted while simultaneously performing a random letter generation task (Baddeley, 1966). The function of the random letter generation task was to interfere with the operation of the central executive of the working memory system (Baddeley, 1986), preventing participants accessing their explicit knowledge base.

The performance paradigm and the random letter generation task also allowed Mullen and Hardy (in press) to examine a further possible explanation for the conscious processing effects identified by Hardy et al. (under review). If high levels of state anxiety and task-relevant cues combine to cause performance decrements then it is possible that performance impairment could be attributed to attentional overload, as predicted by Eysenck and Calvo's (1992) processing efficiency theory. Put simply, task-relevant cues may take up a "chunk" of attentional space, while anxiety-related worry takes up another "chunk". Individually, these do not affect performance, however, together they operate additively and deplete the resources available to maintain task performance. Mullen and Hardy found partial, although not unequivocal, support for conscious processing effects.

Another key aspect of both conscious processing and processing efficiency perspectives is the amount of effort invested by performers. From a conscious processing perspective, increased effort should be related to the intensity of attentional processing as task control is transferred away from automatic processes to more effortful, attention-demanding, higher-order processes. In processing efficiency terms, anxious individuals attempt to compensate for performance decrements produced by task-irrelevant processing caused by worry by increasing attentional resources. In doing so, anxious performers may be able to maintain task performance, but at a greater cost to the processing system compared to the processing costs incurred in low anxiety conditions. Increases in on-task effort can be used to explain how anxious performers sometimes maintain "performance

effectiveness” at the expense of “processing efficiency” (Eysenck & Calvo, 1992). As Eysenck and Calvo note, the weakness of many studies is their propensity to measure only performance effectiveness. Previous research has supported the suggestion that participants increase their effort as a function of increased anxiety (Calvo, Alamo, & Ramos, 1990; Calvo & Ramos, 1989). Such evidence adds weight to Eysenck’s concern that a research focus on performance effectiveness does not accurately reflect the effects of anxiety upon task performance.

Mullen and Hardy (in press) used a self-reported effort measure to examine the patterning of effort associated with conscious processing. Although their performance results partially supported Masters’ conscious processing hypothesis, the patterning of effort scores produced by participants supported Eysenck and Calvo’s (1992) compensatory effort hypothesis, as individuals increased their effort expenditure as a function of elevated levels of state anxiety. By their own admission, the single item, self-reported measure of effort used by Mullen and Hardy was rather “crude” in nature. More sophisticated measures of effort are available and have long been a feature of psychophysiology. However, as Abernethy, Summers and Ford (1998) note, “the methods used to develop this knowledge base have, disappointingly, had only limited impact on research within sport and exercise psychology” (p. 185). Sport-related studies have adopted some psychophysiological measures, for example, heart rate (Boutcher & Zinsser, 1990; Crews, 1989); electroencephalography (Landers et al., 1994) and electromyography (Kontinnen, Lyytinen, & Viitasalo, 1998). One psychophysiological measure that has been largely ignored in the sport-related attention literature is heart rate variability (HRV Mulder & Mulder, 1981). In sports science, HRV has frequently been used in physiological studies examining cardiac and autonomic responses to exercise (Warren, Jaffe, Wraa, & Stebbins, 1997). HRV has also been a prominent feature of human factors research, with studies focusing upon the central regulation of autonomic state, fundamental links between physiological and psychological processes and the evaluation of cognitive development and clinical risk (Berntson et al., 1997). Other researchers have suggested that HRV can be used as an index of mental effort (Althaus, Mulder, Van Roon, & Minderaa, 1998; Mulder, 1992). Laboratory and field studies have shown that HRV, as indexed by spectral analysis of the cardiac signal, can reflect changes in mental effort. Such changes are thought to reflect an increase in the use of controlled processing for task performance

(Aasman, Mulder, & Lambertus, 1987; Tattersall & Hockey, 1995; Vicente, Thornton, & Moray, 1987).

HRV scores can be obtained using a range of methods, ranging from time domain statistics, such as the standard deviation of a series of inter-beat intervals, to spectral analysis of the heart rate signal. The advantage of using spectral analysis is that it provides the researcher with an insight into the sources of variance influencing HRV. Spectral decomposition of the heart rate signal produces periodic components of HRV aggregated within three main frequency bands (Mulder, 1985). The three frequency bands are associated with different functional influences in the modulation of heart rate:

1. A low frequency band (0.02 - 0.06 Hz), believed to reflect thermoregulatory control and adaptation to task demands, although as Grossman (1992) notes, the mechanisms underlying oscillations in this frequency remain unclear.
2. A mid-frequency band (0.07 - 0.14 Hz), sensitive to cognitive loading associated with controlled processing. According to some researchers (e.g. Mulder, 1988), the mid-frequency band is related to short-term regulation of blood pressure. The mechanisms behind this modulation of blood pressure are the subject of some debate (Berntson et al., 1997). While some researchers believe that fluctuations in this frequency are the result of sympathetic traffic to the sino-atrial node, others think that mid-frequency rhythms may reflect the effects of both branches of the autonomic nervous system (Grossman, 1992). Still others believe that the relative balance between sympathetic and vagal control can be indexed by looking at the relative balance between the mid- and high-frequency bands (Malliani, Pagani, & Lombardi, 1994).
3. A high-frequency band (0.15 - 0.50 Hz), which is probably the most well established measure of a discrete set of neural mechanisms (Grossman, 1992). Fluctuations at these frequencies are related to momentary respiratory influences or respiratory sinus-arrhythmia. Respiratory sinus arrhythmia is thought to be predominantly mediated by respiratory gating of vagal efferent activity to the heart (Grossman, 1992). The dominant parasympathetic influence at these frequencies is mainly a function of the slower dynamics of the sympathetic system that are manifested at lower frequencies (Berntson et al., 1997).

The mid-frequency band has consistently responded to changes from rest to task and to a range of between task manipulations (Mulder & Mulder, 1987). It appears that

mid-frequency responses are less sensitive to changes in difficulty levels within the same type of task. However, Jorna (1992) notes that major changes in task structure, which induce changes in the mode of operation, as in the shift from automatic to controlled processing, will induce sizeable HRV effects. Such effects are in line with the changes predicted by the conscious processing hypothesis. A number of laboratory and field based studies have examined HRV in the mid-frequency band under “stressful” conditions (see Mulder & Mulder, 1987, for a review). Unfortunately, none of these have involved sport-related motor skills or stress interventions similar to those experienced by sports performers.

Reductions in the HRVMF band associated with controlled processing appear to dovetail nicely with the predictions of the conscious processing hypothesis. However, the patterning of autonomic activity associated with compensatory effort from a processing efficiency perspective is less clear. According to Mulder (1992), compensatory effort invoked to cope with changes in task demands is not reflected in reductions in spectral power in the HRVMF band. External stressors, such as fatigue and noise, appear to induce quite different physiological states, reflected by increases in spectral power in both the low and mid-frequency bands. Spectral analysis could help distinguish between conscious processing and processing efficiency explanations of the anxiety-performance relationship by identifying cardiovascular markers of the patterning of effort associated with high levels of state anxiety.

Mullen and Hardy (in press) also examined the kinematic processes underlying conscious processing effects. Using two-dimensional analysis of working point (clubhead) and joint behaviour, Mullen and Hardy failed to find any firm kinematic evidence to support the conscious processing effects found for the performance data. The kinematic variables selected by Mullen and Hardy were exploratory in nature and based upon suggestions made in the motor learning (Delay, Nougier, Orliaguet, & Coello, 1997) and control (Handford, Davids, Bennett, & Button, 1997) literature. The present study focused more closely on predictions generated by the conscious processing hypothesis. Specifically, Masters (1992a) suggested that the shift from automatic to controlled task processing should result in changes to the physical characteristics accompanying performance. Automatic task performance is fast, smooth and relatively effortless, while performances governed by controlled processes are slower, erratic and effortful (Schneider, Dumais, & Shiffrin, 1984).

Temporal analyses were supplemented by an examination of the time to the initial acceleration peak of the clubhead following initiation of the downswing in order to index the smoothness of the movement at working point level (Handford et al., 1997; Schneider, Zernicke, Schmidt, & Hart, 1989). Mullen and Hardy also used cross correlations to assess the fluency of the left and right wrist joints. Sidaway, Heise and Schoenfelder-Zohdi (1995) have criticised the use of correlation coefficients to measure motor behaviour that might be non-linear and recommended the use of angle-angle diagrams to assess inter- and intra-limb coordination. However, Beuter, Duda, and Widule (1989) used angle-angle diagrams and failed to identify coordination changes associated with increased physiological arousal in a stepping task. The use of phase plane portraits, in which joint angular velocities were plotted against their angular displacements, proved more effective. Beuter et al. found that the distal (ankle) joint was more susceptible to disruption than proximal (knee and hip) joints. Accordingly, phase plane portraits were preferred to angle-angle diagrams in the present study. Phase plane portraits of the left and right wrist joints were used to examine the smoothness of the putting stroke in the distal (wrist) joint. Analysis of the range of motion of the wrist joints was also included. From an ecological psychology perspective, anxious individuals may attempt to regain control of motor actions by re-freezing degrees of freedom in distal joints (Handford et al., 1997). Although not entirely consistent with notions of regression from a cognitive perspective, such ideas may be relevant in the context of conscious processing effects. It was hypothesised that in attempting to regain conscious control of the putting stroke, anxious performers would “re-freeze” degrees of freedom in the distal (wrist) joint. As Mullen and Hardy noted, this may appear counterintuitive to notions of increased “wrist break” usually associated with the “yips”, but is more in line with current evidence on motor learning strategies.

The main aim of the present study was to further examine conscious processing and processing efficiency explanations of the anxiety-performance relationship. It was predicted that the anxiety intervention would significantly increase both cognitive and somatic state anxiety, in line with multidimensional anxiety theory (Martens, Vealey, & Burton, 1990). In terms of performance, the conscious processing hypothesis predicts that the largest performance decrements occur when cognitively anxious participants use task-relevant cues. Processing efficiency theory, on the other hand, predicts that performance impairment will occur when cognitively

anxious participants putt using task-relevant or task-irrelevant cues. Spectral analysis of heart rate variability and a self-report measure were used to examine the energetical patterning of effort. *In vivo* three-dimensional kinematic analyses of joint and clubhead behaviour provided an insight into the processes underpinning performance.

Method

Participants

Twenty-four right dominant, right-handed male golfers volunteered to take part in the study. All of the participants used a traditional putting technique incorporating either an overlapping or interlocking grip. Putting ability was examined by conducting a median split on absolute error putting performance in the low anxiety control condition in the present study. An independent *t* test confirmed that the putting ability of the two groups was significantly different, $t(17.36)^1 = 0.23$, $p < .05$. Putting ability was included as an independent variable in subsequent analyses. Mean age for the “better” putters ($n = 12$) was 29.92 ($SD = 3.32$) and for the “poorer” putters ($n = 12$), 23.5 ($SD = 0.93$). For the better putters mean handicap was 15.75 ($SD = 1.23$) and mean number of years playing experience was 8.17 ($SD = 1.50$). For the poorer putters mean handicap was 15.67 ($SD = 1.10$) and mean number of years playing experience was 5.08 ($SD = 0.78$). All participants gave informed consent before beginning the study.

Apparatus

Participants putted up and across a 12.5% incline at a hole (diameter = 108 mm) 3 m away, using their own personal putter. Heart rate data were collected using Ag/AgCl electrodes that were attached to three sites on the subjects chest: the sternum, lower left rib cage (V5/V6) and the lower right rib cage. Interbeat intervals were determined using a dedicated R-peak trigger which detected the QRS complex in the electrocardiogram with an accuracy of 2 ms. The data recorder fitted into a belt worn around the participant’s waist and did not interfere with the putting stroke. Putting trials were recorded using a two-camera optoelectric imaging system (MacReflex, Qualisys, Partille, Sweden) operating at 120Hz with a shutter speed of 0.25 ms. Passive retro-reflective markers were placed on the right and left shoulder,

¹ Corrected for unequal variances.

elbow, and wrist, at the top of the club shaft and on the clubhead. During the tone counting condition, described below, a BBC microcomputer generated high and low pitched tones at random, with a frequency of 1 Hz.

Measures

Competitive state anxiety. State anxiety was assessed using the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990). The CSAI-2 is a sport-specific, self-report inventory that has been demonstrated to be a reliable and valid measure of cognitive and somatic anxiety and self-confidence with alpha reliability coefficients ranging from .79 to .90 (Martens, Burton, et al., 1990). The directions at the start of the CSAI-2 were slightly modified to account for the fact that the one of the anxiety conditions was a putting competition and the other was a neutral putting task. Heart rate was also used as a measure of physiological arousal in conjunction with somatic anxiety. As Hardy (1996b) has noted, physiological arousal can influence performance directly, for example by inducing tonic changes in muscular tension that may affect fine motor coordination, or indirectly through performers' perceptions of their physiological state as indexed by the somatic anxiety component of the CSAI-2.

Performance. Polar coordinates, allowing independent measures of "strength" and direction, assessed the accuracy of the putts. The polar coordinates are expressed as the distance of the ball from the start of the putt (r), and the angle of deviation (θ) from a line drawn from the start of the putt to the centre of the hole. Successful putts were therefore scored: $r = 3$, $\theta = 0$.

Heart rate variability. Spectral analysis of the cardiac interval signal was performed with the CARSPAN spectral analysis programme (Mulder, Van Roon, & Schweizer, 1995). Spectral measures are expressed in relative terms (Mulder, 1992), equivalent to the squared coefficients of variation for the measurement period (squared modulation index, SMI). Measures used in the main analysis were HR (bpm) and mean HRV in the mid-frequency band (HRVMF, 0.07-0.14 Hz) and the high-frequency band (HRVHF band, 0.15-0.40 Hz). Analysis of the low frequency (LF) band was not considered valid because of its high vulnerability to non-stationarity effects (Mulder, 1988). Measurement epochs of 5 minutes or less are also too brief to obtain a reliable estimate of power in the LF band. Changes in HR and HRV from

baseline to task were computed for each condition and used as dependent variables in subsequent analyses.

Self-reported effort. A retrospective, self-report measure was used to examine effort (Mullen & Hardy, in press). Participants rated their perception of effort invested in the task via the following question: “Based upon the most amount of effort you have ever put into a golf putt, how would you rate your effort during the last ten putts? 0 = no effort, 10 = the most effort” (Crews, D., personal communication to L. Hardy, 1993).

Manipulation check. The manipulation check took the form of a social validation questionnaire created specifically for this study. Four questions with a dichotomous response scale were included. The first two questions asked whether participants felt that they had performed as requested during the shadowing and tone counting conditions. The third question determined whether participants used the tone counting task as a rhythm to aid their putting and the fourth question asked whether, overall, performers felt they had performed as asked. Finally, an open-ended question asked participants to briefly describe what they were thinking about during the control condition. The questions established adherence to treatment instructions.

Experimental conditions

Each participant performed in all conditions as detailed below:

Task-relevant condition (TR). Participants putted while shadowing task-relevant coaching points to encourage lapses into conscious processing. Participants were asked to select three personal coaching points from a list compiled from a coaching manual (Cochran & Stobbs, 1968). Participants were allowed to generate their own coaching points if they felt that none of the available points were suitable. The performers paraphrased the coaching points into verbal cues that the experimenter repeated aloud during the final stages of each participant’s pre-performance routine between the set up and initiation of the backswing. It was emphasised to participants that they should concentrate on using the coaching points to guide their performance on each putt.

Tone-counting condition (TC). Participants were asked to putt while listening to randomly generated high and low pitched tones. Participants were instructed to give priority to the tones and to count the number of high pitch tones emitted during each

putt (Cohen, Ivry, & Keele, 1990). This task replaced the random letter generation used by Mullen and Hardy (in press), as continuous verbalisation would have had a confounding effect upon heart rate variability (Jorna, 1992; Mulder, 1992).

Control condition. Participants were required to putt as they would normally putt.

Design

Participants were tested on two separate days, once with a neutral instructional set and once with an evaluative instructional set. Administration of the instructional sets was counterbalanced. The evaluative instructions informed participants that they had the opportunity to take part in an indoor putting competition, with prizes of £40, £20, £10, and £5 available. Competitors were to be judged on their putting performance, measured in terms of the lowest absolute error scores, and an evaluation of their putting strokes compared to the strokes of single handicap players. They were informed that the evaluation was to be conducted by a golf professional. It was emphasised that they would have to try very hard if they were to perform well in comparison with the other players. A league table of final results was also to be circulated to all participants at the end of the study. The neutral instructions informed participants that their individual data would not be compared to anyone else's, and that their scores were to be combined with other players of a similar standard in order to expand the experimenter's database for future work. Participants were required to complete the putting task in the control, tone counting and shadowing conditions. Thus, each participant completed three sets of trials on each day. Participants were randomly assigned to treatment orders and the order of the first and last conditions was reversed during the second set of trials.

Procedure

Participants attended individually and were informed that the researcher was interested in the effects of a variety of different conditions on putting performance. On arrival, performers were fitted with the ECG electrodes and the R peak trigger, and then asked to take a seat and relax for 5 minutes. This ensured that heart rate values stabilised prior to the collection of baseline data. A five-minute baseline data collection period followed, during which participants remained seated. Following baseline data collection, participants read the appropriate instructional set and completed the CSAI-2. Participants began putting as soon as the CSAI-2 had been

completed. Each participant completed 20 warm up putts before beginning the experimental procedures, which consisted of 10 putts in each of the conditions outlined above. Each putt was marked to allow measurement of polar coordinates following the session. After completing a block of 10 putts, participants completed the self-reported effort measure and then rested for three minutes in order to allow heart rate effects to dissipate before beginning the next trial. Completion of the post-experimental manipulation check followed the final block of 10 putts. The questions were used to exclude participants who experienced major problems adhering to the instructions. Following the final session, participants were thanked and debriefed about the true objectives of the experiment.

Data Reduction

Heart rate variability. Possible artefacts were identified by calculating the mean interbeat interval (IBI) value and its standard deviation in a 40-second time window. The window was shifted throughout the data set and an artefact was detected if the current IBI value was more than 3 standard deviations away from the current shifting mean. For each participant, the total artefact time was always less than 5% of total registration time during any session. The procedures described by Mulder (1992) were used to correct artefacts. Normal distribution of all HR and HRV data was achieved using natural logarithmic transformations.

Kinematics. Joint angles were defined as follows: elbow angle – the angle created by the shoulder, elbow, and wrist markers; and wrist angle – the angle created by the elbow, wrist, and top of club shaft markers. Preliminary analysis of the data suggested that the optimal sampling frequency was 60 Hz. Filtering was performed by initially estimating optimal cut-off frequencies for displacement, velocity and acceleration using power spectrum assessment. A recursive second-order low-pass Butterworth filter was used to filter the data, and first-order finite differences were used to calculate higher-order derivatives (Giakas & Baltzopoulos, 1997; Giakas, Baltzopoulos, & Bartlett, 1998).

The primary dependent variables were logically divided into distinct subsets that assessed different aspects of the putting stroke. For working point dynamics, backswing and downswing times assessed task completion times. Time to the initial acceleration peak of the clubhead following initiation of the downswing indexed the smoothness of the stroke. Analysis of joint dynamics comprised examination of

phase plane portraits for the left and right wrist and the range of motion of both wrists throughout the entire putt. Due to the large volume of data, phase plane portraits and joint range of motion analyses were restricted to 8 participants.

Results

Putting ability was originally included as an independent variable in our analyses. However, preliminary examination revealed that for all anxiety, performance, cardiac, and self-reported effort dependent variables, no significant effects for putting ability were present. As a result, all analyses reported treated the participants as a single group of 24 participants aged between 19 and 62 ($M = 36.33$, $SD = 16.33$), with handicaps ranging from 10 to 21 ($M = 14$, $SD = 4.4$). Mean playing experience for the group was 6.3 years ($SD = 8.56$).

One-tailed, paired *t*-tests for the CSAI-2 components determined the effectiveness of the anxiety manipulation. Performance scores were analysed using a priori contrasts that tested two interactions, one specifically predicted by the conscious processing hypothesis and the other by processing efficiency theory. The conscious processing contrast tested whether the difference between the tone counting and shadowing conditions changed as a function of anxiety. The processing efficiency contrast tested whether the difference between the control condition and the average of the tone counting and shadowing conditions taken together changed as a function of anxiety.

Self-reported effort, HR, HRVMF, and HRVHF scores were also examined using a set of a priori contrasts. The first of these tested whether the dependent variables increased as a function of anxiety across the three putting conditions, as predicted by processing efficiency theory. The two a priori contrasts used to test the performance scores, one for the conscious processing hypothesis and one for processing efficiency theory, were also employed to examine whether the anxiety and putting conditions produced any interaction effects for the effort variables.

It could be argued that the analysis of the data outlined above should proceed using multivariate analysis of variance (MANOVA) as it may be considered relevant to examine the linear combination of, for example, the polar coordinates, as both relate to performance. However, as hypotheses about the patterns of effects to be obtained across the dependent variables were specific, univariate tests were considered more appropriate. Additionally, the specific nature of the hypotheses

meant that the normal increase in Type 1 error rate associated with multiple tests was no longer applicable (Stevens, 1996). Consequently, no reduction in alpha level was deemed necessary and alpha was maintained at .05 for the anxiety, performance, cardiac, and self-reported effort tests.

Kinematic variables were examined using two-way analysis of variance (ANOVA; Anxiety x Putting Condition, with repeated measures on both factors). Alpha for the kinematic variables was adjusted using Bonferroni corrections according to the subsets identified earlier. For clubhead backswing and downswing times, and joint range of motion for the left and right wrist, alpha was adjusted to .025. For the single index of smoothness of the stroke, time to initial peak acceleration, alpha was maintained at .05. Effect sizes for contrast analyses and ANOVA were computed using omega squared (ω^2) for fixed effect models (Vaughn & Corballis, 1969). Omega-squared was preferred to the eta-squared statistic used in previous studies as it is a less biased estimate of the magnitude of experimental effect (Howell, 1997). As Howell notes, although ω^2 is also biased, it is a much more effective inferential statistic than eta-squared, which is largely descriptive.

Manipulation check

Twenty-three participants indicated that they focused upon the coaching points in the low and high anxiety shadowing conditions. In the tone counting condition, 21 participants confirmed that they concentrated on counting the tones in the low anxiety condition. This number decreased to 20 in the high anxiety condition. Minor problems were also indicated, as 7 participants indicated that they used the tones as a rhythm to aid their putting in the low anxiety condition. This number decreased to 6 in the high anxiety condition. Overall, 100% of participants indicated that they believed they had carried out the instructions as requested. However, responses to the previous questions suggested that this was not the case. McNemar tests indicated that none of the responses to the manipulation check changed significantly from low to high anxiety conditions. The mean number of tones counted correctly increased from 84.58% ($SD = 15.31$) in the low anxiety condition

to 86.25% ($SD = 18.37$) in the high anxiety condition. Wilcoxon's signed ranks test indicated that this change was not significant ($Z = -.286, p > .05$).

Given the problems identified with adherence to the shadowing and tone counting tasks, all data were analysed with and without the problem participants. Removal of the problem participants did not affect the results obtained from the full data set. As a result, data from all participants is reported here.

State anxiety

As predicted, the anxiety manipulation significantly increased cognitive anxiety levels (low anxiety mean = 15.22, $SD = 4.38$; high anxiety mean = 17.21, $SD = 4.27$; $t(23) = 3.12, p < .01$). Neither somatic anxiety (low anxiety mean = 13, $SD = 3.57$; high anxiety mean = 14.22, $SD = 4.73$; $t(23) = -1.63, p > .05$) nor self-confidence (low anxiety mean = 25.96, $SD = 1.22$; high anxiety mean = 24.74, $SD = 4.77$; $t(23) = .95, p > .05$) differed across anxiety conditions.

Performance

For directional bias, neither the conscious processing nor processing efficiency contrast was significant, $F(1, 23) = .841, p > .05, \omega^2 = .006$, and $F(1, 23) = 3.07, p > .05, \omega^2 = 0.08; p > .05$, respectively. For length of putt, the conscious processing contrast was also not significant, $F(1, 23) = .04, p > .05, \omega^2 = 0.004$. However, the processing efficiency contrast did reach significance, $F(1, 23) = 6.1, p < .05, \omega^2 = .21$. Examination of Figure 1 (below) indicates that putts were significantly longer in the high anxiety tone counting and shadowing conditions.

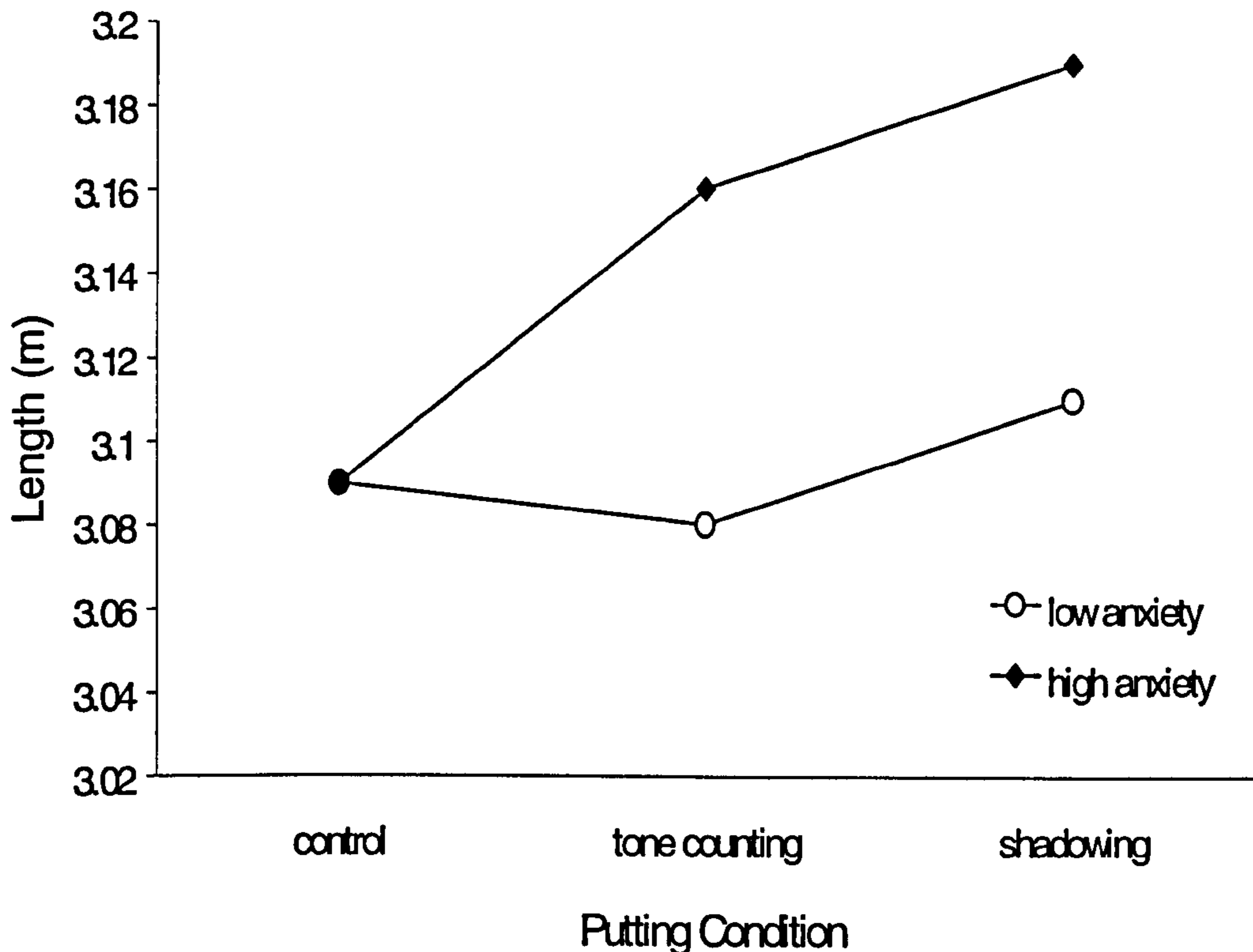


Figure 1. Mean performance scores for length of putt.

Cardiac variables and self-reported effort

For self-reported effort, HRVMF and HRVHF, the main effect for anxiety conditions was not significant, $F(1, 23) = 1.89, p > .05, \omega^2 = .02$; $F(1, 23) = .03, p > .05, \omega^2 = .00$; $F(1, 23) = 3.07, p > .05, \omega^2 = .08$, respectively. The main effect for HR for anxiety condition approached significance, $F(1, 23) = 3.72, p = .06, \omega^2 = .09$. For self-reported effort, HR and HRVMF, neither the conscious processing, $F(1, 23) = .180, p > .05, \omega^2 = .002$; $F(1, 23) = 2.17, p > .05, \omega^2 = .04$; $F(1, 23) = .03, p > .05, \omega^2 = .00$, respectively; nor processing efficiency contrasts were significant, $F(1, 23) = .62, p > .05, \omega^2 = .018$; $F(1, 23) = .00, p > .05, \omega^2 = .00$; $F(1, 23) = 1.18, p > .05, \omega^2 = .05$, respectively.

Table 1. Mean (*SD*) self-reported effort, HR, and HRVMF scores.

Variable	Anxiety	Putting Condition		
		Control	Tone counting	Shadowing
SRE*	High	7.79 (1.32)	7.00 (1.61)	8.17 (1.37)
	Low	7.75 (1.23)	6.58 (1.91)	7.92 (1.25)
HR	High	3.01 (0.35)	2.92 (0.28)	3.01 (0.29)
	Low	2.87 (0.32)	2.75 (0.33)	2.91 (0.25)
HRVMF*	High	7055 (1987)	6985 (1479)	7332 (1743)
	Low	7153 (1829)	6882 (1355)	7286 (1901)

Note. SRE = Self-reported effort; HR = heart rate, HRVMF = heart rate variability mid-frequency band , * = Values reported are untransformed units for ease of interpretation. (N.B. values for cardiac variables are differences from baseline).

Similarly, for HRVHF, the conscious processing contrast failed to reach significance, $F(1, 23) = .52, p > .05, \omega^2 = .002$. However, the contrast examining the processing efficiency prediction did reveal a significant effect, $F(1, 23) = 4.93, p < .05, \omega^2 = .18$. Examination of figure 2 (below) reveals that in both low and high anxiety control conditions and the high anxiety shadowing and tone counting conditions, differences in power in the HRVHF band remained close to baseline levels. In the low anxiety shadowing and tone counting conditions, however, the HRVHF response was considerably elevated from baseline.

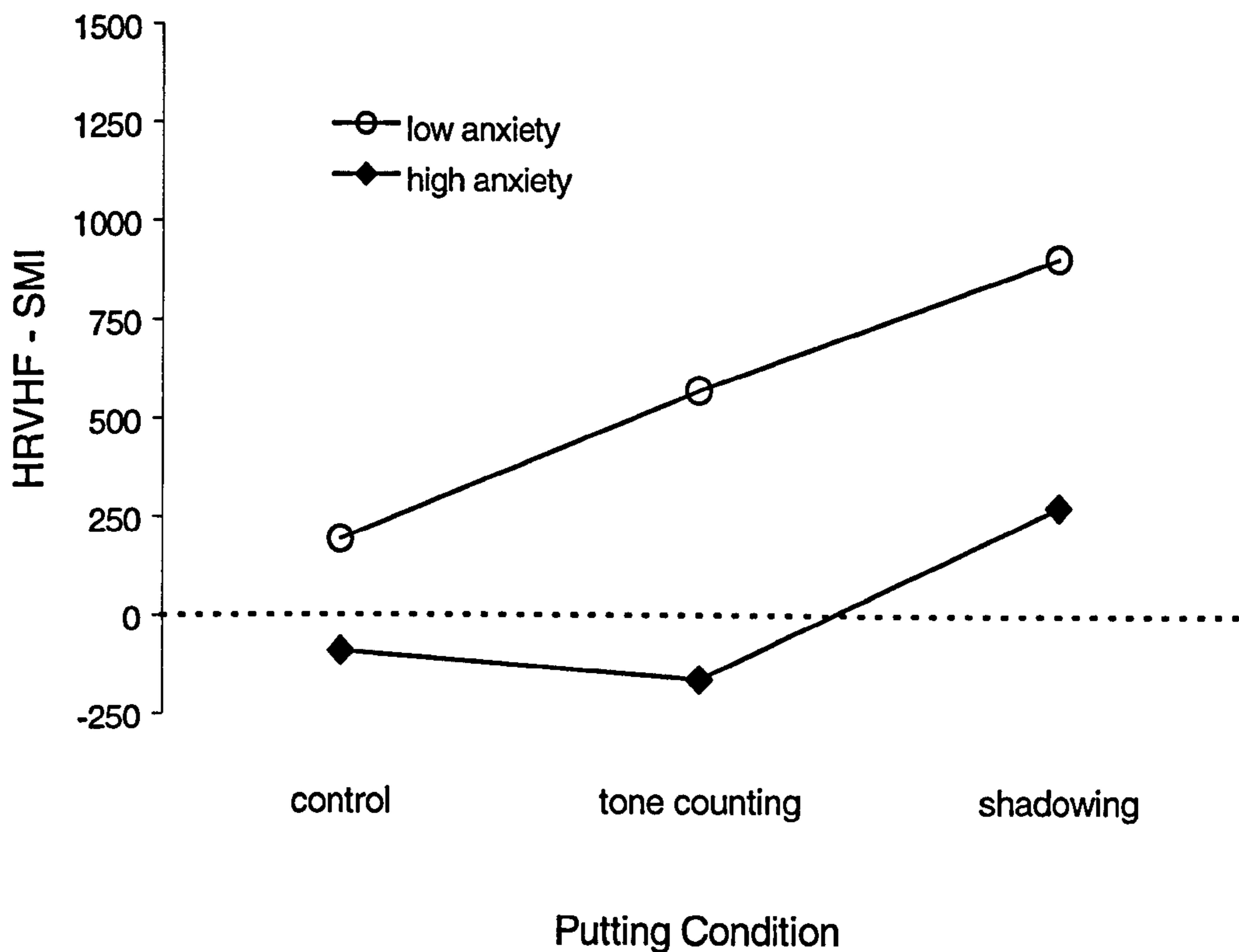


Figure 2. Mean HRVHF difference scores (N.B. Scores are original values prior to logarithmic transformation for ease of interpretation; SMI = squared modulation index).

Kinematic variables

Means (*SD*) for clubhead and joint kinematic variables are presented in Table 2 (below). ANOVA for clubhead backswing and downswing times revealed no significant main effects for anxiety condition or putting condition, $F(1, 23) = 1.30$, $p > .025$, $\omega^2 = .002$ and $F(1, 23) = .22$, $p > .025$, $\omega^2 = .002$; and $F(2, 46) = 3.22$, $p > .025$, $\omega^2 = .02$; $F(2, 46) = 2.86$, $p > .025$, $\omega^2 = .08$, respectively. The Anxiety x Putting Condition interactions for clubhead backswing and downswing also failed to reach significance, $F(2, 46) = 1.21$, $p > .025$, $\omega^2 = .001$ and $F(2, 46) = 1.21$, $p > .025$, $\omega^2 = .001$ for backswing time and downswing time, respectively.

Table 2. Mean (*SD*) scores for kinematic variables.

Variable	Anxiety	Putting Condition		
		Control	Tone counting	Shadowing
BST	High	0.61 (0.08)	0.62 (0.07)	0.61 (0.08)
	Low	0.59 (0.08)	0.62 (0.09)	0.61 (0.09)
DST	High	0.28 (0.03)	0.28 (0.03)	0.27 (0.03)
	Low	0.27 (0.04)	0.28 (0.04)	0.27 (0.03)
TIPA	High	0.72 (0.11)	0.74 (0.12)	0.75 (0.11)
	Low	0.70 (.11)	0.73 (0.13)	0.73 (0.12)
JROM (LW)	High	5.96 (2.47)	6.53 (3.52)	6.58 (4.42)
	Low	7.50 (4.27)	7.70 (3.77)	7.32 (4.36)
JROM (RW)	High	6.15 (2.14)	6.65 (2.22)	6.23 (2.54)
	Low	6.48 (2.10)	7.17 (2.39)	6.29 (2.18)

Note. BST = backswing time; DST = downswing time; TIPA = time to initial peak acceleration at start of downswing; JROM = joint range of motion; RW = right wrist; LW = left wrist.

For the joint range of movement for the right wrist, the main effect for anxiety failed to reach the corrected significance level, $F(1, 7) = 4.48$, $p > .025$, $\omega^2 = .35$. For joint range of movement for the left wrist, the main effect for anxiety was significant, $F(1, 7) = 9.65$, $p < .025$, $\omega^2 = .70$. Examination of the cell means in Table 2 indicates that high levels of state anxiety resulted in a reduced range of motion in the left wrist.

The phase plane portraits for the right wrist revealed no notable differences for any of the experimental conditions. The phase plane portraits for the left wrist joint (Figure 3, below) illustrate the dynamic relationships between angular displacement and angular velocity, and provide further insight into the spatiotemporal organisation of the joint complex under low and high anxiety conditions.

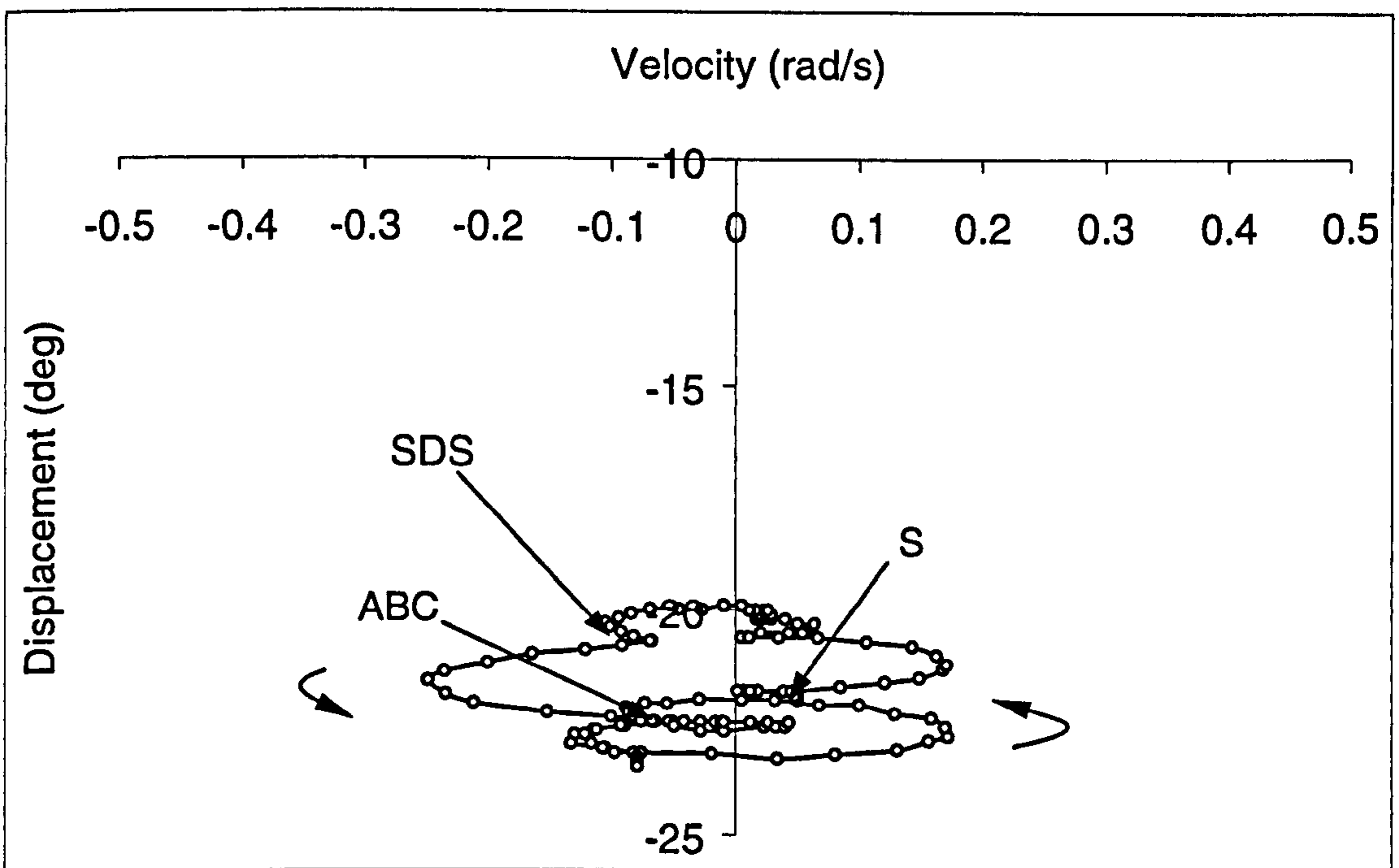
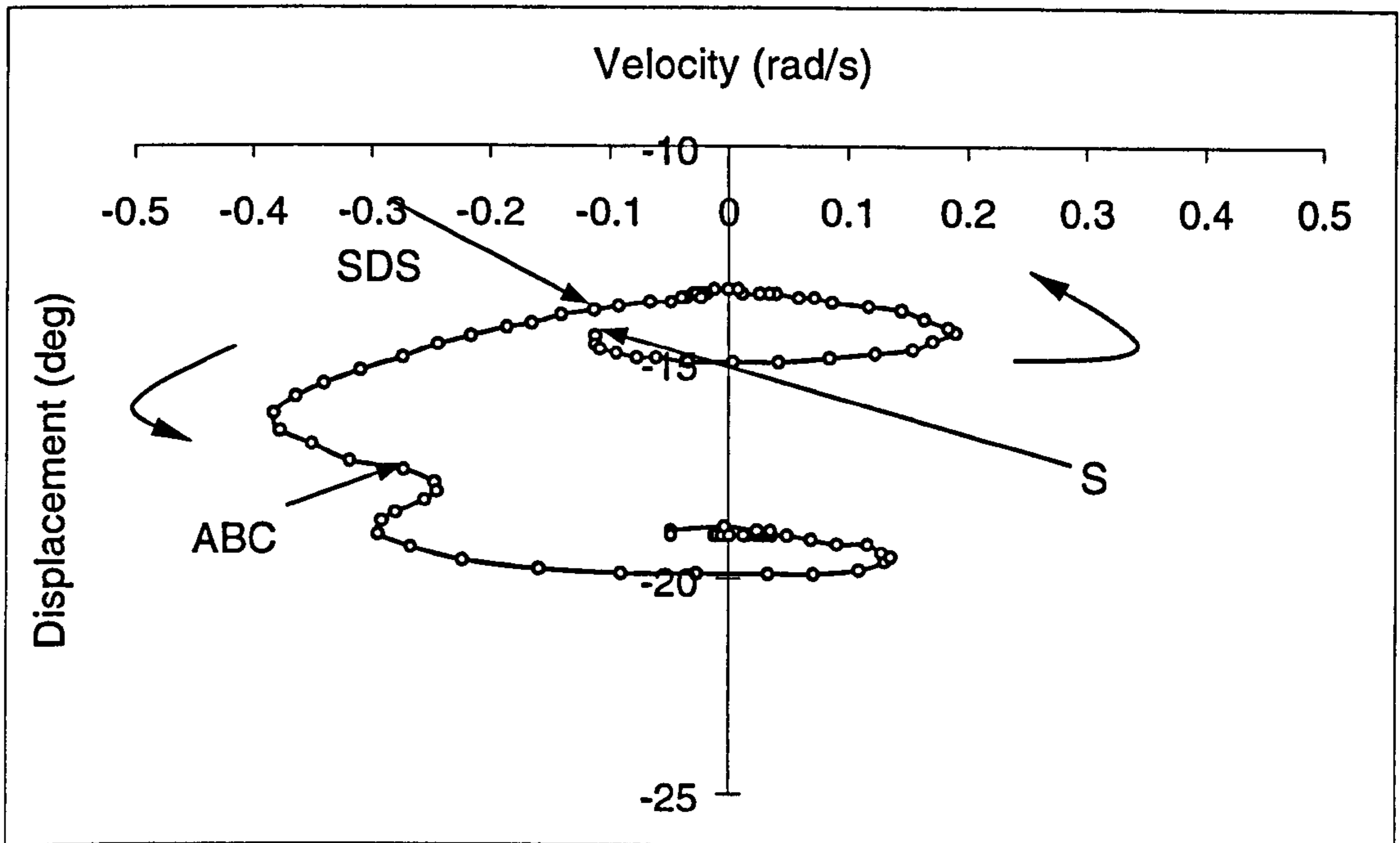


Figure 3. Typical phase plane portraits for the left wrist for the low anxiety (upper) and high anxiety (lower) conditions. S = start of putt; SDS = start of downswing; ABC = approximate ball contact.

The portraits show that that motion proceeds in an anti-clockwise direction with positive velocity to the right of the y-axis and negative velocity to the left of the y-axis. Six out of the eight participants showed consistent differences in the observed phase planes across anxiety conditions. Generally, the diagrams showed that the joint trajectories tended to compact themselves, graphically illustrating the reduced range of motion confirmed by the statistical analysis. The reduced range of motion resulted in several crossings or loops in the trajectory of the portraits. Additionally, maximum negative velocity tended to increase from low to high anxiety conditions, while maximum positive velocity remained approximately stable.

Discussion

The main aim of the present study was to examine the predictions of the conscious processing hypothesis and processing efficiency theory with regard to performance impairment of a motor skill. No firm support for the conscious processing hypothesis was found, although conscious processing effects could not be totally ruled out. The performance data may be best interpreted in terms of processing efficiency theory. Despite the performance effects, the patterning of the various effort indices and kinematic variables failed to provide any additional support for either conscious processing or processing efficiency perspectives. However, the kinematic analysis did produce support for the ecological notion that performers might react to increases in cognitive anxiety by re-freezing degrees of freedom in distal joints.

The success of the evaluative instructions in increasing cognitive state anxiety provides further support for their use in laboratory-based studies in competitive anxiety research (Hardy, Parfitt, and Pates, 1994; Mullen & Hardy, in press; Williams & Elliott, 1999). Despite concerns regarding the ecological validity of such instructions, and laboratory studies in general, in this study the instructional set accounted for 17% of the variance in cognitive state anxiety, a small to moderate effect. Despite this effect, however, in the high anxiety condition the levels of state anxiety reported by participants were still well below those reported by athletes in actual competitions. The self-confidence response of the participants is of note. Previous research has suggested that self-confidence may “protect” against the negative effects associated with high state anxiety (Hardy, 1996a), enabling

performers to continue their efforts successfully. The maintenance of high levels of self-confidence under stress may be a way for performers to enhance motivation and apply the extra effort that offsets performance deficits (Eysenck & Calvo, 1992). As Carver and Scheier (1998) note, "If expectations of success are sufficiently positive, then the person returns efforts towards the goal" (p. 180). Hatzigeorgiadis and Biddle (1998) found evidence to support the notion that expectancy moderates the application of effort by anxious performers. Specifically, high expectancies might stimulate anxious performers to apply extra resources to the task at hand. However, when expectancies are low, such thoughts might discourage individuals, resulting in the withdrawal of effort. The lack of any significant effects for heart rate as an indicator of physiological arousal is probably not surprising as the instructional set was specifically designed to increase cognitive state anxiety. The somatic anxiety response of the participants, which also remained stable across anxiety conditions, provided additional, convergent evidence that the anxiety intervention produced no changes in physiological response.

In terms of putting performance, the contrast analyses allowed a close examination of the predictions of processing efficiency theory and the conscious processing hypothesis. The results lend support to processing efficiency theory, as performance was impaired in the high anxiety tone counting and shadowing conditions. Two interpretations are possible. Firstly, the shadowing and tone counting tasks may have combined with the worry caused by high levels of cognitive state anxiety to reduce attentional resources (Eysenck & Calvo, 1992; Graydon & Eysenck, 1989; Janelle et al., 1999). However, it is feasible that conscious processing may also have occurred, suggesting that performers might be susceptible to both conscious processing and distraction effects. The suggestion that anxiety may affect performance via more than a single mechanism is not new. For example, Eysenck (1988) identified four perceptual and memory effects associated with increased anxiety. It may be that skilled but anxious performers find their performance disrupted by reductions in attentional resources (processing efficiency theory) and attempts to volitionally control motor actions (conscious processing).

From a processing efficiency perspective, the self-reported effort scores suggest that the participants were unable to allocate extra resources to the putting task under conditions of high anxiety. In the high anxiety control condition, resources seem to

have been adequate to cope with the extra demands imposed by high levels of cognitive anxiety. In the high anxiety tone counting and shadowing conditions, however, participants appear to have been unable to cope with the additional demands, were apparently unable to invest extra effort, and performance subsequently deteriorated. The use of a single-item self-report measure requires some consideration in interpreting the effort data. Self-report measures have been criticised in some quarters (e.g, Nisbett & Wilson, 1977). However, because of the difficulty in finding objective measures of effort, self-report indices remain important. As Vicente, Thornton and Moray (1987) note, "If a person feels loaded and effortful, he is loaded and effortful, whatever the behavioural and performance measures may show" (p. 175).

Turning to the HRV data, we failed to find the hypothesised effects for the HRVMF spectral band. If the performance decrements suffered by participants in the high anxiety shadowing condition were indeed caused by conscious processing, then the analysis of the HRVMF band failed to produce evidence that shifts from automatic to controlled task processing might be indexed using this measure. It is possible that the hypothesised reductions in the HRVMF band may have been masked by the impact of physiological responses to increased cognitive anxiety. As spectral power in this band is thought to be reflective of both sympathetic and vagal activity, it is clear that further validity work is required to examine the response of the HRVMF band to increases in state anxiety.

The analysis of the HRVHF band produced results that partially reflect the pattern of the performance scores. It appears that the use of shadowing and tone counting tasks in the low anxiety produced an increase in spectral power in the HRVHF band, compared to control conditions. This may indicate an increase in vagal activity, a decrease in respiratory frequency, or a combination of both factors. This response may have been indicative of an active coping response initiated by the participants to deal with the increased demands imposed by the tone counting and shadowing tasks. In other words, when challenged by a dual task during putting, golfers respond by employing a breathing-based relaxation strategy, which decreases respiratory frequency and increases spectral power in the HRVHF band when they are not anxious. Under stress, this effect is countered by anxiety-induced sympathetic activity. Although in the high anxiety tone counting and shadowing

conditions, power in the HRVHF band recovers to levels similar to the control condition, this pattern of activity now appears to be indicative of a sub-optimal activation pattern. Any inferences regarding parasympathetic control should, however, be interpreted with caution, as “only under conditions in which the respiration pattern remains largely unchanged or is statistically adjusted for would respiratory sinus arrhythmia index variations in cardiac vagal tone” (Althaus, Mulder, Mulder, Van Roon and Minderaa, 1998, p. 421). Respiration was not measured in the present study. However, there is evidence that differences in HRVHF power remain consistent before and after statistical adjustments for average respiration frequencies (Thayer, Friedman, & Borkovec, 1996).

The kinematic analysis failed to produce unequivocal evidence in support of conscious processing or processing efficiency effects. We had originally hypothesised that the range of movement in the wrist joint would only be affected when anxious performers putted using task-relevant cues. In the language of ecological psychologists, an emotional variable like anxiety, and thought patterns such as those induced using task-relevant cues would be classed as forms of organismic constraint (Davids et al., 1997). It was predicted that anxiety and task-relevant knowledge would constrain the movement of individuals in the high anxiety shadowing condition. However, the significant decreases in joint range of motion found for the left wrist indicated that anxious performers may react to increases in cognitive anxiety by re-freezing degrees of freedom, limiting movement variability in a key joint, regardless of the type of knowledge used to guide performance. The data presented here represent the first real evidence of such a regression effect. Re-freezing degrees of freedom would probably be a preferred explanation of anxiety effects from an ecological perspective. It is presently unclear how the dynamical and cognitive perspectives can be integrated in order to explain more fully movement behaviour under stress. The data presented here indicate that dynamical accounts of behaviour require serious consideration by cognitive scientists engaged in anxiety research.

The phase plane portraits provide supportive graphical evidence of the reductions in joint range of motion for the left wrist. The compression of the phase plane portraits in the high anxiety conditions is also suggestive of reductions in fluency in the left wrist. These are illustrated by self-crossings or loops in the

movement pattern, indicating changes in the direction and sign of the angular velocity, which might correspond to periods of hesitation (Beuter & Duda, 1985). Beuter and Duda found similar effects in the distal (ankle) joint of highly aroused children engaged in a stepping task, suggesting that “. . . distal joints may be more susceptible to higher order processing . . . or changes in movement strategies” (p. 240). Interestingly, despite the changes in joint dynamics described above, performance is maintained in the high anxiety control condition. Participants appear to compensate for the changes in joint dynamics, making their performance very robust to anxiety effects (cf. Idzikowski & Baddeley, 1983). The increases in time to initial peak acceleration for the tone counting and shadowing conditions were not predicted. It appears that the longer initial accelerations might indicate longer, smoother transitions from the backswing. However, this suggestion should be treated with caution, as ANOVA for backswing and downswing times produced main effects for putting condition that approached significance ($p = .05$, $\omega^2 = .09$) indicating that the increased time to initial peak acceleration was probably a function of the longer swing times.

A number of limitations were evident in the present study. As participants putted up and across a 12.5% incline, the slope across the putting surface confounded the polar coordinates to some extent. Weaker putts failed to make the top of the slope and rolled back down to the right of the hole. Looking at the cardiac variables, several factors require consideration. Vocalisation can influence the HRV power spectrum (Mulder, 1992) and was strictly controlled in the present study. Performers were specifically instructed not to speak at all during the putting sequences and responded using their fingers to indicate the number of tone counting probes. The metabolic demands of putting could also have introduced artefacts (Mulder, 1988). However, the demands of the putting stroke are unlikely to have unduly influenced the results as HRV data have been reliably collected in much more demanding situations, such as underwater diving (Jorna & Gaillard, 1988). Respiratory influences on the HRVHF spectral band also require attention and future research should consider measuring respiration during performance and statistically adjusting for its effect upon the cardiac cycle. Stationarity of the heart rate signal is a statistical assumption of time series analysis. Measurement epochs were kept as short as possible in order to avoid problems of this kind (Mulder, 1992). The method

of quantification of spectral power may also be problematical, a factor that plagues all HRV research (Berntson et al., 1997). In the present study, HRV data collection and analysis procedures were undertaken using hardware and software developed by the researchers whose theoretical predictions regarding “effort” we were specifically examining (Mulder, 1992; Mulder & Mulder, 1981; Mulder & Mulder, 1987).

Applied Implications

In terms of practical implications for coaches, performers and sport psychologists, several aspects of the data are notable. It appears that using a relevant or irrelevant secondary task can have a detrimental effect upon performance when cognitive anxiety levels are high. Several strategies may help performers deal with such distractions. Overlearning may help performers develop highly automated skills that are more robust in the face of anxiety as expert performers may be able to maintain performance effectiveness despite attentional depletion. The use of process goals by performers is called into question by the current data. Task-relevant knowledge that is fragmented in nature may actively degrade performance. In skilled performers, holistic process goals that focus upon the “whole” skill and encourage “chunking” may be of more use to performers, although this suggestion needs empirical clarification. The joint kinematics also indicated that holistic process goals might be useful to encourage fluidity in key areas of movements that might otherwise be “frozen” as a result of increased anxiety. The use of HRV may also enable researchers to identify energetical influences on HR that play a part in performance impairment. The current data implicate a decrease in the level of vagal activity in anxious performers. Applied relaxation techniques may help performers promote vagal activity and maintain an appropriate activation pattern in the face of increased anxiety and distractors. Refinement of the techniques used in the present study may offer more clues as to the exact nature of the processes involved.

Summary and conclusions

To conclude, the performance data presented here offer little firm support for the conscious processing hypothesis and suggest that the observed deficits were more likely mediated by an overload of attentional capacity. Specifically, any form of additional task, relevant or irrelevant, was detrimental to putting performance. It is

also possible that the performance decrements can be accounted for by a combination of the conscious processing hypothesis and processing efficiency theory. The performance data may indicate that performers are susceptible to distraction and conscious processing. Future research should adopt interventions that can clearly differentiate between conscious processing and distraction effects. The kinematic data produced evidence that supports the notion of regression from an ecological psychology perspective. The use of spectral analysis of HRV as a dependent variable has also provided researchers in sport psychology with an additional tool that may be fruitful in determining the energetical processes underlying the anxiety-performance relationship.

Chapter 6

Conscious processing and the part process goal paradox

(Study 5)

Abstract

The study reported here examined the hypothesis that part process goals lead to conscious processing and subsequent performance impairment when used by skilled, but anxious performers. Holistic process goals were predicted to encourage automatic functioning, thereby helping to maintain performance under stress. Forty skilled golfers were randomly assigned to part or holistic process goal groups. Twenty participants were excluded as they reported problems adhering to treatment instructions. Two-factor ANOVA revealed that both groups maintained performance under stress. Self-reported effort increased as a function of anxiety, appearing to help compensate for the increases in state anxiety. The results failed to support the predictions of the conscious processing hypothesis.

Introduction

The conscious processing hypothesis has recently emerged in the sport psychology literature as a possible explanation for anxiety-induced performance decrements in sport (Baumeister, 1984; Hardy, Mullen, & Jones, 1996, Chapter 2 of this thesis; Masters, 1992b). Masters' conceptualisation of the conscious processing hypothesis is based upon stages of learning (Fitts & Posner, 1967). Masters hypothesised that the automatic control processes of the expert become destabilised under stress as performers attempt to gain conscious control over their actions to try to ensure task success. In so doing, performers are hypothesised to adopt a mode of control based upon explicit knowledge, associated with early stages of learning.

Masters (1992b) and Hardy, Mullen, et al. (1996,) asked novices to learn a golf putting task using an explicit or implicit learning strategy. In a high anxiety transfer test, the performance of the explicit learners was impaired, while implicit learners continued to improve. Masters concluded that the impaired performance of the explicit learners in his study was due to conscious processing. Hardy, Mullen et al. found similar results but offered an alternative interpretation for both their own and Masters' data. In Masters' and Hardy, Mullen et al.'s studies, participants who learned the putting task implicitly did so while generating random letters in order to prevent the build up of explicit, task-relevant knowledge. These participants performed the random letter generation over 400 learning trials and in so doing may have become desensitised to self-generated verbal distractions and at least partially immune to the effects of competitive state anxiety.

Hardy, Mullen and Martin (under review, Chapter 3 of this thesis), using a design that tested the conscious processing hypothesis but avoided confounding by desensitisation effects, also found evidence that supported Masters' (1992b) hypothesis. Experienced trampolinists performed their voluntary competition routines using task-relevant cues in low and high anxiety conditions. Mullen and Hardy (in press, Chapter 4 of this thesis) successfully controlled for the desensitisation hypothesis in their examination of conscious processing effects. Following Hardy, et al. (under review), Mullen and Hardy adopted a performance paradigm, in which skilled participants were asked to perform under low and high anxiety conditions using task-relevant cues to encourage lapses into conscious processing. The participants, golfers, were also asked to perform while

simultaneously performing a random letter generation task (Baddeley, 1966). The random letter generation task prevented participants accessing their explicit knowledge base. The combination of the performance paradigm and the random letter generation task controlled for the problem of desensitisation associated with repeated use of random letter generation in the learning paradigm adopted by Masters and Hardy, Mullen, et al. (1996).

Hardy et al. (under review) also noted that attentional overload, rather than conscious processing, may have caused the performance impairment associated with the combination of high anxiety and task-relevant knowledge. Mullen and Hardy (in press, Chapter 4 of this study) examined the hypothesised attentional effects using Eysenck and Calvo's (1992) processing efficiency theory as a theoretical framework. Mullen and Hardy found partial support for Masters' conscious processing hypothesis. In an attempt to clarify the influence of task-relevant knowledge upon the performance of anxious participants, Chapter 5 of this thesis partially replicated and extended Mullen and Hardy's research design. The study reported in Chapter 5 provided evidence supporting a processing efficiency, rather than conscious processing interpretation of anxiety-related performance effects. However, conscious processing was not totally discounted as an explanation for the performance results in Chapter 5, as anxious participants may have been susceptible to both conscious processing and attentional effects.

An alternative method of addressing the conscious processing hypothesis while controlling for attentional threshold explanations involves goal setting. Adopting a goal setting intervention would also allow the examination of an important issue that has been noted in the anxiety (Hardy, Jones, et al., 1996; Mullen & Hardy, in press) and goal setting (Kingston & Hardy, 1997) literature. Specifically, process goals present something of a paradox in terms of the conscious processing hypothesis. According to Kingston and Hardy (1994a) process goals "specify behaviour in which the performer will engage during performance, and can provide the performer with a primary focus which, if adhered to, can increase the likelihood of successful execution of the target behaviour" (p. 147). Process goals have been recommended by sport psychologists as a means of helping skilled performers deal with high anxiety by providing them with a means of focusing their attention on important aspects of performance (Hardy, Jones, & Gould, 1996; Kingston & Hardy, 1997). However, by their very nature, process goals encourage performers to focus on

specific aspects of a task using explicit knowledge about that task. In combination with high levels of state anxiety, such cues should lead to conscious processing.

A possible solution to the paradox outlined above involves distinguishing between different types of process goal. Holistic process goals may be of use in encouraging performers to conceptualise the whole of a movement. For example “smooth” or “tempo” may be used as holistic process goals for a golf putt. Such goals may function by encouraging “chunking”, allowing the appropriate subactions to be generated automatically (Anderson, 1982). The concept of chunking has been used to describe the automatisisation of cognitive skills, where individual elements of a task are gradually incorporated into single representations, allowing smoother performance (Neves & Anderson, 1981). MacMahon and Masters (1998) produced evidence for the chunking effect using a serial reaction time task. MacMahon and Masters also found that, under pressure, the process of chunking reversed and the skill effectively “de-chunked”. Holistic process goals should not induce lapses into conscious processing because conscious control can only be exerted over parts of a movement. Part process goals, on the other hand, should induce conscious processing as a focus on a part of a movement by a skilled but anxious performer might encourage dechunking.

The notion of holistic process goals or “swing thoughts” has been well documented anecdotally and empirically in the applied golf psychology literature. Owens and Kirschenbaum (1998) noted that some golfers use a mechanical thought to get through a swing confidently. They add, “the best mechanical thoughts are whole swing thoughts” (p. 23), and that partial swing thoughts or specific swing mechanics can create difficulties and interrupt the smooth flow of the stroke. Such advice is not new and Sarazen (1950) noted that players should avoid disrupting their concentration before a shot by wondering if “thirty-three anatomical parts” would perform their appointed functions.

Importantly, such advice has some empirical foundation. Cohn (1991), investigating peak performance in golf, interviewed nineteen professional and North American collegiate golfers. Among other things, the golfers reported a narrow focus of attention involving either a single swing cue or thought or an external focus on the ball or “pin”. Additionally, the golfers reported that automatic performance did not involve conscious thought. Backman and Molander (1991) showed that

explicit instructions impaired the golf putting performance of experts but not novice players, lending support to the notion that conscious processing effects disrupt the automatic control processes of skilled performers. Jackson and Wilson (1999) examined the effect of using a “swing thought” on the putting performance of anxious golfers. Results indicated that the use of a single task-relevant cue helped prevent performance impairment. Jackson and Wilson suggested that the use of the swing thought helped prevent performers from lapsing into conscious processing. Crucially, in a second experiment, Jackson and Wilson found that using four explicit rules related to the putting stroke did disrupt the performance of anxious participants.

All the available evidence suggests that part process goals should induce lapses into conscious processing when highly skilled performers are cognitively anxious. In terms of addressing potential attentional overload explanations of conscious processing effects, holistic and part process goals can be thought of as using equivalent amounts of attentional space. We examined the performance of skilled golfers who putted using part and holistic process goals in high and low anxiety conditions. It was predicted that anxious golfers who putted using a part process goal would suffer performance impairment, while those who used an holistic goal would maintain “normal” automatic functioning and, as a result, performance effectiveness. Mullen and Hardy (in press) and study 4 of this thesis (Chapter 5) also examined the role of effort in anxiety-induced performance breakdowns. Controlled processing is more effortful than automatic processing (Hasher & Zacks, 1979). Using self-report and autonomic indices, Mullen and Hardy and study 4 failed to find any increases in effort associated with shifts from automatic to controlled processing as a result of conscious processing. Instead, the available evidence suggests that individuals allocate extra effort as a function of increased anxiety, as predicted by processing efficiency theory. The present study included a self-reported effort measure to examine the response of anxious individuals using part and holistic process goals and we predicted that anxious participants would generally respond with higher levels of effort. We also predicted that the effort response in the part process goal group in the high anxiety condition would increase as the part process goals encouraged lapses into conscious processing.

Method

Participants

Forty male, right-handed, right-dominant golfers volunteered to take part in the study and provided informed consent before attending the putting laboratory. Intermediate golfers, with handicaps ranging from 10-20, were selected, as their movements would be sufficiently automated and susceptible to conscious processing effects. Novices would naturally be consciously controlling movements and more skilled performers may have strongly established performance routines that are relatively immune to anxiety interventions. Participants were randomly assigned to part and holistic process goal groups. The mean age of the participants in the part process goal group ($n = 20$) was 28.28 years ($SD = 11.32$), their mean handicap was 15.36 ($SD = 3.44$) and their mean number of years playing experience was 8.83 ($SD = 5.13$). For the holistic process goal group ($n = 20$), mean age was 26.56 years ($SD = 9.13$), mean handicap was 15.16 ($SD = 2.71$) and mean playing experience was 8.89 years ($SD = 3.86$).

Apparatus

Participants putted up a 12.5% incline at a hole (diameter = 108 mm) 2.8 m away using their own personal putter. The putting surface was Astroturf packed with “sharp” sand to produce a realistic putting surface. The coefficient of friction of the surface was 0.65.

Measures

Competitive state anxiety. State anxiety was assessed using the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990a). The CSAI-2 is a sport-specific, self-report inventory demonstrated to be a reliable and valid measure of cognitive and somatic anxiety and self-confidence, with Cronbach’s alpha coefficients ranging from 0.70 to 0.90 (Gould, Petlichkoff, & Weinberg, 1987). The directions at the start of the CSAI-2 were slightly modified to account for the fact that the one of the anxiety conditions was a putting competition and the other was a neutral putting task.

Effort. A retrospective, self-reported measure examined effort. Participants rated their perception of effort invested in the putting task via the following question: “Based upon the most amount of effort you have ever put into a golf putt, how

would you rate your effort during the last ten putts? 0 = *no effort*, 10 = *the most effort*" (Crews, personal communication to L. Hardy, 1993).

Performance. Absolute error, with zero recorded for successful putts, and the number of successfully holed putts served as performance outcome measures. Mean absolute error was calculated for each block of 10 putts.

Manipulation check. The manipulation check took the form of a social validation questionnaire created specifically for this study. The check ascertained whether participants had adhered to their treatment instructions. Dichotomous-response questions asked whether participants found their chosen goal useful, whether they mentally pictured themselves using the goal, how difficult it was to concentrate on the goal, and whether the goal made it easy to concentrate on putting. Participants were also asked whether they used any strategy other than the chosen goal, and, if so, what sort of strategy. Finally, participants were asked if, overall, they thought that they had carried out the instructions as requested.

Design

The experimental design was based upon a paradigm successfully used by Jackson and Wilson (1999). Participants were tested in a single session. The design consisted of four phases: warm up, baseline, intervention and competition. The four phases were presented in a fixed order for all participants, ensuring that baseline data were collected prior to exposure to the anxiety intervention. The warm up phase consisted of 10 putts, followed by a further 10 putts in the baseline condition. Following the administration of the anxiety manipulation, participants performed 10 putts in the competitive, high anxiety condition.

Procedure

Participants were provided with written information indicating that the purpose of the study was to examine the effects of goal setting on golf putting performance. Participants were tested individually. On arrival, participants were informed that they would be required to complete a total of 30 putts in three blocks of 10, using a specific goal strategy, and that they would also be asked to complete three

questionnaires during the session. Participants then generated the appropriate process goal. Participants in each process goal group were asked to think of a specific aspect of their putting technique that they would choose to focus on. Participants in the holistic process goal group were asked to think of a general, global goal that encapsulated the whole of their putting action. Participants in the part process goal group were asked to think of a specific subcomponent of the putting stroke that they could use as a swing thought. If participants were unable to generate their own goal, lists of part and holistic process goals specific to putting were provided from which participants in the respective groups could choose their own. Three sport psychologists accredited by the British Association of Sport and Exercise Sciences with knowledge of golf generated the lists of goals. Once the goals had been generated, participants were then given brief training on how to use their particular goal as part of a performance routine. Part of this training ensured that all participants paraphrased their goal into a short phrase. Participants were asked to focus hard on the goal and image the putting stroke using the goal they had generated during the set up phase of the putt. Participants were also asked to repeat the goal to themselves directly before they began the putt. Participants then completed ten warm up putts using the routine. Following the warm up, the CSAI-2 was administered. Participants then completed ten putts in the baseline condition and completed the self-reported effort scale. Following this the anxiety intervention was administered. Participants were informed that the final block of putts formed part of a competition and shown the scores of five other "competitors". The scores were actually yoked to each participant's own baseline score so that this score was always below third place but no worse than equal fourth or fifth of the five scores posted. Participants were informed that they had the opportunity to win a prize of £20, £10, £5 or £2.50 for beating the first, second, third or fourth placed score during the final block of putts. The CSAI-2 was administered immediately following the competition instructions and participants then completed the final round of ten putts. The final self-reported effort scale was then administered and the manipulation check completed. Before leaving the laboratory, the researcher thanked the participants and debriefed them about the true objectives of the study.

Results

CSAI-2 subcomponents, performance and self-reported effort dependent variables were examined using mixed two-way analysis of variance (ANOVA; Goal Group x Anxiety Condition, with repeated measures on the second factor). Effect sizes were computed using omega squared (ω^2) for fixed effect models (Vaughn & Corballis, 1969).

Manipulation check

Crucially, 10 participants in each group reported having difficulty keeping their thoughts on the same goal and using an alternative strategy. These participants were removed from the analysis. Subsequent analyses were conducted upon 20 participants. In the part process goal group ($n = 10$), the mean age of the participants was 31 years ($SD = 12.59$), their mean handicap was 16.90 ($SD = 4.25$) and their mean number of years playing experience was 7.90 ($SD = 4.91$). For the holistic process goal group ($n = 10$), mean age was 28.20 years ($SD = 11.12$), mean handicap was 14.18 ($SD = 2.44$) and mean playing experience was 9.60 years ($SD = 5.82$).

Further responses to the social validation questionnaire indicated that for the large part, participants in both process goal groups found the goal they had selected useful and successfully imaged the goal before putting (part process goal group = 10; holistic process goal group = 9). Nine participants in each group reported that they found the goal that they had selected useful in helping their concentration. In the part process goal group a variety of part process goals were adopted, including “blade square” ($n = 3$), “wrists firm” ($n = 3$), “short back” ($n = 3$), and “head still” ($n = 1$). In the holistic process goal group “smooth” ($n = 6$) proved to be the most popular goal. Two other goals were used, “fluent” ($n = 3$), and “move (the hands, arms and shoulders) as (a) unit” ($n = 1$). There were, however, some further difficulties reported. In the part process goal group, one performer used an alternative strategy, an emotion-focused goal, “breath out before each putt”. In the holistic process goal group, two participants employed alternative strategies. Two external cues were used early in the pre-performance routine: “read the green” and “use markers to line ball up”. Despite these minor remaining difficulties, 100% of participants in both groups thought that they had carried out the instructions as

requested. Chi square tests indicated that none of the responses differed as a function of goal setting group membership.

State anxiety

Table 1 (below) shows the mean scores for cognitive and somatic anxiety and self-confidence in the baseline and competition conditions. ANOVA revealed that the main effect for anxiety condition was significant for cognitive anxiety, $F(1, 18) = 10.32, p < .05, \omega^2 = .15$. The main effects for anxiety condition for somatic anxiety, $F(1, 18) = .11, p > .05, \omega^2 = .04$, and self-confidence, $F(1, 18) = .16, p > .05, \omega^2 = .00$, both failed to reach significance. Examination of the cell means in Table 1 (below) shows that cognitive anxiety increased during the competition phase of the session. No significant Group x Anxiety Condition interactions or main effects for group were found for: cognitive anxiety, $F(1, 18) = 3.03, p > .05, \omega^2 = .06$, and $F(1, 18) = .44, p > .05, \omega^2 = .0001$, respectively; somatic anxiety, $F(1, 18) = 1.92, p > .05, \omega^2 = .04$, and $F(1, 18) = .15, p > .05, \omega^2 = .00$, respectively; or self-confidence, $F(1, 18) = 1.16, p > .05, \omega^2 = .007$, and $F(1, 18) = .004, p > .05, \omega^2 = .00$, respectively.

Table 1. Mean (*SD*) cognitive and somatic anxiety scores.

CSAI-2 Subcomponent	Part process goal		Holistic process goal	
	Low anxiety	High anxiety	Low anxiety	High anxiety
Cognitive anxiety	15.90 (2.81)	19.60 (5.32)	15.80 (5.45)	16.90 (5.80)
Somatic anxiety	14.90 (4.77)	16.90 (5.86)	14.90 (6.03)	15.10 (4.58)
Self-confidence	26.10 (6.05)	24.80 (4.83)	25.30 (5.54)	25.90 (5.92)

Performance

In terms of the number of successful putts, the performance of the part and holistic process goal groups remained relatively stable across anxiety conditions (Table 2,

below). ANOVA revealed no significant Anxiety x Goal Group interaction, $F(1, 18) = .02, p > .05, \omega^2 = .00$; or main effects for anxiety condition, $F(1, 18) = .02, p > .05, \omega^2 = .00$; or goal group, $F(1, 18) = .16, p > .05, \omega^2 = .00$. ANOVA also confirmed that absolute error for both process goal groups remained stable. Neither the Anxiety x Goal Group interaction, $F(1, 18) = .003, p > .05, \omega^2 = .00$; nor main effects for anxiety condition or goal group were significant, $F(1, 18) = .11, p > .05, \omega^2 = .0001$, and $F(1, 18) = 1.65, p > .05, \omega^2 = .03$, respectively.

Table 2. Mean (*SD*) performance scores.

Performance variables	Part process goal		Holistic process goal	
	Low anxiety	High anxiety	Low anxiety	High anxiety
Performance success	6.20 (2.10)	5.90 (1.73)	6.50 (2.07)	6.30 (2.63)
Absolute error (cm)	13.00 (11.00)	12.00 (6.00)	9.00 (6.00)	12.00 (12.00)

Self-reported effort

The patterning of the self-reported effort scores revealed that performers increased their effort expenditure as a function of anxiety across both goal setting groups, part process goal low anxiety mean = 8.00 ($SD = 1.63$), high anxiety mean = 8.70 ($SD = 1.25$); holistic process goal low anxiety mean = 7.50 ($SD = 1.17$), high anxiety mean = 9.10 ($SD = .88$). ANOVA confirmed that the main effect for anxiety condition was significant, $F(1, 18) = 25.74, p < .0001, \omega^2 = .31$. Neither the Anxiety x Goal group interaction, $F(1, 18) = 3.94, p > .05, \omega^2 = .07$; nor the main effect for group, $F(1, 18) = .01, p > .05, \omega^2 = .00$, were significant.

Discussion

The main aim of the study was to examine the effect of part and holistic process goal strategies on golf putting performance under stress. It was hypothesised that under conditions of high anxiety, part process goals would induce lapses into conscious processing, resulting in performance impairment, while holistic process goals would

encourage automatic processing, and help to maintain performance. An attempt was also made to examine the patterning of self-reported effort across goal setting and anxiety conditions. It was hypothesised that the use of part process goals would result in higher levels of effort under stress as they induced conscious processing.

The anxiety intervention proved successful, significantly increasing cognitive anxiety. Despite this success, ecological validity remains a problem in laboratory-based anxiety research. As other researchers have found, the actual levels of cognitive anxiety reported in the laboratory fall short of those reported in actual competition (Chapter 5 of this thesis; Williams & Elliott, 1999). It appears that despite the ingenuity shown by researchers in developing anxiety interventions, it is unlikely that any lab-based intervention can approximate the recipe of emotions experienced by athletes in actual competition. Jackson and Wilson's competition intervention has, however, proved to be successful in elevating cognitive anxiety, and offers researchers a viable alternative to more common anxiety interventions, such as evaluative instructions (Calvo, 1985; Janelle, Singer, & Williams, 1999; Mullen & Hardy, in press) and time-to-event paradigms (Hardy & Parfitt, 1991).

Bearing in mind the increase in cognitive anxiety, the absence of performance decrements was a little surprising. However, performance in high anxiety control conditions has remained consistently stable, or even improved in previous studies (Mullen & Hardy, in press; Chapter 5 of this thesis), indicating that performance effectiveness can be quite robust in the face of stress. Both performance dependent variables remained stable as a function of anxiety and goal setting conditions. The part process goals failed to produce the hypothesised conscious processing effects. The stability of performance can at least be explained by the patterning of self-reported effort. Participants in both goal-setting groups increased their effort expenditure in the high anxiety condition. Mullen & Hardy (in press) also found that anxious participants expended more effort. The allocation of additional effort by anxious performers is a central prediction of Eysenck and Calvo's (1992) processing efficiency theory, which states that high levels of state anxiety produce a dynamic response from performers in order to maintain task performance at acceptable levels. In order to accomplish this goal, performers allocate extra resources to the task. This increase in effort, while maintaining performance effectiveness results in less efficient processing. In the present study, the increased effort may have helped

prevent performance impairment, supporting a processing efficiency interpretation of the data.

The stability of self-confidence in the present study matched results found in previous studies. Mullen & Hardy (in press) suggested that self-confidence might play a key role in enabling anxious performers to allocate extra effort to tasks. The findings regarding the role of self-confidence have to date been mixed. While Mullen and Hardy found that confidence remained stable and effort increased across anxiety conditions, performance effectiveness was only maintained for the poorer putters in the study. The data presented in Chapter 5 of this thesis indicated that individuals might be able to maintain self-confidence levels despite increases in cognitive anxiety. Self-reported effort, however, remained stable in a high anxiety condition and it appeared that the anxious performers were unable to allocate extra resources to the putting task and performance deteriorated. The role that self-confidence plays in allowing performers to allocate extra resources to the task requires further clarification. Carver and Scheier (1998) highlight the importance of self-confidence in helping individuals to persist at tasks under difficult conditions. Carver and Scheier suggest that a form of "confidence threshold" might exist, below which "persistence gives way to giving up" (p. 6). Researchers investigating the anxiety-performance relationship may need to consider wider theoretical constructs to adequately explain performance impairment under stress.

The social validation questionnaire played an important role in identifying problematic participants. Ten participants were removed from each process goal group and statistical power was seriously compromised. It appears that the goal-setting intervention was not totally effective. One possible explanation for this problem is that the goal setting intervention was unable to modify the performance routines of the participants. Even though the participants were of intermediate skill levels, they may have possessed well-developed, automatic performance routines. Future research should include a training period, during which participants are taught how to use part and holistic process goals effectively. The issue of goal-setting effectiveness might also be addressed by extending the number of putting trials. More practice may enable individuals to use the goal-setting strategies more effectively.

Summary and conclusions

In terms of practical implications, the results offer little support for the efficacy of holistic process goals over part process goals for anxious performers. The results do, however, indicate that performers can benefit from expending additional effort when they are anxious. The processes by which this extra effort can be applied remain unclear. In conclusion, the present study offers little evidence for conscious processing effects using part process goals and the conscious processing - process goal paradox remains unresolved.

Chapter 7

Summary and Concluding Comments

Introduction

The purpose of this final chapter is to draw together the findings of the thesis. The chapter is divided into five sections, as follows: the first section provides a resume of the aims and major findings of the research, the second section examines the major conceptual and theoretical issues emanating from the five studies, the third section addresses the applied implications generated by the research programme, the fourth section highlights the strengths and limitations of the programme, and the final section provides recommendations for future research.

Summary

This research project set out to examine the conscious processing hypothesis as a possible explanation for anxiety effects upon the performance of motor skills. As indicated in the introduction, anxiety research has concentrated largely on predicting *when* anxiety produces a negative effect upon performance. In terms of identifying the mechanisms through which anxiety exerts its negative influence, much previous sport psychology research has relied largely upon the simplistic attentional theories of Easterbrook (1959) and Wine (1971, 1980). Masters (1992b) formulated the conscious processing hypothesis based on evidence derived from previous research (Bliss, 1893; Boder, 1935; Baumeister, 1984; Baumeister & Showers, 1986) suggesting that pressure might cause performers to turn the focus of their attention inwards. These studies, however, had failed to make an explicit link between declarative knowledge about task performance and the consequences of using such knowledge when cognitive anxiety was high.

At the commencement of this programme of research, Masters (1992b) had produced the only real evidence for conscious processing effects. However, conscious processing was not the only viable interpretation of Masters' data. Study 1 was specifically designed to address a task difficulty interpretation of Masters' data from within a multidimensional state anxiety framework. To achieve this, study 1 replicated and extended Masters' original experiment. Participants in Masters' study

acquired the skill of golf putting under explicit and implicit learning conditions. The novices in the explicit learning group were given instructions on how to putt correctly and were asked to use this information during their practice sessions. The novices in the implicit learning group performed a random letter generation task that prevented them generating or accessing explicit knowledge about putting. After 400 practice trials, both groups, along with several others, putted under high anxiety conditions. Under stress, the implicit learning group continued to improve, whereas the explicit learning group did not. However, the implicit learning group was not asked to continue the random letter generation task during the high anxiety condition. As a result, their continued improvement could be attributed to a reduction in task difficulty. Study 1 controlled for this possible confound by adding an extra implicit learning group that continued to perform the random letter generation task in the high anxiety condition. It was hypothesised that the new implicit learning group would suffer performance impairment under stress. The results failed to support this hypothesis, adding support to Masters' conscious processing hypothesis. However, study 1 was not without its own limitations. Another possible confound was identified. In performing the random letter generation task over 400 learning trials, participants may have become desensitised to self-generated verbalisations and at least partially immune to the effects of competitive state anxiety.

Study 2 was designed to provide a test of the conscious processing hypothesis that was not confounded by desensitisation effects. A performance, rather than learning, paradigm was adopted. Experienced trampolinists were asked to perform using explicit knowledge under low and high anxiety conditions. Explicit knowledge was provided for the performers by means of a shadowing technique, as suggested by Masters (1992a). The performers' coach called out a coaching point for each specific move in the voluntary competition routine and participants were asked to concentrate on using the explicit "cues" to guide their performance. The combination of explicit knowledge and high state anxiety resulted in the trampolinists registering a decrement in performance, thereby supporting the predictions of the conscious processing hypothesis. However, the performance deficits could also be attributed to an attentional threshold explanation. Attentional effects may have been caused by the relevant cues taking up a portion of attentional

capacity and anxiety taking up a further portion, thereby depleting attentional capacity sufficiently to impair performance.

The purpose of study 3 was to control for both the desensitisation and attentional threshold hypotheses. The performance paradigm used in study 2 was retained and an additional task was included in the experimental design. Retaining the performance paradigm avoided the problem of desensitisation associated with the learning paradigm used in study 1. Skilled golfers were asked to putt while simultaneously performing the random letter generation task used in study 1. The addition of the random letter generation task also afforded an examination of the attentional threshold explanation identified in study 2. From a conscious processing perspective, the random letter generation task should have prevented performers accessing their explicit knowledge base, while the shadowing task encouraged lapses into conscious processing. However, according to the attentional hypothesis, both the task-relevant shadowing task and the task-irrelevant random letter generation task should have served as distractions, consuming attentional resources, and in combination with high levels of cognitive anxiety, impairing performance. Study 3 also extended the research project in two additional ways: (a) a self-report scale was included to examine the patterning of effort invested by performers, and (b) an interdisciplinary approach was adopted, incorporating an exploratory, *in vivo* two-dimensional kinematic analysis of the experimental task, golf putting. Performance differences were identified in the skill level of the sample, resulting in a dichotomisation based on putting ability in the low anxiety control condition. For "better" putters, the results partially supported the conscious processing hypothesis, as performance deteriorated when the better golfers putted using explicit knowledge in the high anxiety condition. The patterning of self-reported effort supported the processing efficiency prediction that anxious performers increase the amount of effort invested in a task. The kinematic analysis revealed little in the way of effects that could be interpreted as offering firm support for conscious processing.

Study 4 was a refinement of the design used in study 3. Additionally, the interdisciplinary focus was extended to include a three-dimensional, *in vivo* kinematic analysis using a more complex model of joint dynamics, and spectral analysis of heart rate variability as a cardiovascular index of effort. The results lent themselves to a processing efficiency interpretation. However, conscious processing

effects could not be totally discounted. While self-reported effort remained stable as a function of both anxiety and putting conditions, heart rate variability scores partially mirrored those found for performance. The patterning of heart rate variability indicated that the combination of high anxiety and relevant and irrelevant tasks may have produced a sub-optimal respiratory activation pattern. The kinematic data supported the ecological notion that anxious performers might attempt to regain task control by "re-freezing" degrees of freedom in the distal (wrist) joint.

The focus of study 5 was more applied in nature, although still laboratory based. Throughout this research programme, concern has been expressed about the use of process goals by highly skilled but anxious performers. The conscious processing hypothesis suggests that the use of process goals by skilled, but anxious performers might actively encourage lapses into conscious processing. However, holistic process goals that encapsulate a movement in its entirety might maintain a "global" task focus and automatic task control, helping to prevent lapses into conscious processing. Study 5 examined the use of "part" and "holistic" process goals by experienced golfers under high and low anxiety conditions. The use of a goal setting manipulation also avoided the potential problems associated with attentional overload experienced in earlier studies. The performance of both the part and holistic process goal groups remained stable across anxiety conditions. However, it appears that participants may require initial training in the use of goal-setting strategies before the efficacy of part and holistic goals under stress can be examined. Self-reported effort increased in both groups as a function of anxiety, supporting a processing efficiency interpretation of the data.

Theoretical Issues

A number of theoretical issues have been addressed in this project, which are fundamental to explaining anxiety effects upon motor performance. These issues are discussed as follows: the conscious processing hypothesis as a viable explanation for anxiety effects upon motor performance; personality variables; ecological interpretations of the anxiety-performance relationship; the measurement of anxiety; interdisciplinarity; and finally, ecological validity.

The conscious processing hypothesis as a viable explanation for anxiety effects upon motor performance

The first three studies of the current research programme all produced data that supported the conscious processing hypothesis. However, the conscious processing hypothesis was unable to account for all the performance effects found throughout the programme. For example, the performance effects in study 4 suggested that performers might be susceptible to both distraction and conscious processing. Processing efficiency theory was included in study 3 as a potential alternative to the conscious processing hypothesis. The performance effects from the present programme may be best explained using a combination of the conscious processing hypothesis and processing efficiency theory. Of particular note is the role of compensatory effort. Such effort might have the potential to exert a positive moderating effect upon the anxiety-performance relationship, contingent upon whether performers perceive themselves to have at least a moderate chance of succeeding (Eysenck, 1982). Eysenck (1992) noted that quantitative changes in the allocation of processing resources might also be accompanied by qualitative changes in processing strategies. Anxious performers may increase effort invested in a task to such an extent that they lapse into conscious processing. Thus, when cognitive anxiety is elevated, an increase in effort may be beneficial up to a point. However, beyond this threshold further increases in effort may lead to lapses into conscious processing causing performance impairment.

The conceptualisation of effort implicit in the emerging model of human performance under stress is consistent with “wet” models of cognitive functioning (Hockey, Coles, & Gaillard, 1986). Wet models differ from “dry”, linear processing models in that they account for the “intensive” aspects of behaviour, that is, its energy or degree of vigour. According to Hockey et al., an energetical framework allows researchers to account for (a) the variability associated with changes in state, for example, behaviour changes under stress, (b) relationships between information processing operations and the underlying pattern of biological activity, and, (c) individual differences in all these areas. Hockey (1986) claimed that adaptive regulation to changes in state is essential to preserve performance. According to Hockey, the central energetical construct in the active control of resources is *effort*. Mulder (1986) differentiated between two types of effort, the intensity of processing

associated with shifts from automatic to controlled processing, as predicted by the conscious processing hypothesis, and effort as compensatory control (cf. Eysenck & Calvo, 1992). This distinction is implicit in the way that effort has been conceptualised in the present programme. Mulder claimed that the two types of effort have different physiological concomitants, and outlined the ways in which these concomitants could be measured. The use of spectral analysis of heart rate variability in the present project has helped begin the energetical mapping of the effort response of anxious performers. If Mulder was correct and the two types of effort are indeed distinct from one another then it appears that separate measures may be necessary to map the compensatory and intensive aspects of the effort response under stress. However, as Mulder also intimates, there may only be one energetical effort resource. It is possible that some threshold exists beyond which information processing strategies change, as in the shift from automatic to controlled processing, as a function of energetical resource allocation in the form of increased effort.

Alongside effort, self-confidence may also play an important moderating role in the context of the anxiety-performance relationship. According to Eysenck (1982), anxious performers will invest effort in a task only if they perceive themselves to have at least a moderate chance of succeeding. At the outset of the present research programme, self-confidence did not play a major part in the predictions of the conscious processing hypothesis. However, as the programme progressed and the findings were interpreted using combinations of processing efficiency theory and the conscious processing hypothesis, it became apparent that self-confidence might have a crucial role to play in accounting for the data. Carver and Scheier (1998) note that "the interruption of action in the face of adversity is tied to a deliberative assessment of the likelihood of success, given continued efforts" (p.176). Earlier, Carver and Scheier (1988) had indicated that as long as favourable expectancies regarding goal attainment were maintained, then anxiety would increase performance. Self-confident performers presumably retain favourable goal attainment expectancies. As such, self-confidence has also been specifically proposed as a mechanism that might "protect" performers against the negative effects of anxiety upon performance (Hardy, 1996a). As Bandura (1997) stated, "the stronger the sense of efficacy, the bolder people are in taking on the problematic situations that breed stress and the

greater their success in shaping them more to their liking" (p. 141). One might speculate about the manner in which self-confidence might operate. It may be that some self-confidence threshold exists, above which cognitively anxious performers might retain favourable task expectancies and return efforts towards a task.

Further support for an amalgamation of the conscious processing hypothesis and processing efficiency theory can be found in proposals suggested by Hardy (1997). Hardy, seeking to explain potential mechanisms underlying performance catastrophes, suggested that the conscious processing hypothesis and processing efficiency theory might have the potential to do so. Hardy tentatively proposed that if anxious but confident performers invest effort in a task then performance might be improved. However, if performers increase their effort to such a degree that they lapse into conscious processing, then performance might suffer dramatically. Performance catastrophes (Hardy & Parfitt, 1991; Hardy, Parfitt, & Pates, 1994) could thus be explained by a withdrawal of effort, an effort-induced lapse into conscious processing, or both. Cognitively anxious performers may thus find the investment of effort beneficial up to a point, beyond which further increases may lead to catastrophic performance decrements due to lapses into conscious processing.

Catastrophe models may be the most promising means of modelling the differential effects found within the present research programme. Cusp catastrophe models examine the three-dimensional, interactive relationship between cognitive anxiety, physiological arousal and performance. Hardy (1996a) has extended the basic cusp catastrophe model to include personal control and self-confidence as additional variables, resulting in a five-dimensional butterfly model. One can speculate that effort may also need inclusion in catastrophe models in order to reflect the complex interactions that may occur. Effort may need to replace one of the control parameters in Hardy's (1996a) butterfly catastrophe. Hardy (1996a) used Guastello's (1982; 1987) method of dynamic differences to test a butterfly model of anxiety and performance. The results partially supported the model. Although catastrophe models and the analysis techniques used to test them are complex, they may be the best way forward in terms of modelling the relationship between anxiety and performance (Hardy, 1996b). Future research adopting this approach will need to adopt an alternative to Guastello's method of dynamic differences, which might

currently be considered disreputable. Hardy (1996) identified two alternative surface-fitting procedures that might be considered by researchers in this respect (Oliva, Descarbo, Day, and Jedidi, 1987; Cobb, 1981).

Personality variables

Dispositional factors may also be important in helping to explain the precise way in which anxiety affects motor performance using the conscious processing hypothesis. Humphreys and Revelle's (1984) information processing model of arousal and performance included several personality variables, and similar dimensions might be relevant in the context of conscious processing effects. Masters, Polman, and Hammond (1993) suggested that some individuals may be more predisposed than others to lapse into conscious processing. Masters et al. devised the Reinvestment Scale to measure the tendency to focus on the mechanics of movements. Despite the criticisms levelled at the Reinvestment Scale in Chapter 1, it is possible that a complete understanding of conscious processing effects may need to examine the influence of dispositional individual differences.

Self-focus (Baumeister, 1984) may also be important. The potential influence of private and public aspects of self-consciousness on performance was considered in Chapter 4. There was a suggestion that the presence of the video camera may have increased self-focus and conscious processing in the experimental conditions. As noted earlier, however, the use of the video camera may not have unduly influenced self-focus due to the differential effects of self-focus manipulations on public and private aspects of self-consciousness (Carver & Scheier, 1998). It was argued that, as a video camera would appear to affect the social side the self, which is unrelated to an awareness of internal states, there would have been negligible effects upon conscious processing. However, a predisposition to focus on the private aspect of the self might provide researchers with a dimension of personality worthy of further investigation in the context of conscious processing.

Ecological interpretations the anxiety-performance relationship

The current research programme was placed largely within a cognitive theoretical framework. However, some of the hypotheses generated for the kinematic analysis in studies 3 and 4 were "borrowed" from the ecological paradigm. Various

researchers have suggested that cognitions and emotions should be considered as dynamical processes (Davids, Bennett, Court, Tayler, & Button, 1997; Kelso, 1995; Thelen, 1995). In this context, anxiety would be regarded as an organismic constraint that interacts with environmental and task constraints to shape behaviour. Thus, anxiety would be viewed as a control parameter, constraining the collective variables underpinning task performance. Within the motor control literature, there have been calls for the integration of cognitive and ecological models (Abernethy & Sparrow, 1992). Williams, Davids and Williams (1999) have noted that current attempts to integrate cognition and action take two approaches. The first of these are attempts by movement scientists to integrate intentionality within an ecological framework and cognitive scientists to incorporate dynamical models into neural network models of cognition (van Gelder, 1998; Kelso, 1995; Thelen, 1995). The second involves a “shifting focus” (Bongaardt, 1996). As Williams et al. point out, the concept of shifting focus refers to an approach that requires more than one model to explain movement behaviour. “Quite simply, the argument is that in order to study movement behaviour one needs a shifting focus between the three key processes (coordination, exploration, and planning), suggesting that more than one type of model is necessary to describe behaviour at all levels of the movement system” (p. 376).

Heterarchical models of movement behaviour (Rumelhart & Norman, 1982) may be one way in which the conscious processing hypothesis might contribute to an integrated cognitive-dynamic explanation of the processes underpinning the anxiety-performance relationship (Hardy, Jones, & Gould, 1996). Such systems comprise higher-order strategic control mechanisms and lower-order operators. As noted in the introduction of this thesis, the higher-order mechanisms might direct the lower level mechanisms without conscious awareness of the operations performed at lower levels. Thus, the lower level operators may be composed of self-organising structures functioning according to the principles of dynamical systems. The operation of the lower level operators might become subverted by conscious attempts to regain task control by the higher level operators of cognitively anxious performers.

Ecological theories are non-linear and, once again, intuitive links to catastrophe models of anxiety and performance also appear to have the potential to provide a

framework for a dynamical account of the anxiety-performance relationship. For example, it may be that a more fine-grained analysis of the processes underpinning performance could lead to an extension of the single behaviour dimensions included in cusp and butterfly models of anxiety and performance. Higher-order catastrophes using two, or more, behaviour dimensions (Zeeman, 1976) may be way of modelling the effects of combinations of control parameters such as cognitive anxiety, physiological arousal, self-confidence and effort upon behaviour dimensions that include key kinematic processes such as the restrictions in joint ranges of motion presented in Chapter 5.

The measurement of anxiety

The present research project relied upon the manipulation of state anxiety as the basis for the experimental designs adopted. As such, the measurement of performers' anxiety responses is an important issue. With the exception of study 2, which utilised the children's version of Spielberger's (1970) State-Trait Anxiety Inventory, the present research programme relied upon the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990a) to measure participants' response to the anxiety interventions. Several researchers have recently called into question the validity of the CSAI-2 and all other available anxiety measures. For example, research addressing performers' directional interpretations of their affective state using a modified version of the CSAI-2 has provided empirical evidence that performers can interpret statements in the CSAI-2 quite differently (Jones & Hanton, 1996; Jones, Swain, & Hardy, 1993). Further anecdotal evidence that performers can also interpret items on the CSAI-2 quite differently was presented by Barnes, Sime, Dienstbier, and Plake (1986), who felt sufficiently strongly about this point that they removed the first item from the CSAI-2. The item confused their participants, who were unsure whether "I am concerned about this competition" was asking whether they were worried about the impending competition or just that the competition was important. Furthermore, the items included in the CSAI-2 may not have represented the most important aspects of competitive anxiety for the trampolinists who participated in Study 2 and the golfers who participated in studies 3, 4, and 5. For example, "My hands are clammy" would be more likely to concern a golfer about to putt than a trampolinist waiting to

perform their routine. Task specific versions of the CSAI-2 may be more appropriate. Taken together, this evidence suggests that the construct validity of the CSAI-2 can be called into question. Lane, Sewell, Terry, Bartram and Nesti (1999) have also questioned the structural validity of the CSAI-2, concluding that further validation of the CSAI-2 is required. The limitations identified above have obvious implications for the findings of the present research project. In mitigation, however, the CSAI-2 currently remains the “gold standard” in terms of the measurement of competitive state anxiety in the absence of any better or more appropriate instrument.

Interdisciplinary research

Sports scientists have also been encouraged to take a more “rounded” or holistic approach to the study of human movement (Dishman, 1994; Maguire, 1990; Morgan, 1989). The majority of calls for such integration have promoted an interdisciplinary, rather than mono or multidisciplinary, perspective to be taken by researchers in sports science (Burwitz, Moore, & Wilkinson, 1994). Interdisciplinary research has the advantage of bringing expertise from different subdisciplines to bear collectively upon research problems. A truly interdisciplinary approach has the advantage of enabling the *interactions* between different aspects of human behaviour to be studied. Multidisciplinary research, on the other hand, produces a more fragmented picture of human behaviour in that typically only an additive characterisation of behaviour can be composed. The methods adopted in studies 3 and 4 represent a genuine interdisciplinary focus, including kinematic and innovative physiological approaches to the study of the anxiety-performance relationship. Such interdisciplinary approaches may offer researchers a much more global insight into the processes and mechanisms underlying anxiety effects.

The use of spectral analysis of heart rate variability enabled an examination of the dynamics of the cardiovascular system in anxious performers. The specific hypothesis proposed for the response of the mid-frequency band was not supported. However, examination of the high-frequency band revealed a possible change to performers’ activation states associated with respiratory activity under high anxiety, dual-task conditions. As mentioned above, spectral analysis of heart rate variability

has the potential to provide a window on the energetics underlying human functioning under stress.

The kinematic analysis of movement behaviour produced evidence of changes in joint control strategies associated with high anxiety. Kinematics would appear to be an important feature of an interdisciplinary focus on the conscious processing hypothesis. Masters (1992a) originally suggested that the loss of fluency of movements under the control of conscious processing might be indexed using kinematic analysis. Studies 3 and 4 approached this problem using different strategies. Study 3 relied upon the suggestion that higher-order derivatives might be more susceptible to conscious processing effects (Fuchs, 1962; Lee & Swinnen, 1993). No evidence was found to support these ideas. Study 4 used ideas generated by Beuter, Duda, and Widule (1989) and Beuter and Duda (1985) to examine the fluency of joint dynamics. The phase plane portraits used in study 4 indicated that a reduction in the range of motion of the left wrist joint resulted in a “compressed” angular velocity-displacement pattern. The compression produced several crossings in the phase plane portraits, which may be indicative of a loss of fluency (Beuter & Duda, 1985).

Masters (1992a) originally suggested that losses of fluency might be indexed by changes in jerk. Masters’ proposal was founded in the notion that the central nervous system might optimise movement smoothness by minimising mean-square jerk (Hogan & Flash, 1987). Jerk is the third time derivative of time-position information, or the rate of change of acceleration. Hogan and Flash were attempting to construct a quantitative measure of smoothness or gracefulness. However, Young and Marteniuk (1997) demonstrated that jerk is not minimised for end-effector or joint kinematics during the acquisition of a multi-joint kicking task. The fact that smoothness may not be a feature of movement optimisation casts doubt upon Hogan and Flash’s minimum-jerk model of motor planning. As little evidence exists for the optimisation of mean-squared jerk during the acquisition of a multi-joint movement, it seems logical to suggest that the same parameter should not be responsible for losses of fluency experienced by anxious performers consciously processing information. However, this issue requires empirical clarification.

Ecological validity

The importance of ecological validity in the context of the present research programme warrants some attention. Sport psychology has adopted a more applied focus in recent years with limited attention being paid to measuring precise parameters in controlled environments. Martens (1979) led the move towards the adoption of more ecologically valid field settings and away from laboratories. In terms of research focus, the present project has concentrated upon establishing causal relations in controlled laboratory settings. As such, this move towards more “traditional” experimental methods can be criticised by researchers searching for research high in external validity. Thus, in terms of ecological validity, several aspects of the research programme are open to criticism. Before discussing these it is probably worth providing the reader with a framework within which the specific criticisms can be placed. Davids (1988) defined ecological validity as “a transient phenomenon characterised by informed and systematic attempts to analyse actual behaviour within specific environmental contexts, utilising unobtrusive, realistic, and reliable methods of investigation” (p. 127). Davids provided researchers with several criteria to judge the ecological validity of their research. These criteria included *realism*, which consists of *behaviour constancy* and *variable specificity*. Behaviour constancy refers to the extent that researchers adopt the actual movement pattern used in sports tasks. In the present project, steps were taken to ensure that experimental tasks were relevant to participants in order to ensure behaviour constancy, but also to enhance participants’ motivation during the studies. Variable specificity refers to the replication in the research environment of variables found in real-life situations. One of the major limitations of the research conducted as part of this programme involved the contrived anxiety interventions. Throughout the project the various anxiety interventions successfully increased cognitive anxiety, which was central to the conscious processing hypothesis. However, despite the significant increases reported in cognitive anxiety, the actual levels reported by participants were below those found in actual competition. The criticism of variable specificity could also be directed at the shadowing, random letter generation, and tone counting tasks used to encourage and prevent lapses into conscious processing. The manipulation checks administered throughout the project indicated that there were indeed some problems experienced by performers in implementing these tasks.

However, exact variable specificity is not always possible, or desirable. In the context of the present research aims to uncover strictly controlled relations among variables, it would be impossible, not to mention unethical, to sufficiently isolate such variables in field settings to allow precise interventions and measurement. In mitigation, in study 5 the research programme did progress to the use of more realistic interventions using self-talk, imagery and process goals to attempt to induce conscious processing.

Dauids' second criterion was termed *union* and, in the present context, involves the union of laboratory control and a naturalistic setting producing minimal interference with real-life activity. One method of achieving union in a research programme is to progress from conducting laboratory-based experimental designs to field-based studies. Although study 2 was field-based, the design was not without limitations. It was not possible to achieve further progression within the confines of the present project. The adoption of an interdisciplinary focus was partly responsible for the retention of laboratory settings. It should be pointed out that the persistence with, and refinement of, the techniques used in the present research programme has produced internally valid evidence that can underpin future research that may have a more applied focus. It must be noted, however, that the immediate concerns for future research into the conscious processing hypothesis will almost certainly require further work in controlled laboratory settings. Study 2 aside, the persistence with the golf putting task did mean that the experimental task was consistently realistic and this afforded objective, unobtrusive, *in vivo* measurement of the kinematics of the movement. Dauids' final criterion involves the use of *eclectic analysis*, which refers to the adoption of a range of research methods ranging from tightly-controlled laboratory experiments to idiographic, qualitative designs. While the interdisciplinary focus of the present research project has meant that a range of measurement methods have been adopted, the range of research methodologies and designs has been somewhat limited. Hopefully, this situation can be redressed by future research, which could adopt idiographic and qualitative methodologies to address some of the issues concerning the conscious processing hypothesis.

Applied Implications

The experimental focus of the research programme has highlighted several practical issues of interest to performers, coaches and sport psychologists.

Explicit learning strategies

Study 1 differed from the remaining studies in that the research design was based upon a learning paradigm. The performance impairment experienced by the explicit learning group highlighted the fragility of skills acquired using traditional explicit approaches to motor learning. The robustness of the performance of the implicit learning group under stress indicated that coaching strategies adopting a more implicit orientation might result in performance that is more resistant to the effects of competitive state anxiety. While the secondary task used in study 1 proved successful in encouraging implicit learning, it would prove difficult to use with sports performers. Random letter generation would be arduous and tiring to use in practice, almost certainly undermining the intrinsic motivation necessary to persist at practice. Alternatives such as modelling and imagery might be of use to coaches and performers in developing more holistic conceptual representations of movements, thereby encouraging less reliance upon verbally mediated processes. Demonstrations, traditionally a popular coaching strategy, would appear to play an important role in such processes. Coaches can also use metaphor and imagery to convey information about complex movements (Masters, 1992a). For example, a soccer goalkeeper coach might typically employ visual analogies to describe the basic “set” position of the goalkeeper. A common analogy used is that of a gunfighter ready to “draw” with both hands. This simple analogy conveys the information contained in the following description by Wilson (1980, p. 37):

. . . the ‘keeper’s basic position should be with feet slightly apart and knees slightly bent. The main part of his weight should be on the soles of the feet with the immediate spring coming from the toes. The body is inclined forward slightly . . . and so too are the arms . . . If you incline your arms, and consequently your hands, very low you should appreciate that shoulder or head high shots require a greater movement than a midway position. Similarly, a high arm and hand position demands awareness of the extra movement involved for a low ground

shot. Ideally, therefore, I would advocate a midway position, one assuring equal confidence and success with low or high shots.

Clearly, the use of analogy and metaphor by coaches might allow performers to avoid translating the explicit information contained in the above description from verbal perceptual processes across the action-language bridge into action perceptual processes before action is initiated (cf. Annett, 1991). It would be possible to test this suggestion by designing a study in which participants acquire a motor skill explicitly and using analogy. The use of analogy might avoid the problem of lower levels of performance experienced by the implicit learners in studies that used random letter generation to encourage implicit learning (Masters, 1992b; Hardy, Mullen et al., 1996). The robustness of analogy learning to stress could then be tested using a stress transfer trial, such as that used in study 1.

The earlier discussion of ecological models of motor control and learning might also be relevant in the context of implicit learning. In dynamical systems terms, implicit learning would be considered as discovery learning. An ecological interpretation of Masters' (1992b) and Hardy, Mullen, and Jones' (1996) findings would suggest that more stable dynamics were revealed through discovery learning. According to Williams et al. (1999), "These dynamics proved to be more resistant to the perturbing forces enforced by the organismic constraint of anxiety" (p. 322). As such, any future research on analogy learning might consider cognitive and dynamical interpretations of implicit learning effects.

Process goals

The final four studies of the present project concentrated on examining the performance of experienced but anxious participants. The applied sport psychology literature currently recommends using process goals as a method of retaining or regaining focus during performance (Bull, Albinson, & Shambrook, 1996; Kingston & Hardy, 1994a; Kingston & Hardy, 1997). The use of process goals typically involves performers focusing upon a specific subcomponent of a task. According to the conscious processing hypothesis, the explicit content of process goals should have deleterious effects upon performance when competitors are cognitively anxious. Within the current research programme, explicit, task-relevant knowledge consistently caused performance impairment, with the exception, ironically, of the

final study that specifically examined the use of part and holistic process goals upon the performance of anxious golfers. For highly-skilled performers, the use of holistic process goals has been advocated as a subtle way of avoiding the explicit content of part process goals. Holistic process goals might help skilled performers avoid lapses into conscious processing by encouraging global representations of entire movement sequences, promoting “chunking” and automatic processing. However, strong recommendations regarding the use of goal setting strategies by skilled but anxious performers should be tempered with caution until more conclusive evidence regarding the use of explicit knowledge under stress has been presented. With this point in mind, holistic process goals appear to provide practitioners with the safest method of implementing process goal strategies for skilled performers. Part process goals may still be effective for performers who are less than expert.

It does appear that increases in effort can compensate for the negative effects of anxiety upon performance (cf. Eysenck & Calvo, 1992). Recommendations for practitioners would seem a little premature until the exact role of effort in the anxiety-performance relationship is clarified. For example, it remains to be seen whether compensatory effort is the result of qualitative or quantitative changes in energetical resource allocation. Specifically, it is unclear whether compensatory effort arises as a result of increases in performer’s current energetical patterns, or whether qualitative changes in energetical resource allocation are necessary before compensatory mechanisms can be initiated.

Dealing with distractions

Study 4 also produced evidence suggestive of distraction effects under conditions of high state anxiety. Several strategies may help performers deal with the effects of distraction. Overlearning and simulation training are two such strategies. Simulation training involving practice in the face of typical distractors may assist performers in dealing with the same distractions under the pressure of competition. Overlearning of skills would enable performers to reproduce skills in competition no matter what situations or doubts arose. However, as Hardy, Jones and Gould (1996) note, no empirical research has directly addressed the question of how much overlearning is required to achieve such a state and any recommendations made to practitioners would have to be based largely on anecdotal evidence.

Research Strengths

The main strength of the present research programme has been the interdisciplinary focus on a specific research question. The methods adopted have laid the foundations for future research to build a comprehensive, holistic picture of the cognitive and energetical dynamics underlying performers responses to competitive anxiety. The use of spectral analysis of heart rate variability (HRV) is particularly notable. HRV has been more commonly applied in physiologically-oriented sports science. The use of HRV in the current research project represents a unique and innovative approach to the study of the energetical processes underlying the behaviour of anxious performers. In addition, the research programme has addressed a number of limitations and recommendations for future research that have been identified by previous researchers. These include the need for:

1. The removal of conceptual ambiguities (Hardy & Jones, 1990).
2. Psychophysiological techniques to predict different metacognitive states during performance (Hardy & Jones, 1990).
3. The development of sensitive and precise measures of performance (Weinberg, 1990).
4. Standardised performance environments and tasks (Gould & Krane, 1992).
5. The adoption of causal rather than correlational research designs (Gould & Krane, 1992).
6. Process measures of performance (Weinberg & Hunt, 1976).
7. The incorporation of multi-theory tests (Gould & Krane, 1992).
8. Consideration of both positive and negative effects of anxiety upon performance (Hardy & Jones, 1990).
9. The inclusion of metacognitive variables other than multidimensional anxiety within research designs (Hardy & Jones, 1990).
10. Future research in sport psychology to be carried out within an interdisciplinary context (Morgan, 1989).

Research Limitations

Many of the research limitations of this research programme have been identified in the discussions of each individual study, and within the section addressing ecological validity. These have been addressed in some detail and will only be listed here. The limitations discussed in the context of ecological validity were (a) anxiety interventions; (b) secondary tasks used to encourage and prevent lapses into conscious processing; and, (c) adoption of a narrow experimental focus that resulted in a lack of eclectic analysis.

Sample sizes were adequate but not optimal. The researcher was faced with the problem of including enough participants to ensure that the relatively small effect sizes expected using contrived anxiety interventions could be detected while at the same time ensuring that the amount of data collected for the kinematic analyses was manageable. Traditionally, studies examining biomechanical variables use small sample sizes due to the large quantity of data generated. In this respect, the present studies used relatively large sample sizes. The time spent by the author processing the kinematic data for studies 3 and 4 was substantial. Furthermore, the skills required to adequately “clean”, filter and enter the data into a manageable database form are non-trivial and probably mitigate against a single researcher conducting worthwhile examinations of the anxiety-performance relationship using kinematic *and* physiological variables. A “team” approach may prove to be more effective in this respect. However, such an approach may lead to a more fractured multidisciplinary approach being adopted. In the author’s opinion, the ability to adopt an inter, rather than multidisciplinary, approach to research questions may produce more meaningful results.

On reflection, the magnitude of the effect sizes that could be expected as a result of the hypothesised interaction between anxiety and putting conditions may have been predictable for two reasons. Firstly, as noted above, the anxiety effects were much reduced in the laboratory environment. Secondly, the size of the changes in kinematic parameters would also be small given the fine nature of the putting task and the small changes in movement patterns that might be needed to cause performance impairment. Future research should either use more realistic anxiety interventions, select criterion tasks where increases in anxiety might produce larger effects upon kinematic processes, or considerably increase sample sizes.

The lack of ecological validity related to the secondary tasks used to induce and prevent lapses into conscious processing resulted in problems with adherence. The manipulation check administered at the end of studies 3, 4, and 5 highlighted these problems. In study 4 preliminary analysis of the data negated the need to remove “problem” participants, maintaining sample size. However, the problems experienced by some of the participants in study 5 resulted in a trimming of the sample size by 50%. Clearly, statistical power was compromised in this study. As noted in the discussion section of study 5, some form of intensive training using the intended goal-setting interventions appears to be essential in future research. The limitations of the CSAI-2 as a self-report measure of competitive state anxiety have already been alluded to. Given the limitations in the CSAI-2 identified by many researchers, hopefully, steps will be taken to rectify this situation in the near future.

Future Research Directions

Clearly, the hypothesised conscious processing effects require further clarification. The present research programme has provided moderate support for the effects of anxiety-induced conscious processing. Future research needs to clarify whether or not anxious performers do actually lapse into conscious processing. For example, skills will differ in the extent to which conscious processes are necessary for task control. Conscious processes may play a more functional role in sports such as rock climbing, for example, whereas in sports such as tennis conscious processes should be minimally involved in movement production. The extent to which conscious and automatic processes interact to produce optimal performance also requires clarification. For example, in golf putting it seems logical to suggest that conscious processes play a major part in the pre-performance routines of experienced golfers. During the actual putting stroke, automatic processes probably predominate. Researchers should attempt to clarify whether or not this actually happens. Psychophysiological indices might play an important role in answering this question. The role of process goals as a means of enhancing or regaining task focus also requires further examination. Researchers should ensure that they provide some form of structured goal-setting training programme for participants in future studies.

Study 1 indicated that implicit learning might be more robust in the face of disruption by stressors such as anxiety. Analogy learning using modelling and

imagery was suggested as a practical method of encouraging implicit learning. Future research should examine the potential of analogy learning as means of facilitating implicit modes of learning. Such research should also examine the suggestion that skills learnt implicitly by analogy might be more resistant to the negative effects of anxiety.

The present research programme has highlighted the role of effort in the anxiety-performance relationship. Future research should attempt to clarify the exact circumstances under which performers exert more effort and under what circumstances this additional effort enhances performance or causes lapses into conscious processing. Psychophysiological measures should be used to establish the energetical basis of compensatory and conscious processing effort responses. Self-confidence has also been highlighted as a mechanism that might moderate the effects of anxiety upon performance. Future research efforts should attempt to clarify this suggestion. In addition, researchers should combine cognitive anxiety, physiological arousal, effort and self-confidence in research designs that examine their interactive effects on athletic performance. Other variables may also be important in this respect. For example, personal control (Carver & Scheier, 1988), expectancy (Hatzigeorgiadis & Biddle, 1998), and competence (Schonpflug, 1983). Future research should attempt to clarify the exact circumstances and variables that affect resource allocation in anxious performers.

In the context of the heterarchical models that provided a theoretical framework for the conceptualised conscious processing effects, researchers should seek to clarify the possibility that cognitive anxiety and physiological arousal / somatic anxiety exert their effects at different "levels" of such systems. For example, conscious processing effects are hypothesised to be mediated by the effects of cognitive anxiety upon higher-order mechanisms. Physiological arousal / somatic anxiety may function by affecting lower-order automatic mechanisms. The hypothesised differential effects upon performance might be indexed by manipulating the subcomponents independently and mapping athletes' performance effectiveness and energetical and kinematic responses.

One of the limitations highlighted earlier was the lack of diversity in terms of methodological approaches adopted within the present research programme. A recommendation for future research would involve the adoption of a wider range of

research methods. For example, qualitative methods may enable researchers to gain an insight into athletes' perceptions of the processes and factors that influence their performance under stressful conditions. Single-subject experimental designs may also be useful in determining idiographic behavioural and energetical profiles of anxious performers.

The measure of anxiety adopted within the present project was the CSAI-2. Some of the major limitations of this self-report instrument have been highlighted earlier. Researchers should attempt to clarify the validity of the CSAI-2 as a measure of anxiety, as researchers have highlighted major deficiencies in its structure. Despite the difficulties associated with measurement in the area of stress and anxiety, a major challenge faced by researchers is to develop *in vivo* measures of the anxiety response, in order to examine the on-going cyclical influences of anxiety upon performance (Hagtvet & Ren-min, 1992). The use of spectral analysis of heart rate variability (HRV) as a possible measure of energetical resource allocation underlying the behaviour of anxious performers requires further exploration in this respect. HRV could possibly be used in conjunction with complementary physiological indices of respiration, as suggested in the present project, and blood pressure, which is thought to underlie changes in the mid-frequency band of the heart rate power spectrum, to establish energetical patterns. However, before this happens a major challenge for HRV researchers is to develop indices that move beyond the measurement of tonic (long-term) responses toward more sensitive indices capable of mapping phasic (short-term) responses to competitive state anxiety.

Conclusion

The main purpose of this research programme was to examine the conscious processing hypothesis as a possible explanation for the effect of anxiety upon performance. The results have indicated that task-relevant knowledge may have a debilitating effect upon anxious performers. Research into the conscious processing hypothesis is in its infancy and there is clearly much still to be understood. However, this research programme has made a significant contribution to understanding some of the conceptual issues surrounding both the conscious processing hypothesis and processing efficiency theory.

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