Cognitive strategies as a function of effort in elite, average and recreational cyclists.

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ABSTRACT

The purposes of this study were two-fold; to develop a cycling-specific cognitive strategy classification system, and to investigate the differential and interactive effects of effort and competitive status, on associative strategy use in cyclists.
Subjects consisted of 8 elite, 8 average, and 8 recreational cyclists (n = 24). A light-weight micro-cassette recorder was used to document the subjects' verbalized thoughts while training. Effort was measured by the rating of percieved exertion (RPE), and through the recording of heart rate every 60 seconds.

A cycling-specific subcategory of thought (equipment monitoring) was identified, which had not previously been identified in similar research on marathon runners. The implications of sport specific classification systems are discussed. Statistical analyses showed no support for the popular notion that cognitive strategy use varies according to competitive status. Neither did they show support for the notion that it varies according to effort. The statistically non-significant findings are discussed in the light of the stochastic nature of cycling, and recommendations are made to cater for this in future research.

CHAPTER 1:

COGNITIVE COPING STRATEGIES IN ENDURANCE SPORT: A LITERATURE REVIEW

1.1 INTRODUCTION

The sport psychology literature abounds with terms describing the collective psychological techniques used to enhance athletic performance. Terms such as "intervention strategies" (Whelan, Mahoney & Meyers, 1991), "cognitive strategies" (Morgan, 1985), and "cognitive skills" (Okwumabua, 1985), are often used interchangeably, and to denote the same techniques. The most widely used of these techniques include visualization and mental rehearsal, anxiety/arousal management, and self instruction and self monitoring. While the term "cognitive coping strategies", as it appears in the title encompasses all of these techniques, the majority will only be mentioned in passing. The focus of this review will lie specifically with thought processes occuring during endurance events, and the term cognitive strategies will in the present review be used solely to refer to this category of techniques.

Just about all athletes would acknowledge having various thoughts during endurance events. It is ludicrous to imagine someone running a marathon without ever thinking something along the way. It is only when an athlete deliberately adopts a particular thought process to facilitate performance however, that his thoughts may be termed a "strategy". The last two decades have seen an increasing amount of research done in this area of sport psychology. This review will attempt to trace the development of this line of research, with particular emphasis on Morgan's distinction between associative and dissociative thought processes (Morgan, 1977). As different researchers have investigated these processes in different ways, the review will not look at research developments in a chronological fashion. Rather it will attempt to draw together all of the past research by focusing on the main methodological issues and the resultant findings. It is hoped that this will help clarify the present state of our knowledge in this field, its implications for practical application, as well as possible future directions for research.

1.2 HISTORICAL DEVELOPMENT OF THE RESEARCH

Though still in its infancy, sport psychology has over the past three decades increasingly established itself as a separate discipline in its own right. This reflects the growing awareness of psychological factors, along with natural ability and learning experiences, being one of the three major determinants of optimum performance in sport. Rushall (1989) has proposed that sport psychology is the key to sporting excellence, and described it as "the sport science that governs the quality of a performance" (p165). This is in keeping with Ryder, Carr & Herget's (1976) suggestions that running records are still way below human physiological limits, and that restraints on performance are psychological.

With respect specifically to endurance events, Morgan (1977) points out that one might intuitively expect performance to depend not only on physical ability, but also on the willingness to tolerate any discomfort associated with the hard work. With the rapidly increasing professionalization of sport, and the concommitent emphasis on performance and winning, it is not surprising then that researchers began to study the psychology of endurance events. While this type of athletic activity includes swimming, cycling and canoeing events, the overwhelming majority of research was done on distance runners. This was probably due to the phenomenal growth of the sport amongst the average (perhaps previously inactive) members of the community.

The early research in this field consisted largely of descriptive studies aimed at identifying various groups of athletes. It was hoped that this might provide clues as to what inspired the jogging phenomenon amongst such a diverse population. With respect to more elite athletes, it was felt that it would assist in selection, counselling and training. Comparing individual psychological traits and profiles to the "ideal", could facilitate predictions of performance (Freischlag, 1981), "psyching up" (Morgan,1974), and clinical interventions, eg. in the case of staleness (Puffer & McShane, 1992), or as "emotional first aid" after competition (Morgan, 1974). Underlying this search for the ideal "marathon personality" was the assumption that cognition and affect were major determinants of athletic performance. Today this view has been taken a step further with the hypothesis that personality characteristics such as affect, cognition and perception could potentially alter the cost (in terms of oxygen consumption) of physical exercise (Crews, 1992; Williams, Krahenbuhl & Morgan, 1991).

The descriptive studies concerning the characteristics of the marathoner largely made use of various personality inventories such as the Cattell 16 PF Inventory and the Eysenck Personality Inventory (Cratty, 1973). Using a number of such psychological tests, Morgan & Costill (1972) found marathoners to score within the normal limits of extraversion-introversion, neuroticism-stability, and depression. However they scored significantly below the norm for anxiety. Clitsome and Kostrubala (1977) failed to identify a specific "marathon personality", but did find a tendency for them to be more introverted than the general population. There seems to be some dispute about the latter claim however, with certain studies (eg. Gontang, Clitsome & Kostrubala, 1977) supporting it, and others (e.g. Morgan & Pollock, 1977), disputing it.

The difficulty with distinguishing the marathoner from the general population in terms of psychological as well as psycho-social/demographic characteristics, in all likelihood stemmed from the vast diversity within the marathon population itself. Greater progress was however made in distinguishing elite marathoners from their non-elite counterparts. Morgan (1985) proposed a "mental health model" of human performance, which stipulated success in sport to be inversely correlated with psycho-pathology.

This theory gained more corroborative support with a gradual change of focus from psychological traits to more transitory psychological states. Studies using the Profile of Mood States Questionnaire (McNair, Lorr & Doppleman, 1971) have consistently found elite athletes to have an "iceberg profile", scoring above the population mean on vigour, and below the mean on tension, depression, anger, fatigue and confusion (Morgan, O'Connor, Ellickson & Bradley, 1988). The fact that differences in state more than trait were found between elite and non-elite athletes, lead Morgan & Pollock (1977) to conclude that these differences represented a consequence of running rather than an antecedent condition. The idea that running might alter mood states is associated with, and probably contributed extensively to, the research concerning people's reasons for running and the benefits thereof.

The physiological and psychological benefits of regular exercise have been well documented (e.g. Berger & Owen, 1987; Ewing & Scott, 1984). It is now generally accepted that running is related to decreased levels of anxiety and depression, thus resulting in enhanced psychological well-being. Some have even proposed running to be a therapeutic medium for treating depression (Greenspan, Fitzsimmons & Biddle, 1991; Bartmann, 1991; Kostrubala, 1977). People who run are clearly aware of these benefits, as studies of various runners have consistently found perceived psychological benefits to be second only to physiological benefits as reasons given for their behaviour (Clough, Shepherd & Maughan, 1989; Summers, Sargent, Levey & Murray, 1982; Harris, 1981; Carmack & Martens, 1979).

Anecdotal evidence has in fact long claimed that many runners experience a "high" whilst running. This transcendental experience is characterized by feelings of euphoria and analgesia during the run, and followed by feelings of relaxation or quiescence thereafter. Various authors have postulated that running time and distance are major determinants of the onset of such experiences (Carmack & Martens, 1979; Kostrubala, 1977). Glasser (1976) was the first person to propose that the runner may become addicted to these pleasurable feelings. He suggested that the pain, misery and upset associated with a missed run, represented withdrawal symptoms resulting from the lack of euphoric and intensely pleasurable feelings usually gained from running. He described this as a positive addiction in so far as it did not come to "dominate" the person's life.

The weakness of Glasser's work was the lack of strong experimental control. More recently however, the findings from a number of other studies have supported Glasser's notion of addiction to running (Clough et al., 1989; Perkins, 1988; Summers et al., 1982; Carmack & Martens, 1979). Another controlled study by Morris et al. also supported the view that exercise increases endorphin activity, producing an addiction and resulting in a withdrawal syndrome if stopped (Morris, Steinberg, Sykes & Salmon, 1990). However Crossman et al., in an exploratory study on the response of competitive athletes to a layoff from training, found no evidence for unpleasant effects of withdrawal from exercise. They also proposed however that two opposing processes may determine responses to layoff; negative effects of withdrawal from exercise, and positive effects related to dissipation of fatigue from overtraining (Crossman, Jamieson & Henderson, 1987). Presumably the second factor would play a greater role in the case of competitive athletes than in that of their non-competitive counterparts.

Pargman proposed that all runners may be located on a continuum according to the nature or strength of their motivation for running, the two ends of which being designated addiction/ dependence, and commitment/dedication (1980). Runners who fall into the former category are characterized by a reliance on regular running, to the extent that a withdrawal syndrome is suffered after a layoff in training. In contrast to this, those in the latter category run for more intellectual or rational reasons, which may at best be described as pragmatic, e.g. for health reasons based on their doctors' recommendations. Pargman's continuum serves to illustrate that not everyone exhibits the same responses to running, or to the discontinuation thereof. In spite of the evidence suggesting that many runners do experience a high, Schomer (1987) for instance, found that the clear majority of his 31 subjects fell into the committed-dedicated runner class, and showed no evidence for experiencing any sort of "high". Hinton & Taylor (1986) have in fact hypothesized that the increasing (often anecdotal) awareness of a "runner's high" has established the appropriate expectancies for this phenomenon to occur via a placebo response mechanism. The assertion that "runner's high" may be based on the psychophysiological mechanism characteristic of certain types of placebo responsivity certainly warrants further investigation.

A final area of research concerning running and mood state, is that of the possible negative effects which the former may have on the latter. Such research usually appears in the literature of overtraining or staleness. Besides various physiological indices, these syndromes are usually characterized by feelings of restlessness, insomnia, undue fatigue, and loss of energy (Sperryn, 1984). Psychological self-report variables of mood and affect have in fact proved to be better descriptors and measures of overtrained states than physiological indices (Rushall, 1989). As these psychological changes occur prior to the onset of physical symptoms, they may also be used as warning signals to introduce a taper in training load, so as to prevent the onset of physiological breakdown.

We have noted the gradual change in focus from personality traits to more temporary psychological states in the sport psychology literature. This research has aided our understanding of the psychological benefits of running, and has gone a long way toward increasing our understanding of the running phenomenon. Another, and perhaps more recent development, has been the shift in research focus from a theoretical understanding to that of a more applied knowledge. It has concentrated on the development and adaptation of various techniques which are practically useful in enhancing performance. Most of these techniques were originally borrowed from clinical psychology, and have since been specifically adapted for use in the sport setting. The most common of these include hypnosis (e.g. Morgan, 1970), relaxation and stress management (e.g. Ziegler, Klinzing & Williamson, 1982), biofeedback (e.g. Goldstein, Ross & Brady, 1977) and visualization and mental rehearsal (e.g. Ungerleider, Golding, Porter & Foster, 1989).

Another related area of research has been the study of athletes' thought processes during endurance events. The possibility of shaping these thought processes in such a way as to optimize performance, makes this potentially a very useful area of applied research. Having sketched a brief history of the development of this, and related types of sport psychological research, the remainder of this review will now focus on cognitive coping strategies in endurance sport. In doing so it will use Morgan &

Pollock's (1977) association/dissociation distinction as a basic framework, as most individual studies since then have done the same.

1.3 ASSOCIATION/DISSOCIATION

Morgan used the term "dissociation" to refer to the process whereby runners dealt with their pain and fatigue by diverting their thoughts away from these negative bodily sensations.
"Association" on the other hand referred to the process of specifically concentrating on these and any other physical sensations by means of constant self-monitoring. He was not however the first to propose that associative thought processes may aid running performance. Two years previously, Fred Rowe, himself a runner, described running as a form of meditation:

> Running in harmony with the breathing rhythm, running relaxedly, and running with complete awareness of what one is doing...gives the runner economy of energy leading to purity of movement. (In McCloy Layman, 1980, p270).

While he only discovered these possible beneficial effects of associative thinking in 1977, Morgan had already been aware of the dissociative process and its positive uses for quite a while. In fact he assumed that early Tibetan monks used a similar method in making possible their extraordinary runs. He points out that some of their alleged running feats compare rather favourably with today's best marathoners running under the most ideal conditions with all the current scientific support available to them. Morgan noted that the "cognitive strategy" used by these monks remarkably resembled that used by marathon runners he had previously studied. Both groups used dissociative techniques to divert attention from painful bodily stimuli. While the marathoners mentally "built houses", "wrote letters", or with every step "trod on the imaginary faces of detested co-workers", the monks allegedly repeated sacred phrases or mantras while fixing their eyes on distant objects.

This originally led Morgan & Pollock to hypothesizing that the principal "cognitive strategy" used by world class runners during competition, was dissociation of sensory input (Morgan & Pollock, 1977). To their surprise however, they found that while average marathoners did employ such strategies, elite runners in contrast associated, and attempted to process sensory feedback so as to modulate their pace accordingly. They concluded that elite marathoners' exceptional anatomical and physical capacities facilitated their use of associative cognitve strategies, which in turn allowed them to efficiently match physical performance to competitive demands.

Since then, a number of researchers have investigated the potential advantages of both dissociative and associative cognitive strategies. Some have found dissociation to be the more useful of the two in enhancing performance (e.g. Okwumabua, Meyers, Schleser & Cooke, 1983; Pennebaker & Lightner, 1980), while others have found association to be the preferred strategy. This has especially been the case with researchers who have emphasized the importance of injury prevention. As injury is the major limiting factor in many athletes' performances (Sperryn, 1984), it is not surprising that aetiological factors of injuries have become a topical area of research (e.g. Macera, 1992).

There is an underlying assumption that the ignoring of sensory cues occuring during dissociation will result in a higher risk of injury (Morgan & Pollock, 1977). Despite the obvious physical limitations of being injured, it has also been proposed that injuries may in some cases lead to the unwanted development of mental barriers (Madden, Kirkby & McDonald, 1989). On the other hand, prevention of injury through the use of association may result in the long term improvement of aerobic conditioning, and ultimately of race times (Schomer, 1987). Association may also improve performance by ensuring more economical movement (Schomer, 1990). Anderson points out that this is quite feasible as association "keeps muscles loose, and relaxed muscles use less oxygen and can contract more powerfully than overly tight ones" (Anderson, 1992, p7).

It seems then that a substantial amount of support has been offered pointing to the benefits of both strategies. Different studies have however inevitably been characterized by different methodological variables. It is this author's hope that an analysis of these methodological differences and their respective findings, will allow the drawing of a synopsis regarding our current state of knowledge in this field, so that ultimately we may have a clearer idea as to which strategies work best under particular conditions.

1.4 METHODOLOGICAL VARIABLES IN PAST RESEARCH

1.4.1 SUBJECT GROUPINGS

It has already been mentioned that researchers have in the past attempted to isolate particular variables distinguishing athletes from non-athletes. Similar attempts have also been made to distinguish the elite in the former category from their non-elite counterparts. Obviously the types of differences studied has depended on the scientific context, e.g. physiological differences in a sports medicine context etc. In this particular context, we look at differences in cognitive strategy use as a function of the runners' competitive status (i.e. elite, non-elite, etc).

With regard to competitive status, research looking at the thought processes occuring during endurance events has largely used one of three types of subject groupings. They are firstly, the sole use of elite athletes (e.g. Silva & Appelbaum, 1989; Morgan et al., 1988), secondly the sole use of non-elite athletes, (e.g. Okwumabua, 1985; Summers et al., 1982), and thirdly comparisons between elite and non-elite athletes (e.g. Schomer, 1990 & 1987). On the whole, these studies lend support to Morgan & Pollock's (1977) original assertion that elite runners tend to associate while non-elites tend to dissociate. Morgan (1978) later proposed that the elites' tendencies to associate may have been part of the reason for their good performances, and this notion appears to a certain extent to have become accepted by the sport psychological fraternity in general (e.g. Orlick, 1980).

This does not however imply that non-elite athletes do any worse for using dissociative strategies. On the contrary, some research suggests that the use of dissociation actually enhances performance amongst the non-elite (Pennebaker & Lightner, 1980;

Weinberg, Smith, Jackson & Gould, 1984). Morgan (1978) hypothesized that association works for elite runners as their superior physiological capacities result in them experiencing less pain, hence making it easier for them to concentrate on bodily cues. Non-elite runners on the other hand experience significantly more pain which if they do not dissociate from, would make their task that much more difficult. Anderson (1992) however argues that this does not seem a likely scenario as both elite and non-elite runners complete marathons at about 80-85% of maximal aerobic capacity. The implication is that the two groups both run at similar perceived intensities, thus effectively nullifying the argument that elites can "afford" to associate more than non-elite runners.

Another possible explanation for the differential effectiveness of cognitive strategies across different status of runners, is that elite runners simply practice association more as a result of training hard more often than non-elite runners, and hence are able to use it more effectively in competition. This raises the possibility that it is largely the experience or "practice effect" which mediates the (un)successfulness of particular cognitive strategy use. This possibility will be dealt with in greater detail, below.

While a substantial amount of the research suggests that elite athletes associate more than non-elites, (the assumption being that competitive status is the major determinant of associative strategy use), not all research has supported this notion. Schomer (1987 & 1986) found no support for the idea that elite runners predominantly use association while non-elite runners prefer dissociation. Instead, he found *qualitative* differences within associative thinking as practised by the two groups of runners. Elite runners tended to be more specific in their body monitoring, and exhibited more preciseness and control in terms of adapting their pace to the perceived requirements. Percentage of associative strategy use did not however vary significantly as a function of competitive status.

It seems then that one cannot assume that all elite runners associate and non-elite runners dissociate, as was previously thought. No group of runners relies solely on one particular strategy, and the effectiveness of any particular strategy seems to be mediated by a factor(s) beyond just competitive status.

1.4.2 THOUGHT CLASSIFICATION

The classification of cognitions is vital if they are to be shaped in such a way as to enhance performance. The classification system in effect needs to be structured in such a way as to allow its use as a theoretical framework upon which practical applications of the knowledge may be based. Morgan & Pollock's association/ dissociation distinction fulfils such a need. Since they originally postulated it, a number of authors have used this system in their studies of cognition (Wrisberg & Pein, 1990; Silva & Appelbaum, 1989; Fillingham & Fine, 1986; Summers et al., 1982). Others have based actual intervention programmes on the system (Saintsing, Richman & Bergey, 1988; Okwumabua et al., 1983).

Not all authors have however stuck rigidly to Morgan & Pollock's two categories. Sacks et al proposed a third category - "meditative thinking", which differs from association and dissociation in that the runners are not focusing either on themselves or on specific distracting thoughts, but are instead "not particularly focusing at all" (Sacks, Milvy, Perry & Sherman, 1981). Railo & Unestahl (1979) also speak of "meditative running", although in so far as their process requires a "passive concentration on something", be it a mantra or particular body movement, it may still be described as dissociating behaviour.

Weinberg (1985), spoke of "positive self-talk" as a category distinct from association and dissociation. However Kirschenbaum & Wittrock (1984), in their vision of athletic skill development as a self-regulatory process, understood self-instruction and self-monitoring to be complementary functions. This appears to be a valid assumption, as using one of these mechanisms in isolation from the other would not be very fruitful in terms of effecting adaptive changes. Thus the runner who through self-monitoring becomes aware of a tightening of his calf muscles but does not (instruct himself to) do anything about it, may just as well not be aware of the problem in the first place.

Schomer (1987) was aware of the complementary nature of self- monitoring and positive self-talk, when he proposed the latter (under the term "command and instruction"), to be one of ten sub-categories of runners' thoughts. Schomer identified these ten exhaustive, mutually-exclusive and independent theme categories after content analysing recorded verbalizations of runners' cognitions. Using Morgan & Pollock's original association/ dissociation distinction as a framework, he identified four subcategories as being associative in nature (viz. feelings and affects; body monitoring; command and instruction; pace monitoring). The remaining six were dissociative in nature (environmental feedback; reflective activity thoughts; personal problem solving; work, career and management; course information; talk and conversational chatter).

Schomer then amalgamated his subcategories with Nideffer's (1981) attentional style categorization, which classifies attention according to direction (internal/external) and width (narrow/ broad). This gave him ten valid and reliable cognitive strategy sub-classifications (see Figure 1, p32) which were seen to offer "further instructional insights and mechanisms for future optimal manipulations of cognitive strategies" (Schomer, 1987, p42).

While other researchers investigating association/dissociation patterns have since made use of Nideffer's work, (e.g. Wrisberg & Pein, 1990), it may be worthwhile noting that other authors have also proposed other classifications of attentional style. Three of Cratty's (1984) five attentional dimensions, namely quality, flexibility and duration of attention are not catered for in Nideffer's scheme. It is quite possible that they may offer further insight into the practical application of cognitive strategies, especially in the light of evidence alluding to the flexible nature of actual cognitive strategy use by athletes (See later).

1.4.3 METHOD OF DATA COLLECTION

The vast majority of researchers investigating cognitive processes during endurance events have used retrospective methods of data collection. These have taken the form either of interviews or the administration of questionnaires at some point in time after the completion of the endurance event(s) (Wrisberg & Pein, 1990; Silva & Appelbaum, 1989; Ungerleider et al., 1989; Saintsing et al., 1988; Morgan et al., 1988; Spink, 1988; Fillingham & Fine, 1986; Okwumabua, 1985; Weinberg, 1985; Weinberg et al.,1984; Okwumabua et al., 1983; Summers et al., 1982; Freischlag, 1981; Carmack & Martens, 1979; Morgan & Pollock, 1977; Lumian, 1974).

Sacks et al. (1981) have pointed out that such retrospective methods may represent a source of error in the aforementioned studies. Subjects may forget or distort some of their previous thoughts, perhaps as a result of certain types of thoughts carrying more emotional investment than others. In an attempt to counter this methodological weakness they "tested" their subjects every three hours during a 100-mile running event.

While the method used by Sacks et al. represents a strengthening of research design, the information was still gleaned in response to specific cues - subjects responded to specific pre-selected questions, every three hours. There is always the chance that some information may have been forgotten even within the three hour period, and there is no guarantee that the questions posed will prompt the offering of all thought processes spanning the previous three hours.

Schomer's (1987) innovative method of data collection went a long way toward solving these difficulties. Using light-weight microcassette recorders, he collected continuous on-the-spot verbalizations of runners' thought processes during training runs. In support of this method, Schomer offers Ericsson & Simon's assertion that "the most important condition under which verbalization can be expected to be an accurate account of cognitive activity, is that the verbal report has to be made concurrently with the task-related cognitive activity" (In Schomer, 1987, p61). While this method may not necessarily present an exact version of thought processes, it is certainly an improvement on the administration of retrospective interviews and questionnaires.

M.Blackburn (Personal communication, 8 March 1993) compared three different techniqúes of thought documentation during treadmill running: Thought verbalization and post-exercise interview; questions presented on slides during run and post-exercise questionnaire; video-taping of run and post-exercise narrative of thoughts. The results did not shed doubt on the accuracy of verbal reports taken during exercise. He did however express some concern that *continuous* verbalization in an endurance activity would cause some interference, if only with respiration. Blackburn concluded that better thought recording during treadmill running was achieved through a combination of thought verbalizations triggered by random signals, and video-taping of the subject during the run (where subjects were asked to elaborate on their thoughts while watching the videos post-exercise).

While Blackburn's methodology represents a further improvement, especially by providing more information in the form of the video recording, this must be balanced against the potential quality of information lost as a result of the laboratory setting.

1.4.4 SITUATIONAL VARIABLES

i. **Different sports:** Thus far in our review of cognitive strategies in endurance sport, we have dealt exclusively with distance running. The simple reason for this is that there seems to be very little similar research done in other endurance sports. While several researchers have identified conitive style differences between elite and non-elite athletes in other sports (Okwumabua et al., 1983), these do not represent cognitive strategies per se, and as the sports are not really endurance events, the association/dissociation distinction is probably not as applicable anyway.

Bakker et al. (1993) looked at association/dissociation patterns in triathletes and found some support for Morgan & Pollock's original assertion that elite marathoners associate more than non-elites. Spink & Longhurst looked at the effects of cognitive strategy use on the performances of advanced swimmers, but found most of the improvements due to analgesic suggestions (In Spink, 1988). Chorkawy and Ford both found up to 15% improvements in maximum performance of nationally ranked swimmers, after using numerous psychological techniques, one of which was associative thinking (In Saintsing et al., 1988). Clingman & Hilliard (1990) studied race walkers and found that differences between particular internal focii were more important than the association/dissociation distinction per se.

A final variation on the running theme has occured in laboratory settings, where a number of studies have shown dissociative strategies to improve performance on "artificial" leg-lift tasks (Spink, 1988; Weinberg, 1985; Weinberg et al., 1984). Gill & Strom (1985) similarly found that athletes performed more repetitions on a quadriceps machine when being externally focused. To what extent such tasks are comparable in terms of endurance to running a marathon, is however unsure. Laboratory tasks such as those cited above are typically not nearly as long temporally as are applied tasks such as running a marathon. Clearly however, there is much scope for similar research in the applied settings of endurance swimming, cycling, canoeing and triathlon events.

ii. **Distance:** As may already have become obvious in the previous section, there is some confusion as to what exactly represents an endurance event. It has already been noted that changes in state of mind may occur as a function of the time/distance spent running. These are however changes in affect, and they do not necessarily imply corresponding changes in cognitive strategy.

Past researchers have used a wide range of distances under the banner of endurance events. Okwumabua et al. (1983) and Sacks et al. (1981) investigated the use of cognitive strategies over the distances of 1,5 miles and 100 miles respectively. The former study found the use of dissociation to be positively correlated to improvements in performance. However to what extent this may be attributed to the relatively short distance or to the novice status of the subjects, is unclear. It is important that this confusion is cleared up if we are to ascertain exactly under what conditions particular cognitive strategies are most useful.

iii. **Status of the endurance event:** This refers to the competitive or training "nature" of the event being undertaken by the subjects. Summers et al. (1982) made a direct comparison between cognitive strategy use in the two settings. They found that 69% of average runners usually dissociated during training, but that this figure dropped to only 6% during a race. The rest of the time was spent in associative thinking (30,7%), and other thought patterns which Summers et al. failed to identify as distinctly associative or dissociative in nature (63,3%).

These findings are supported by a more recent study which also points to a predominance of dissociative thinking during training, and associative thinking during racing (Masters & Lambert, 1989). A similar pattern of selective cognitive strategy use seems to apply to elite runners (Morgan et al., 1988).

iv. **Acquisition of cognitive strategy skills**: It seems that many runners develop and use association/dissociation skills of their own accord. Studies of runners taking part in a number of marathons have supported this notion (Silva & Applelbaum, 1989; Okwumabua, 1985; Summers et al., 1982). While these studies simply used retrospective techniques to ascertain "naturally-occuring" cognitive strategy use, others have actually attempted to control use through the "teaching" of particular strategies. It is possible that the method of teaching used in each of such cases may have affected their respective results.

Spink (1988) and Weinberg (1985) both gave instructions to subjects after randomly assigning them to either association, dissociation or control conditions. Saintsing et al. (1988) used a similar technique, although their subjects were additionally "periodically reminded during the semester...to think about their specific instructions." (p35). In all cases the content of these "instructional packages" were basically just instructions to focus on sensory feedback in the case of the association conditions, and to think of anything but that in the dissociating conditions.

Are such "teaching" techniques sufficient to ensure the proper implementation of, and the deriving of maximum benefit from the cognitive strategies? This seems highly unlikely as Okwumabua et al. (1983) instructed their subjects in cognitive strategy use over a 5-week period, and found that the techniques used by all subjects, irrespective of which strategy they had originally been told to use, became increasingly associative.

Schomer's (1990) study featured an innovative method of training subjects in cognitive strategy use. He actively shaped their thought processes over a 5-week intervention period by using light-weight two-way radios during training runs. This created a "practice effect" which various authors have deemed necessary for the successful implementation of cognitive strategies (Spink, 1988; Rothstein, 1979). This is in line with proposals by other researchers that simulation of competitive conditions in training is important to ensure effective use in competition (Orlick, 1980; Railo & Unestahl, 1979).

Singer (1988) recognized the importance of the nature of the teaching method used. He asserted that the chosen method should encourage the learning of, as well as support the use of the newly acquired skills. He advocated the demise of "dictatorial" teaching styles to ensure the possibility of cross-situational applications of the techniques. In short, different athletes require different techniques under different circumstances, and hence the ultimate goal of teaching should be "to provide individuals with the ability to diagnose situations, task demands and personal status on their own, and to self-generate appropriate strategies that would contribute to their own performance effectiveness" (p51).

1.4.5 COGNITIVE STRATEGIES AND INDIVIDUAL ATHLETE VARIABLES

This section will examine the variables within individual athletes, which are examined most often in the literature on cognitive strategy use in endurance events.

I. **Performance**: Two studies have correlated associative/ dissociative thought patterns with performance in a "natural" race setting. Silva & Appelbaum (1989) found cognitive strategy use to be related to performance in the US Olympic marathon trials. Their results suggested that the top finishers employed both associative and dissociative techniques, while lower finishers indicated the early adoption and maintenance of a dissociative strategy.

Okwumabua (1985) however found no relationship between cognitive strategy use and finishing time in a similar study with non-elite runners. A possible reason for this is that one would expect quite a vast difference in ability amongst a random group of non-elite runners. A similar group of elite runners is however less likely to feature as vast a difference in physical ability, and hence we might expect psychological factors such as cognitive strategies to play a larger role in determining finishing position.

ii. **Experience**: From the section on differences between elite and non-elite athletes, we may already have had an inkling that past running experience may prove to be an important moderator (if not the most) of cognitive strategy use. Crews (1992) contends that in general, experienced runners benefit from associative strategies, while lesser experienced runners benefit more from the use of dissociative strategies. (Note that experience does not necessarily imply elite status). A number of researchers have supported this notion (Weinberg et al., 1984; Okwumabua et al., 1983; Nideffer, 1979).

Madden et al. (1989) found age to be a moderate predictor of strategy use. In so far as age could be taken to be a fairly good predictor of past running experience, this might also be taken as support for Crews' contention. Adding weight to this notion is the fact that the use of associative strategies is related to the prevention of running injuries, and research has found increasing age to be inversely proportional to the rate of running injuries (Macera, 1992).

Evidence against the hypothesized relationship between association and running experience was offered by Wrisberg & Pein (1990), who found that experienced runners dissociate more often than novice runners. It is not clear how they defined "experienced" however, and as all their subjects were university students, it is unlikely that many of the so-called "experienced" subjects had been running for any significant number of years. One interesting discovery that they did make, was that first-time runners initially associate, before later turning to dissociation as a coping mechanism. This phenomenon can probably be explained by the intense hardship associated with anyone's first training run.

If runners' use of association does increase correlationally with experience, what factors might explain this relationship? Pennebaker & Lightner's (1980) study suggests that the direction of attention, i.e. internal or external (corresponding to association and dissociation respectively), may be mediated by the novelty of the situation. Thus we might expect lesser experienced runners to concentrate more on their surroundings than their more experienced counterparts who have "seen it all before." An alternative explanation is that through experience, runners gradually learn the benefits of associating. Quite simply, experienced runners have also had significantly more time in which to practise the technique. As Schomer has said; "all runners need to go through an exacting learning process and through successive approximations to achieve the capacity to effectively associate for prolonged periods of time...(after all), the cognitive side of the runner is as accessible to training as the physiological side" (1987, pp 59 & 61).

iii. **Task-related focus**: Clingman & Hilliard (1990) proposed that it is not the internal focus of association per se which is helpful, but rather the particular focus chosen from a number of possibilities. Their study of race walkers supported this by showing that a focus on cadence (number of steps per designated time period) led to better performance than did a focus on stride length (the distance covered in a single step). While both are associative techniques, for some reason, one was more appropriate and beneficial than the other. The findings of Johnston & McCabe (1993) support this notion that different associative techniques may be more beneficial to particular tasks/events.

iv. **Self-efficacy**: Bandura's (1977) theory of self-efficacy sees behavioural changes as being mediated by the strength of the conviction that the particular behaviour can be successfully executed. Weinberg (1985) examined the relationship between self-efficacy and cognitive strategy use in a controlled laboratory setting. He found that subjects in the high self-efficacy condition performed better, regardless of which cognitive strategy they had been assigned to use. These findings are supported by those of Okwumabua (1985). Her results showed no relationship between association/dissociation and performance, but indicated a strong positive relation between self-efficacy and performance.

This is perhaps not surprising in the light of Bandura's claims that past performance accomplishments are one of the primary sources of efficacy expectations. Presumably those runners performing well at any particular time also have a history of success. The research on self-efficacy has important implications for the teaching and use of cognitive strategies in endurance sport. It seems likely that the two could be used in a complementary nature to maximize beneficial effects. It is also possible that self-efficacy may be a mediator of which particular cognitive strategy would be the most beneficial under particular circumstances. Finally, as Weinberg (1985) points out, self-efficacy theory may hold important implications for the teaching of cognitive strategies. Telling people that the strategy was known to improve performance, may bolster their perception of its value and hence indirectly enhance the effectiveness of its implementation and use.

v. **Effort sense**: Morgan & Pollock (1977) related effort sense to the association/dissociation distinction. They proposed that association represented a "switching on" of the athlete's "perception of effort" function, while dissociation signified a "switching off" of the same function. This notion is supported by Schomer's (1990) findings of a convergence of associative thought processes and percieved training intensity, in 8 out of 10 runners. This relationship between association and effort sense effectively explains why the former can lead to increased aerobic capacity. Association, by enhancing the awareness of sensory information, allows training at a higher intensity without the concommitant increasing risk of injury. Association also controls the flow of running energy potential, thus ensuring its expenditure at a rate matching environmental demand (Schomer, 1990).

vi. **Pain perception**: Perhaps somewhat related to effort sense is the issue of pain perception. It could be assumed that effort and performance in endurance events is limited by pain tolerance. Using eye pigmentation as an indicator of ability to tolerate pain, research has found a tendency in elite runners towards lighter shades, supposedly an indicator of greater pain tolerance (Nideffer, 1981). While it seems clear that some people do have naturally higher pain thresholds than others, studies have shown that pain perception can also be augmented/reduced by various psychological factors (ibid.).

Sacks et al. (1981) have claimed that pain during endurance events is considered more a sign or signal than something distressing in and of itself. This certainly seems the case with more experienced or elite runners, whose associative strategies allow constant monitoring and adaptation of their bodily responses, ultimately allowing them to avoid hitting the "wall" (Morgan, 1978). Nideffer (1979) has proposed that by dealing objectively and rationally with the painful stimuli, these athletes are in effect dissociating from the pain on an emotional level.

Lesser experienced runners on the other hand negotiate temporary pain zones by dissociating from the experience on all levels (Morgan, 1978). Their rationale for this is that directing attention away from the pain, will lessen its perception. This notion is supported by findings that attention to pain does in fact increase the magnitude of its perception (Pennebaker & Lightner, 1980).

A final note of interest concerns the controlled study of Spink (1988). He found the effects of dissociative cognitive strategies to be enhanced by its coupling with analgesic suggestions. Thus subjects were told that the particular cognitive technique was known to reduce pain perception. While this has important implications for the teaching of cognitive techniques, it may well be related to what was said before about the role of self-efficacy in determining the success of cognitive strategy use.

vii. Life stress: Felsten and Wilcox (1992) have asked why life stress is always ignored in studies of "stress" and athletic performance. While they acknowledge the immediate influence of sport-specific anxiety on performance, they feel that the influence of stress from other domains also warrants more attention. Allthough such factors are more likely to play a role in sports requiring fine motor activity, they may also play a role in endurance sports. This may be the case in so far as life stress has a bearing on possible moderators of successful cognitive strategy use such as those mentioned above, e.g. self-efficacy.

1.5 APPLIED USE OF COGNITIVE STRATEGIES IN ENDURANCE SPORT

Pennebaker & Lightner (1980) have noted that the amount of information that can be processed at any one time is limited. They concluded from this that the use of either association or dissociation necessarily restricts the use of the other. Schomer (1987) however, used a serial modal model of thinking, consistent with both Klatzky's and Gilhooly's broader frameworks for the whole information processing system (in Schomer, 1987), to show that the two processes are not necessarily mutually exclusive. This is supported by research findings indicating that people do switch from one strategy to another while running (Okwumabua, 1985; Sime in Sacks et al., 1981; Sachs, 1980).

Orlick (1980) has noted that the phenomenon of concentration cycles requires flexibility of cognitive strategy use. Silva & Appelbaum (1989) in fact found an "adaptive flexible" approach to cognitive strategy use to be related to finishing position in Olympic marathon trialists. This suggests that being adaptively flexible with respect to strategy use, requires a skill which needs to be developed. This is in keeping with Morgan's assertion that effective switching between associative and dissociative strategies requires a "finely tuned perceptostat that takes years of training to develop" (1978, p49).

While it seems that some athletes naturally develop and master such techniques over time, it is desirable from a sport psychological perspective that the development and implementation thereof may be aided to ensure optimal performance. While a number of authors have "taught" cognitive strategies to athletes in an applied setting, Schomer's method of shaping thought processes seems the most promising, and although he used sophisticated equipment for the purpose, he also offered suggestions as to how runners can learn to direct their thinking on their own or with the help of a running colleague (Schomer, 1990).

1.6 CONCLUSION

This chapter has sketched a historical account of the research leading to Morgan & Pollock's original formulation of the association/dissociation distinction in endurance sport. Additionally it has reviewed more recent studies, with the goal of assessing our current state of knowledge in the field.

In summary, the current state of our knowledge suggests that first-time runners tend to associate to the pain they experience. If they continue running, most will over time develop "dissociative" techniques to deal with these unpleasant symptoms of fatigue. Many however drop out of their exercise programmes before ever reaching this stage. Teaching them dissociative techniques early on may hence increase their chances of compliance. More experienced runners (including the elite) however tend to use a greater percentage of associative techniques. This applies especially in races or in "tougher" training runs. In these cases associative techniques serve to minimize risk of injury, while maximizing economy of movement. While many experienced runners seem to use association spontaneously, their thought processes can be shaped in such a way as to optimize effectiveness of the techniques.

A number of variables appear to mediate the effectiveness of cognitive strategies. These include intrapersonal factors such as motivation for running, performance expectations, self-efficacy and life stress, and situational factors such as the type of endurance event, the distance and training or racing nature of the event. This raises many issues to which future research should be directed, of which the method of teaching cognitive strategies is probably one of the most important. Teaching should be aimed not only at efficient learning of the techniques, but also at the efficient implementation thereof. Due to the myriad of moderating variables, the latter necessarily implies an adaptively flexible approach to cognitive strategy use.

As the vast majority of studies have been done on distance running, it is imperative that researchers now turn their attentions to cognitive processes in other endurance sports. As there are so many variables affecting the appropriateness of particular strategies under particular conditions, we need to make sure that the knowledge we seek ultimately, is practically useful. To this end it is vital that future research is undertaken in applied settings to provide the most practically relevant information. In doing so, the benefits of cognitive strategy use must be kept in perspective, as they can never make up for a lack of physical capacity or skill. Undoubtedly however, cognitions do affect performance, and in so far as they may be shaped, have the potential to make the difference between losing and winning, silver and gold.

CHAPTER 2:

METHODOLOGY

The previous chapter reviewed the literature on cognitive strategies in endurance sport. It concluded with a summary of the current state of knowledge in this field. The summary emphasized the necessity for more research in applied settings, and especially in sports other than running. A goal of this research was therefore to create a cycling-specific cognitive strategy classification system using Schomer's (1987) "applied" technique of thought recordings as a basis for the study.

Another goal was to look at the relationship between competitive status (i.e. elite, average or recreational) and cognitive strategy use, to see whether there was any support for Morgan & Pollock's (1977) assertion that elite and non-elite athletes prefer to use association and dissociation respectively. In accordance with Schomer's (1987) findings it was expected that no relation would be found between the use of association and competitive status, but rather that there would be a relation between association and percieved effort.

2.1 AIMS OF THE RESEARCH

The primary and secondary aims of the research, were hence respectively :

a) To develop a cycling-specific cognitive strategy classification system.

b) To investigate the relationships between associative strategy use, competitive status and effort, in elite, average and recreational cyclists. More specifically:
   i. The effects of competitive status on association.
   ii. The effects of effort on association.
   iii. The interactive effects of status/effort on association.

2.2 SUBJECTS

Subjects were chosen to fit into three distinct categories of competitive status; elite, average and recreational. They were contacted through advertisements placed at local cycling clubs, and in a local cycling publication. Only male subjects were used, as no female cyclists initially responded to the advertisements. All subjects had completed the Argus Cycle Tour on at least one occasion, and were classified as elite, average and recreational according to their fastest times recorded on the Tour.

Cyclists defined as elite all had a best time of at least under 2hr 45min, and best position ranging from 1st to 190th (mean time = 2hr 33min; mean position = 69,25). This translates into approximately the top 0,41% of riders completing the Tour each year. They ranged in age from 20 - 50 years, with a mean of 25 years. (The 50 year old had ridden 2hr 38min in the Argus Tour only three years previously, and ridden 2hr 41min in the most recent one).
The best times of the average cyclists ranged from 2hr 47min to 3hr 07min (mean = 2hr 59min). They ranged in age from 19 to 46 years (mean = 27,75 years).

The fastest times by the recreational cyclists ranged from 3hr 51min to 5hr 45min (mean = 4hr 23min), with the exception of one subject who had completed all 17 Argus Tours, including a time of 2hr 50min eight years previously, but who now considered himself very much "recreational". (His most recent time was 4hr 00min). Their ages ranged from 16 - 57 years (mean = 30,25 years).

2.3 APPARATUS

Thought verbalizations were recorded using an Olympus Pearlcorder S914 micro-cassette recorder, which was worn in a specially designed padded pouch/belt around the waist. A Pearlcorder ME4 electret condenser microphone was pinned to the cyclists' shirts, just inside the shoulder, with the cord running down and under either arm to the recorder. MC-60 cassettes were used with a tape speed of 1,2cm/s to allow one hour of recording on each side. The tapes were transcribed using an Olympus Microcassette Transcriber model T600 and an Olympus Head Set model E87.

Heart rate was recorded using a Polar Vantage XL heart rate monitor by Polar Electro OY. It was pre-set to record heart rate every 60 seconds for the duration of the rides.

The Borg scale (Borg, 1978) was printed on a card and shown to cyclists at the end of each trial. This enabled them to rate their perceived exertion (RPE) for the ride. (See Appendix 4).

2.4 PROCEDURE

Each subject underwent between two and four experimental trials, during which data was recorded using the aforementioned apparatus. The trials were normal training rides of not more than one hour (due to restrictions of tape length), over any course of the subjects' choice. The data from the last two trials of each subject was analysed. (From here on the term "experimental trials" refers solely to these two rides). The trials prior to these two were to allow the cyclists to feel comfortable using the equipment. If at the end of a ride subjects deemed the recordings as fairly representative of their thoughts, that data was analysed. If not, another trial was undertaken to allow the subjects to get used to using the equipment, thus eliminating as much as possible of the distraction initially created by the equipment and verbalizing process.

At the start of each ride the following was said to the cyclist: *"I'm interested in what people think about while cycling. So I'd like you to say aloud whatever comes into your mind during this cycle. All the material will be treated totally confidentially, so just speak your mind, be it an idea, feeling or general thought. Are there any questions before you start?"*

At the end of the ride RPE was recorded, and heart rate was manually down-loaded. The recordings were then transcribed. A stop-watch was used to keep track of how much time had elapsed at each stage of the transcriptions. It was started every time the tape played, and stopped every time it was paused. Temporal quarters of each ride were calculated from the total time elapsed on the heart rate monitor's stop-watch function, and clearly marked on the transcriptions to enable percentages of associative thoughts to be calculated per quarter, and ultimately correlated with average heart rates for the same quarters.

Thoughts were classified into ten subcategories, using Schomer's (1987) cognitive strategy classification system. (For a complete description of each subcategory, see Appendix 1). Whenever verbalizations were unintelligible, they were classified as "indeterminate" (x). A single thought unit was identified according to Schomer's definition thereof as "the most concise intelligible cognitive expression (sentence or phrase) that could be understood when isolated" (p 47). Where a particular unit clearly did not fit into any of the established categories, this was assumed to be cycling-specific and classified as a new category. The total number of thoughts per subcategory were added and recorded. From this the number of associative thoughts were then tallied and expressed as percentages for the entire ride, as well as per quarter.

Percentages of associative thoughts were compared across the three groups of cyclists to investigate the relationship between associative strategy use and competitive status (i.e. elite, average or recreational). Percentages of association were also correlated with RPE to see whether there was a relationship between associative strategy use and effort.

There was some concern however that a single rating of perceived exertion for the entire ride may not be accurate enough in the case of cycling. As a result of being able to free-wheel (especially downhill), there might well be a greater range of effort *within* any one ride, than there would be in a marathoner's training run. Palmer et al. (in press) did in fact find bunch cycle racing to be stochastic in nature, but attributed the uneven heart rate responses rather to the tactical nature of bunch riding, rather than to terrain. It was felt however that even in the case of a solitary cyclist, there might be too great a range of effort within any one ride, for a single RPE value to be an accurate measure of effort.

Hence it was felt that for cyclists, heart rate would be a more appropriate measure of effort as it would allow numerous measures to be taken at different stages within the ride. Heart rate was thus recorded every 60 seconds, from which a mean heart rate for each temporal quarter of the ride was calculated. Percentages of associative thought per quarter were then compared to average heart rates per quarter, in an attempt to get a more precise indication of the relationship between association and effort in cyclists.

CHAPTER 3:

RESULTS

This chapter presents the results of the study. The research methodology and the ensuing data analyses were designed in accordance with the aims of the study:

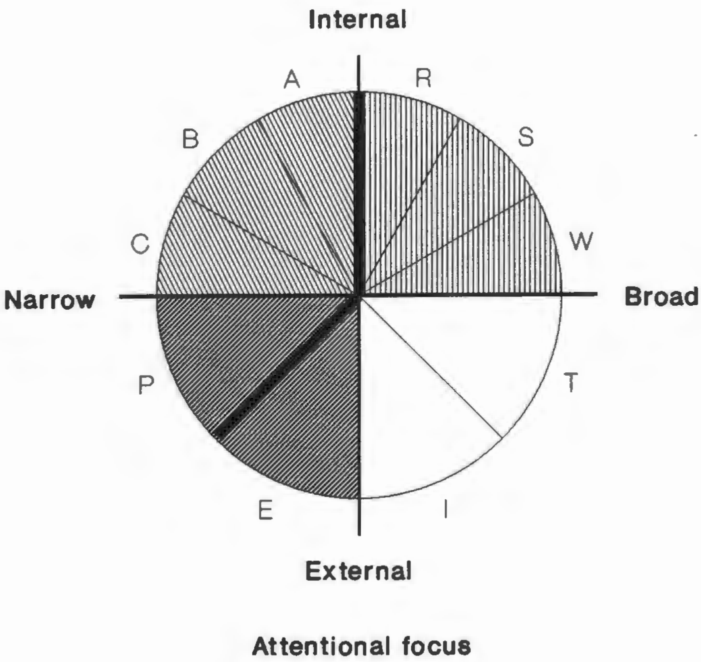
a) To develop a cycling-specific cognitive strategy classification system. This was done by using Schomer's (1987) classification system as a basis, and by identifying new subcategories for those cycling-specific thoughts which by exclusion, did not fit any of Schomer's subcategories.

b) To investigate the relationships between associative strategy use, competitive status and effort, in elite, average and recreational cyclists. More specifically, the relationships investigated were:
   i. Associative strategy use and competitive status. (One-way analysis of variance).
   ii. Associative strategy use and perceived exertion (RPE). (Correlation).
   iii. Interactive effects of heart rate and competitive status on associative strategy use. (Factorial analysis of variance).

3.1 A CYCLING-SPECIFIC COGNITIVE STRATEGY CLASSIFICATION SYSTEM

Schomer's (1987) ten subcategories of thought (Appendix 1) within the association/ dissociation framework, were the result of his amalgamation of thought themes with Nideffer's (1981) attentional style categorization. Figure 1 is a reproduction of Schomer's (1987) complete cognitive strategy classification system. The disc form clearly shows how his ten subcategories are placed within Nideffer's attentional style axes. The associative strategies are delineated from the dissociative ones by a thicker black line.

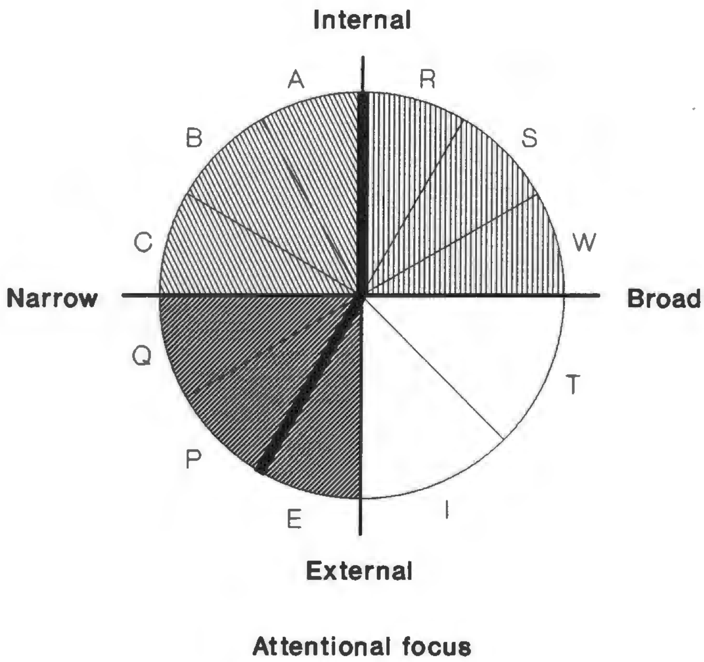
The transcribed thought recordings of this research were classified into Schomer's ten subcategories of thought. (See Appendix 3 for an example of a portion of analyzed text). Some thoughts, which were clearly specific to cycling as opposed to running, however did not fit into any of the established subcategories. All of these cycling-specific thoughts had to do with cycling equipment, e.g. "new part seems to be holding out OK"; "front tyre's looking a bit flat". These thought units were classified as associative, as they were all geared towards the maintenence of the task-related activity, i.e. cycling. In terms of attentional style, they were classified as narrow/external. Hence a new cycling-specific, associative, narrow/external subcategory of thought called "equipment monitoring" (Q) was identified. Where it fits into Schomer's classification scheme relative to other subcategories, is shown in Figure 2.



A Feelings and affects
B Body monitoring
C Command and instruction
P Pace monitoring
E Environmental feedback
R Reflective activity thoughts
S Personal problem solving
W Work, career and management
I Course information
T Talk and conversational chatter

Associative mental strategy: A, B, C, P
Dissociative mental strategy: E, R, S, W, I, T

Figure 1: ***Schomer's cognitive strategy classification system (1987, p48)***



A Feelings and affects
B Body monitoring
C Command and instruction
Q Equipment monitoring
P Pace monitoring
E Environmental feedback
R Reflective activity thoughts
S Personal problem solving
W Work, career and management
I Course information
T Talk and conversational chatter

Associative mental strategy: A, B, C, Q, P
Dissociative mental strategy: E, R, S, W, I, T

Figure 2: ***Revised, cycling-specific cognitive strategy classification system***

3.2 RELATIONSHIP BETWEEN ASSOCIATION, COMPETITIVE STATUS AND EFFORT

To test whether elite cyclists display a preference for associative strategy use, a one-way analysis of variance was executed on the total percentages of associative thoughts. For each subject, the mean percentage association of the two rides was used. (See Table 1 for summary of means and standard deviations). Analysis yielded an insignificant statistical difference between the three groups of cyclists [$F(2,23)=0{,}01$, $p=0{,}988$]. Elite athletes hence did not show a preference for associative strategy use.

	n	Mean	StDev
Elite	8	46,27	18,52
Average	8	45,81	17,37
Recreational	8	45,06	10,26

Table 1: ***Means and standard deviations of percentage association, for elite, average and recreational cyclists***

To test whether, within each subject, the level of effort measured by RPE could have determined associative strategy use, differences in percentages of association, and differences in RPE values across the two experimental trials, were calculated for each subject. (See Appendix 5 for raw % association and RPE data). The calculated differences of percentage association and RPE were then correlated for all subjects. This yielded a slight positive, yet insignificant correlation, $r = 0{,}291$ ($p = 0{,}345$).

Factorial analysis of variance was used to analyse the interactive effects of competitive status and effort, on associative strategy use. Average heart rate per quarter of each experimental trial was used as an indicator of effort, rather than RPE. Due to logistical problems, heart rate was however not recorded for all the experimental trials. Hence some subjects had 8 recorded heart rate measurements (from two experimental trials), some had 4 (from one experimental trial), and others had none. The latter were not included in this analysis. Across the three groups of subjects, a total of 24 training rides were completed using a heart rate monitor (7 by four elite cyclists, 10 by seven average cyclists, and 7 by five recreational cyclists). See Appendix 6 for heart rate measures.

Since there were unequal numbers in each group, and either four or eight measures of heart rate per subject, a least-squares approach to the analysis of variance was required. A design matrix of dummy variables was set up to identify subjects and represent group membership (Howell, 1987). The complete design matrix has been reproduced in Appendix 7.

Regression analysis, using Method 1 (Howell, 1987) was performed to identify the variance components for each factor. This method adjusts the effect of each factor for all other effects, and tests only the unique variance attributable to each. Thus for heart rate (HR), status (S) and heart rate/status interaction (HR*S), where SS_y represents percentage association, we obtain SS_{HR*S} as SS_y $(R^2_{HR,S,HR*S} - R^2_{HR,S})$, SS_{HR} as SS_y $(R^2_{HR,S,HR*S} - R^2_{S,HR*S})$ and SS_S as SS_y $(R^2_{HR,S,HR*S} - R^2_{HR,HR*S})$. See Table 2.).

None of status, heart rate, or the status/heart rate interaction showed any significant effects. Differences between subjects accounted for a large portion of the variance. Of the three factors being investigated, heart rate was however closest to being significant. For summary, see Table 3.

Source	df	SS
Status (S)	(s - 1)	$SS_y(R^2_{HR,S,HR*S} - R^2_{HR,HR*S})$
Heart rate (HR)	(hr - 1)	$SS_y(R^2_{HR,S,HR*S} - R^2_{S,HR*S})$
HR*S	(s - 1)(hr - 1)	$SS_y(R^2_{HR,S,HR*S} - R^2_{HR,S})$
Error	N - s*hr	$SS_y(1 - R^2_{HR,S,HR*S})$
Total	**N - 1**	$\mathbf{SS_y}$

Table 2: ***Partitioning of the analysis of variance model***

Source	df	SS	MS	F
Status	2	241,2	120,6	0,36
HR	1	804,4	804,4	2,432
Status/HR	2	136,8	68,4	0,207
Subjects	6	7781,0	1296,8	
Error	**90**	**29762,3**	**330,69**	

Table 3: ***Summary table of the factorial analysis of variance for effects of status, heart rate (HR), status/heart rate interaction, and subjects***

CHAPTER 4:

INTERPRETATION OF THE RESULTS

The goals of this chapter are to interpret the results, draw conclusions, and discuss implications for future research.

4.1 A CYCLING-SPECIFIC SUBCATEGORY OF THOUGHT

Results suggested the existence of a new cycling-specific subcategory of thought, which was not previously identified in Schomer's (1987) study of marathoners. This subcategory called Equipment monitoring (Q), consists of thoughts relating to the equipment, which are necessary for the continuation of the task at hand, in this case, cycling. As such, it includes mainly the bicycle and its individual parts, eg gear and braking systems, wheels, etc. Focii in this subcategory are associative by nature as they are task-related, and may be classified as narrow and external according to Nideffer's (1981) attentional dimensions. In terms of Schomer's (1987) classification system, this then places "*equipment monitoring*" in the narrow/external quadrant, and between "*command and instruction*" and "*pace monitoring*" on the associative side of the classification disc (see Figure 2, Chapter 3).

The only possible scenario in which this category may apply to runners is with respect to running shoes, where a problem with them might interfere with goals of the run. As one would not often expect this to be the case, it is not surprising that this subcategory was not identified in Schomer's study. Thoughts on "equipment" are clearly more likely to appear amongst cyclists than amongst runners, as the former have much more equipment which needs to function adequately for completion of the activity. To be comprehensive then, future studies on the identification and shaping of cyclists' thoughts should use Schomer's (1987) cognitive strategy classification system, and include "equipment" as the eleventh subcategory.

The identification of a cycling-specific subcategory raises an important issue with respect to the use of Schomer's (1987) cognitive strategy classification system across different sports. It suggests that if the classification system is to be used in a new sport, either for research or for the applied shaping of cognitions, it is imperative that a pilot study be done to check for any new sport-specific subcategories. If this is not done, the resultant data may be either incomplete or incorrectly classified. It seems likely however that the eleven subcategories used in this study will prove to be exhaustive for most other endurance sports. One would not expect sports like rowing or swimming to throw up new subcategories of thought, previously unaccounted for in studies of marathoners and cyclists. Finally, it should be noted that when in future, a pilot study is undertaken to identify all possible subcategories of thought in a new sport, it should ideally take place in the true setting, to ensure that all potential sources of stimulii have the opportunity of presenting themselves as attentional focii.

4.2 EFFECTS OF STATUS AND EFFORT ON ASSOCIATIVE STRATEGY USE

An examination of the means of the three groups of cyclists suggests that there was a slight increase in percentage associative strategy use across recreational, average and elite cyclists respectively. This lends slight support to Morgan & Pollock's (1977) finding that elite runners prefer to associate while the non-elite prefer to dissociate. The differences across the three groups were however not significant.

A contributing factor to the non-significant results may have been the definitions used for status. Subjects were classified according to their previous fastest time in the Argus Cycle Tour. While the criteria for the elite status was a time of below 2hr 45min, all the average cyclists had a time of around 3hr 00min. A few of them were in fact very close to the 2hr 45min threshold which signified elite status. Hence there was not a very clear distinction between the two groups of cyclists, and this may have somewhat blurred the results.

If there really are differences in associative strategy use as a function of status, the results would also have been more likely to show these differences statistically, had there been more than just 8 subjects in each group. A larger sample size would have proportionately decreased the standard deviations, and hence made it easier to detect differences across the groups.

The standard deviations of percentage association amongst the recreational riders, was substantially below those of the elite and average categories. This could be taken to mean that better (i.e. elite or average) riders are more flexible when it comes to cognitive strategy use, than recreational riders are. A review of the literature (see Chapter 1) suggests that different strategies are more effective under different circumstances. From this it may be assumed that *flexibility* of cognitive strategy use has an adaptive function in endurance sport. In the light of this assumption, it is perhaps not surprising that elite and average cyclists (whose classification criteria according to time were not very distinct), showed more flexibility of cognitive stategy use than their recreational counterparts.

Ultimately we should be aiming towards educating athletes and coaches about cognitive strategy use. It is this goal of practical application at which all research such as this is aimed. The apparent necessity of flexibility of cognitive strategy use has important implications for the teaching of cognitive strategies. It tells us that we cannot simply teach developing athletes particular strategies, but that we must also teach them *when* particular strategies are more desirable than others, in order to maximize the chances of achieving the ideal performance state under different conditions. The existing studies have all been done under different circumstances with different subjects. Perhaps it is now time for a meta-analysis of which cognitive strategies work best under what conditions.

The insignificant correlation between effort as measured by RPE, and percentage association, is in marked contrast to Schomer's (1987) highly significant findings. It has already been mentioned in Chapter 2, that RPE as well as heart rate were recorded for each ride, because it was suspected that a single rating of effort may not be as applicable to cycling, as the latter may involve a greater range of effort than running. The idea was that if a simple correlation between association and RPE was insignificant, a more detailed analysis of association by average heart rate per quarter might provide more significant results. This however did not prove to be the case.

Factorial analysis of variance showed that heart rate as a measure of effort, yielded no more significant relationship with association than did perceived exertion (RPE). Comparatively, it was however closer to being statistically significant than status was. It is possible that the chosen methodology still did not do the association/effort relationship justice. Most of the subjects' rides were an hour long. If one considers that the calculated average heart rate per quarter was hence usually representative of approximately a 15 minute period, it is quite possible that any cyclist climbed and descended one or more hills during this time. The mean heart rate over these 15 minutes would not however show the extreme (highest and lowest) recordings of heart rate, as they would cancel each other out. Hence preciseness of the association/effort relationship measure would be lost.

While measures of heart rate per quarter may be more accurate than one global rating (e.g. RPE) for the entire ride, they may still not be accurate enough. To study the association/effort relationship in cyclists more precisely, it may be necessary then to get even more regular measures of effort. Ideally one would overlay thought verbalizations with heart rate as measured at the exact moment of verbalization. Practically this would mean recording heart rate every few seconds, and overlaying these exactly on the thought verbalizations, so that one got an accurate picture of what was said when, and in conjunction with what amount of effort.

Alternatively, future research on the determination of variation in cognitive strategy use might provide more conclusive evidence of a strong association/effort relationship if undertaken in a more controlled laboratory setting. Some preliminary data which has already been gathered using a cycle-ergometer seems to support this notion. It appears from this preliminary data that cognitions recorded during interval training on the ergometer, with clearly delineated hard/easy stages, do show a more definite relationship between associative strategy use and effort.

There are a number of possible explanations for this. A laboratory setting would provide a purer picture of the relationship between any two variables, e.g. effort and association, as there would be fewer distracting stimulii demanding a shift of attentional focus away from what is being investigated. Traffic is for instance a very real problem in this respect. In the laboratory one would also be able to control variables to a far greater extent. Effort could for instance be varied in set amounts and over pre-determined time-spans. Additionally there would be no wind, and so the method of data collection used in this study would be more reliable, as there would be no category "x" (unintelligible).

Finally, a laboratory setting would facilitate the improvement of data collection by allowing additional, and perhaps more comprehensive methods of data collection. M.Blackburn (Personal communication, 8 March 1993) did a study in which he tested a number of techniques to record the thoughts of runners while running on a treadmill. Results indicated that better thought recording was achieved when the thought verbalization technique (of Schomer, 1987) was used in conjunction with video-taping of the subject as he ran. After the runs, subjects watched the video tapes and were asked to clarify and expand on any verbalized thoughts. The present author suggests that Blackburn's *laboratory* techniques were valid, as Schomer had previously already identified the subcategories of thought occuring during a run in the true setting.

Since the present research has now identified new cycling-specific subcategories in a "true" cycling setting, it is now desirable that future attempts to document *particular* relationships such as the association/effort one, should be undertaken in a more controlled laboratory setting.

Besides the applied setting, there are two other possible reasons why this study did not find a significant relationship between associative strategy use and effort. Firstly, while transcribing the thought verbalizations, it seemed for most subjects that the more tired they were, the less they verbalized their thoughts. Intuitively this is not surprising. The implications however are that in stages of the ride where cyclists were tired and might consequently have been associating more, they in fact verbalized less thoughts. Hence the percentage association would in fact have been artificially lower over that particular quarter as well as over the entire ride. Secondly, all subjects chose their own routes. As a result, the two experimental trials were for some subjects very similar with respect to effort, and hence were not ideal for examining the effects which different levels of effort have on associative strategy use.

The factorial analysis of variance confirmed the insignificant effects which status and effort individually have, on associative strategy use. It also showed no significant interaction effect of status and heart rate. Realistically there are probably lots of variables whose interactive effects determine percentage of associative strategy use. The high between-subjects variance apparent in this study, is testimony to this. For instance, the particular goal wanting to be achieved on any single ride could also have been an important determining factor. A serious cyclist whose goal is simply to have an easy recovery ride, would need to hold himself back. While the ride itself would in accordance with the goal be at low-effort, association would still be required to ensure that he was not exerting himself too much.

4.3 LOGISTICAL LIMITATIONS TO THE METHODOLOGY

While some methodological problems associated with this study represented a trade-off for doing it in an applied setting, there were others which were purely the result of logistical limitations.

i. The fact that cyclists were asked to restrict rides to one hour is a confounding variable, as in reality many of the subjects' training rides are of longer duration. Additionally, it sometimes happened that subjects actually did ride for slightly over an hour, and the recorded thought verbalizations, which cut off after the 60 minutes worth of tape ran out, were hence not representative of the entire ride.

ii. The process whereby thought transcriptions were divided into quarters could not always be exact. Firstly, heart rate was recorded every 60 seconds, so where a quarter of a ride spanned a certain number of minutes *and some seconds*, there was some overlap of heart rate across it, and the following quarter. Secondly, whenever the tape recorder was stopped during the transcribing process, the stop-watch should theoretically have been stopped at the very same moment. Practically however, some error would have crept in here. Thirdly, the transcribing equipment allowed for different playback speeds, but had no set point for actual speed. Actual speed hence had to be estimated to ensure that the quarters were marked in the proper places. While the effects of these logistical limitations were probably very small, they were however a source of some error.

iii. Transcriptions were classified into the cognitive subcategories by the experimenter, and classifications were hence potentially subject to bias. If two independant raters could have been employed to do this job in a double-blind fashion, it would have minimized this risk.

iv. While subjects may have perceived their effort to be just as high right at the beginning of any ride as at any other stage, this may not have been reflected in the heart rate measures. At the start of any ride, a cyclist's heart rate is presumably relatively close to resting pulse. It may take a few minutes before it rises enough to adequately reflect perceived effort. Hence the heart rate measures for the first quarters were probably slightly too low, which would have affected the analysis of the association/heart rate relationship.

v. As heart rate was only recorded on 24 of the 48 experimental trials (50%), the factorial analysis was completed on the data of only four elite, seven average, and five recreational cyclists. While such limited data would have decreased the chances of finding significant results, it should however be remembered that each of these subjects was represented by either 4 or 8 measures of heart rate.

vi. Ideally, subjects would be totally unaware of the equipment used to record verbalized thoughts. Realistically however, there were times when their thoughts did focus on the equipment. In spite of this confounding variable however, Schomer's (1987) method of thought recording is probably still the best method we have for use in a true setting.

Finally, this research identified a new cycling-specific subcategory of thought. One may assume that this research has hence revised Schomer's (1987) original categories for specific use with cyclists, and that the revised categories are exhaustive for all possible thoughts in a cycling setting. However, the experimental trials in this study consisted of training rides, which in all cases except one, were completed by the subjects on their own. In competitive racing however, cyclists do not ride alone. Especially amongst the elite, a lot of time is spent in a bunch, as the drafting effect serves to lower energy expenditure (Palmer et al., in press). The tactics involved in bunch riding and all its tactical components, eg. "breaking away" etc, call for what may potentially be another new subcategory of thought, possibly called "tactical awareness".

Thoughts in this subcategory would be associative by nature, as they are task-related. This would make "tactical awareness" the only associative subcategory of thought occuring in the broad/external quadrant of attentional focus. (See Figures 1 & 2, Chapter 3). We could hypothesize that if similar research was conducted in an interactive team sport such as soccer or rugby, this subcategory would feature strongly. Unfortunately cyclists involved in competitive racing (and the same would probably hold for sportsmen and women in interactive team sports), are quite understandably reluctant to carry recording equipment to verbalize their thoughts in such a setting. In training, these types of thoughts rarely appear, and hence they do not warrant a separate subcategory. However, to ensure adequate preparation for competition, it should be noted that some tactical strategizing is vital in training, even if it just takes the form of mental fantasy or visualization.

4.4 CONCLUSIONS AND FUTURE DIRECTIONS

The aim of this final section is to place this research within the wider context of sport psychology as a growing discipline, summarize the main findings, and to discuss future directions the research should take.

In the twentieth century sport success has become increasingly lucrative not only to athletes themselves, but also to a myriad of sponsors etc, who have a lot to gain from other people's performances. With so much vested interest, mainly commercial, (but not forgetting others like national fervour), it is perhaps not surprising that science is attempting to gain control over as many determinants of sporting performance as possible. Hence we have seen enormous growth in the sport sciences, one of the youngest of these being sport psychology. In an attempt to gain some control over (the often elusive) mental components of sport performance, sport psychology has amongst other things, started examining the make-up and functions of cognitions in sporting performance. It is within such a context that research of the nature of this study has been undertaken.

This research has accomplished its primary aim of identifying a cycling-specific cognitive strategy classification system. Hence the first step in the study of the nature and possible shaping of cognitions during cycling, has been completed. As has already been suggested, it was imperative that this first step was undertaken in a true setting, to allow the identification of any regularly occurring cognitive focii. Partly as a result of the lack of control in this true setting however, the secondary aim of exploring the relationships between associative strategy use, competitive status and effort, was inconclusive. Because a cycling-specific cognitive strategy classification system was however devised, it now opens the door to future, more controlled studies in a laboratory setting.

Let us not however forget that practical utility should be the ultimate goal of all sport psychological research. Once enough controlled studies have been done to explore the determination of cognitive variation in greater detail, techniques can then be developed to apply this new-found knowledge. Research focus will hence shift once more to the real setting. The two main research questions should then become - are the newly developed techniques of practical utility in the true setting, and how do we best train athletes in their use?

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APPENDIX 1: Schomer's cognitive strategy classification system, with a description of the 10 sub-categories of thought used as a frame-work in this research. (Taken directly from Schomer 1987, pp 45-47).

1. *Feelings and affects* (A). Thoughts concentrating on general sensations of the whole body, like feelings of vitality or fatigue, overall tiredness and stiffness without mention of specific body parts (for example: "I feel bushed", "still feeling fine", "I could embrace the world now, no aches and pains", etc.).

2. *Body monitoring* (B). Thoughts of a here and now nature containing specific mention of anatomy, body parts, or body physiology like breathing rhythm, heart-beat, or painful calf muscles (for example: "That thigh does seem a bit tired", "shoulders are stiff", "hands are cold", etc.).

3. *Command and instruction* (C). Thoughts reflecting emphatic self-regulatory instructions to specific body parts or instructions to whole body functioning distinctly related to the activity and maintenance of running (for example: "Relax your shoulders", "slow, slow, go easy", "breathe deeply now", etc.).

4. *Pace monitoring* (P). Verbalized feedback on current performance with respect to time, distance, speed or any other available form or method of pacing (for example: "Running a bit fast for this section", "about a minute to go", "three kilometres to go", etc.).

5. *Environmental feedback* (E). Thoughts of a here and now nature on the weather condition, temperature, light conditions, smell and noise level (for example: "Bit of cloud over there, not too hot", "once you're on this stretch it's so calm", "these car fumes - terrific, jic!", etc.).

6. *Reflective activity thoughts* (R). Thoughts on past and future issues related to running, like past race experiences or training sessions, and future race preparation and planning (for example: "The times I have run this race I have always made it", "I will enter the Peninsula Marathon next year - give it a try", "I remember the way I struggled up this hill", etc.).

7. *Personal problem solving* (S). Thoughts revolving around issues of an intrapersonal or interpersonal nature including reflective introspection, belief system evaluation and modification (for example: "Shame, I wonder how my girl is", "feeling very self-conscious about that revolting photograph in the paper", "you know, as a kid I couldn't get myself to look into people's eyes", etc.).

8. *Work, career and management* (W). Thoughts spent on job, work and career opportunities including thoughts centering around the execution, planning and construction of work (for example: "Must get the kids to school on time tomorrow", "I'm supposed to cut the lawn - rats!", "I wonder if the patient I treated at work today is going to have another operation", etc.).

9. *Course information* (I). Thoughts of a descriptive nature about scenery and general whereabouts that are of no consequence to pace (for example: "Those mountains look absolutely great at sunset - absolutely beautiful", "I'm going to run around this shopping complex", "flowers all around me, what a scene", etc.).

10. *Talk and conversational chatter* (T). Direct speech when in communication with other runners and thoughts expressing follow-up chatter to initial exchanges, as well as unintelligible or extraneous chit-chat (for example: "Hi (name), good to see you out here again - ya, I'm well", "how are your new Nikes? Comfortable?", "That was (name), hell of a fellow, you know", etc.).

APPENDIX 2: Revised, cycling-specific, cognitive strategy classification system

1. *Feelings and affects* (A). Thoughts concentrating on general sensations of the whole body, like feelings of vitality or fatigue, overall tiredness and stiffness without mention of specific body parts (for example: "feeling comfortable", "that doesn't feel good", "don't feel so strong today", etc.).

2. *Body monitoring* (B). Thoughts of a here and now nature containing specific mention of anatomy, body parts, or body physiology like breathing rhythm, heart-rate, or painful calf muscles (for example: "heart rate 171", "legs a bit sore from yesterday", "slight pain in my chest", etc.).

3. *Command and instruction* (C). Thoughts reflecting emphatic self-regulatory instructions to specific body parts or instructions to whole body functioning distinctly related to the activity and maintenance of cycling (for example: "push harder with the legs", "relax shoulders a bit", "don't stand up yet", etc.).

4. *Equipment monitoring* (Q). Thoughts of a here and now nature containing specific mention of cycling equipment, like the brake or gear systems, wheels or pedals, necessary to the satisfactory continuation of cycling (for example: "new part seems to be holding out OK", "front tyre's looking a bit flat", "bike feels terrible today", etc.).

5. *Pace monitoring* (P). Verbalized feedback on current performance with respect to time, distance, speed or any other available form or method of pacing (for example: "one minute to the top", "time 25:50", "two more short hills, then downhill all the way", etc.).

6. *Environmental feedback* (E). Thoughts of a here and now nature on the weather condition, temperature, light conditions, smell and noise level (for example: "hell, it's hot today", "can smell someone's braai", "much colder than yesterday morning", etc.).

7. *Reflective activity thoughts* (R). Thoughts on past and future issues related to cycling, like past race experiences or training sessions, and future race preparation and planning (for example: "tomorrow there's a R100 first prize - big

deal", "in a race I'd be doing 60 km/hr here", "next week's training could be quite heavy", etc.).

8. *Personal problem solving* (S). Thoughts revolving around issues of an intrapersonal or interpersonal nature including reflective introspection, belief system evaluation and modification (for example: "got to get Tony out to South Africa", "people will think I'm mad", "I never used to get upset so easily", etc.).

9. *Work, career and management* (W). Thoughts spent on job, work and career opportunities including thoughts centering around the execution, planning and construction of work (for example: "must find out about importing those glasses", "I'll have to be more firm with (name) on Monday", "absolutely must do some work tonight", etc.).

10. *Course information* (I). Thoughts of a descriptive nature about scenery and general whereabouts that are of no consequence to pace (for example: "litter all over the place here", "this must be one of the most beautiful parts of Cape Town", "hell of a colour they've painted that house", etc.).

11. *Talk and conversational chatter* (T). Direct speech when in communication with other cyclists and thoughts expressing follow-up chatter to initial exchanges, as well as unintelligible or extraneous chit-chat (for example: "morning!", "howzit - you going up to the Nek?", "isn't this too early for you?", etc.).

APPENDIX 3: An example of a portion of analysed text (average subject).

"Wind's picking up a bit. Wonder what it's like in False Bay
|-------------- E --------------| |------------------- S ---------------------

today. Funny how it's easier with a cyclist ahead of you. It
-------| |--------------------------- R ------------------------------------| |--

pulls you along. Guy's probably daydreaming like I do. Then they
---- R -------------| |----------------------- S -----------------------| |-------------

come up behind and give you a hell of a fright. This is a nasty
------------------------ R -------------------------------------| |------------------

little stretch, up to Chapmans. 'Morning!' That woke him up. Not
---------- P ---------------------------| |--- T ----| |-------- S -----------| |---

many cyclists on the road, though there were quite a few this
-- | ---

morning in Camps Bay. Ah! Legs are tired. Heart rate OK. One
-------------------------------| |-A-| |------ B -------| |------- P ------| |----

more kay to the top. Roads are quite quiet. Two cars overtaking.
-------------- P ----------| |-------------- I -----------| |------------ I ----------|

Takes the pleasure out of cycling. Got to sort out (name) at
|------------------ R --------------------| |--------------- W -------------

work. Getting a bit worried about it. OK, push. Nearly there. 17
------| |-------------------- S --------------| |-- C ----| |------ P -----| |-

minutes. Not bad going."
--- P --| |-------- P -------|

APPENDIX 4: Borg's (1978) rating scale for perceived exertion (RPE).

6	
7	VERY VERY LIGHT
8	
9	VERY LIGHT
10	
11	FAIRLY HARD
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY VERY HARD
20	

KINDLY RATE YOUR TRAINING INTENSITY (PERCIEVED EXERTION) ON THIS SCALE

APPENDIX 5: Raw data - Percentage associative strategy use and RPE values for all subjects.

E = Elite
A = Average
R = Recreational

Subject	% Assoc Trial 1	% Assoc Trial 2	RPE Trial 1	RPE Trial 2
E 1	41,50	30,69	11	13
E 2	48,97	79,26	10	18
E 3	32,69	40,32	10	11
E 4	79,02	75,24	9	13
E 5	14,60	35,48	6	11
E 6	54,47	60,94	13	16
E 7	41,10	50,88	9	15
E 8	23,58	31,58	10	11
A 1	72,20	58,69	14	16
A 2	75,89	66,03	11	17
A 3	44,03	50,63	11	15
A 4	17,24	39,78	11	13
A 5	21,37	18,33	11	15
A 6	34,38	38,37	9	13
A 7	49,21	52,88	11	12
A 8	36,85	57,05	11	15
R 1	53,38	51,77	10	15
R 2	32,26	37,06	13	14
R 3	50,01	40,82	10	13
R 4	62,49	55,98	9	13
R 5	52,83	32,76	11	12
R 6	50,64	50,67	9	13
R 7	21,44	32,63	11	12
R 8	51,79	44,45	11	14

APPENDIX 6:

Raw data - mean heart rate measures (HR) and % association (Ass) for the four quarters of each experimental trial (in which heart rate was recorded).

E = Elite
A = Average
R = Recreational

Subject		1st quarter	2nd quarter	3rd quarter	4th quarter
E 1	Ass HR	57,14 177,44	96,46 160,89	80,37 142,11	66,00 125,13
E 1	Ass HR	90,38 164,54	82,61 178,92	61,70 174,23	62,50 167,00
E 2	Ass HR	40,00 130,07	10,00 120,33	22,22 115,40	70,00 139,67
E 3	Ass HR	45,45 155,64	41,67 167,50	36,84 158,20	77,55 166,20
E 3	Ass HR	100,00 158,92	70,00 181,42	43,75 166,00	47,62 152,08
E 4	Ass HR	50,00 123,20	63,64 159,50	58,33 155,00	20,00 143,29
E 4	Ass HR	61,11 125,14	30,43 124,40	5,88 115,00	50,00 120,79
A 1	Ass HR	50,50 122,92	48,86 130,27	64,20 132,33	77,14 134,79
A 1	Ass HR	77,97 126,33	66,00 128,25	68,85 142,50	75,47 129,42
A 2	Ass HR	68,42 153,17	76,00 163,17	80,00 149,50	77,78 144,46
A 3	Ass HR	43,90 151,47	63,72 172,6	13,24 158,40	37,93 144,33
A 4	Ass HR	12,50 122,56	9,09 119,30	37,50 130,40	0,00 134,89
A 5	Ass HR	5,26 144,83	21,95 162,23	26,32 158,54	47,37 145,92
A 6	Ass HR	50,00 133,07	62,96 145,62	50,00 169,62	3,03 135,62
A 6	Ass HR	71,43 117,92	9,09 123,00	57,14 115,54	14,29 112,42

Subject		1st quarter	2nd quarter	3rd quarter	4th quarter
A 7	Ass HR	36,67 147,38	35,90 162,88	40,00 161,25	40,74 157,00
A 7	Ass HR	39,29 145,50	55,00 150,60	58,70 155,73	68,49 156,29
R 1	Ass HR	31,58 132,27	32,76 149,91	41,89 142,45	17,02 141,27
R 2	Ass HR	54,55 160,40	47,22 167,4	66,67 152,8	57,50 154,11
R 3	Ass HR	37,50 146,20	25,64 135,00	26,80 143,53	31,00 142,38
R 4	Ass HR	52,33 134,50	51,28 153,40	42,57 144,80	54,26 123,22
R 4	Ass HR	52,48 148,25	64,86 162,25	53,51 159,08	46,74 141,55
R 5	Ass HR	33,33 176,62	51,02 172,77	47,92 168,62	43,14 138,62
R 5	Ass HR	52,00 173,33	63,83 178,64	54,55 164,73	28,57 149,18

APPENDIX 7: Statistical design matrix.

G = Status
S = Subject
HR = heart rate

Row	G	S1	S2	S3	S4	S5	S6	G1	G2	G1*HR	G2*HR
1	1	1	0	0	0	0	0	1	0	177,44	0,00
2	1	1	0	0	0	0	0	1	0	160,89	0,00
3	1	1	0	0	0	0	0	1	0	142,11	0,00
4	1	1	0	0	0	0	0	1	0	125,13	0,00
5	1	1	0	0	0	0	0	1	0	164,54	0,00
6	1	1	0	0	0	0	0	1	0	178,92	0,00
7	1	1	0	0	0	0	0	1	0	174,23	0,00
8	1	1	0	0	0	0	0	1	0	167,00	0,00
9	1	0	1	0	0	0	0	1	0	130,07	0,00
10	1	0	1	0	0	0	0	1	0	120,33	0,00
11	1	0	1	0	0	0	0	1	0	115,40	0,00
12	1	0	1	0	0	0	0	1	0	139,67	0,00
13	1	0	0	1	0	0	0	1	0	155,64	0,00
14	1	0	0	1	0	0	0	1	0	167,50	0,00
15	1	0	0	1	0	0	0	1	0	158,20	0,00
16	1	0	0	1	0	0	0	1	0	166,20	0,00
17	1	0	0	1	0	0	0	1	0	158,92	0,00
18	1	0	0	1	0	0	0	1	0	181,42	0,00
19	1	0	0	1	0	0	0	1	0	166,00	0,00
20	1	0	0	1	0	0	0	1	0	152,08	0,00
21	1	0	0	0	1	0	0	1	0	123,20	0,00
22	1	0	0	0	1	0	0	1	0	159,50	0,00
23	1	0	0	0	1	0	0	1	0	155,00	0,00
24	1	0	0	0	1	0	0	1	0	143,00	0,00
25	1	0	0	0	1	0	0	1	0	125,14	0,00

Row	G	S1	S2	S3	S4	S5	S6	G1	G2	G1*HR	G2*HR
26	1	0	0	0	1	0	0	1	0	124,40	0,00
27	1	0	0	0	1	0	0	1	0	115,00	0,00
28	1	0	0	0	1	0	0	1	0	120,79	0,00
29	3	1	0	0	0	0	0	0	0	0,00	0,00
30	3	1	0	0	0	0	0	0	0	0,00	0,00
31	3	1	0	0	0	0	0	0	0	0,00	0,00
32	3	1	0	0	0	0	0	0	0	0,00	0,00
33	3	1	0	0	0	0	0	0	0	0,00	0,00
34	3	1	0	0	0	0	0	0	0	0,00	0,00
35	3	1	0	0	0	0	0	0	0	0,00	0,00
36	3	1	0	0	0	0	0	0	0	0,00	0,00
37	3	0	1	0	0	0	0	0	0	0,00	0,00
38	3	0	1	0	0	0	0	0	0	0,00	0,00
39	3	0	1	0	0	0	0	0	0	0,00	0,00
40	3	0	1	0	0	0	0	0	0	0,00	0,00
41	3	0	0	1	0	0	0	0	0	0,00	0,00
42	3	0	0	1	0	0	0	0	0	0,00	0,00
43	3	0	0	1	0	0	0	0	0	0,00	0,00
44	3	0	0	1	0	0	0	0	0	0,00	0,00
45	3	0	0	0	1	0	0	0	0	0,00	0,00
46	3	0	0	0	1	0	0	0	0	0,00	0,00
47	3	0	0	0	1	0	0	0	0	0,00	0,00
48	3	0	0	0	1	0	0	0	0	0,00	0,00
49	3	0	0	0	0	1	0	0	0	0,00	0,00
50	3	0	0	0	0	1	0	0	0	0,00	0,00
51	3	0	0	0	0	1	0	0	0	0,00	0,00
52	3	0	0	0	0	1	0	0	0	0,00	0,00
53	3	0	0	0	0	0	1	0	0	0,00	0,00
54	3	0	0	0	0	0	1	0	0	0,00	0,00
55	3	0	0	0	0	0	1	0	0	0,00	0,00
56	3	0	0	0	0	0	1	0	0	0,00	0,00

Row	G	S1	S2	S3	S4	S5	S6	G1	G2	G1*HR	G2*HR
57	3	0	0	0	0	0	1	0	0	0,00	0,00
58	3	0	0	0	0	0	1	0	0	0,00	0,00
59	3	0	0	0	0	0	1	0	0	0,00	0,00
60	3	0	0	0	0	0	1	0	0	0,00	0,00
61	3	0	0	0	0	0	0	0	0	0,00	0,00
62	3	0	0	0	0	0	0	0	0	0,00	0,00
63	3	0	0	0	0	0	0	0	0	0,00	0,00
64	3	0	0	0	0	0	0	0	0	0,00	0,00
65	3	0	0	0	0	0	0	0	0	0,00	0,00
66	3	0	0	0	0	0	0	0	0	0,00	0,00
67	3	0	0	0	0	0	0	0	0	0,00	0,00
68	3	0	0	0	0	0	0	0	0	0,00	0,00
69	2	1	0	0	0	0	0	0	0	0,00	132,27
70	2	1	0	0	0	0	0	0	0	0,00	149,91
71	2	1	0	0	0	0	0	0	0	0,00	142,45
72	2	1	0	0	0	0	0	0	0	0,00	141,27
73	2	1	0	0	0	0	0	0	0	0,00	160,40
74	2	1	0	0	0	0	0	0	0	0,00	167,40
75	2	1	0	0	0	0	0	0	0	0,00	152,80
76	2	1	0	0	0	0	0	0	0	0,00	154,11
77	2	0	1	0	0	0	0	0	0	0,00	146,20
78	2	0	1	0	0	0	0	0	0	0,00	135,00
79	2	0	1	0	0	0	0	0	0	0,00	143,53
80	2	0	1	0	0	0	0	0	0	0,00	142,38
81	2	0	0	1	0	0	0	0	0	0,00	134,50
82	2	0	0	1	0	0	0	0	0	0,00	153,40
83	2	0	0	1	0	0	0	0	0	0,00	144,80
84	2	0	0	1	0	0	0	0	0	0,00	123,22
85	2	0	0	1	0	0	0	0	0	0,00	148,25
86	2	0	0	1	0	0	0	0	0	0,00	162,25
87	2	0	0	1	0	0	0	0	0	0,00	159,08

Row	G	S1	S2	S3	S4	S5	S6	G1	G2	G1*HR	G2*HR
88	2	0	0	1	0	0	0	0	0	0,00	141,55
89	2	0	0	0	1	0	0	0	0	0,00	176,62
90	2	0	0	0	1	0	0	0	0	0,00	172,77
91	2	0	0	0	1	0	0	0	0	0,00	168,62
92	2	0	0	0	1	0	0	0	0	0,00	138,62
93	2	0	0	0	1	0	0	0	0	0,00	173,33
94	2	0	0	0	1	0	0	0	0	0,00	178,64
95	2	0	0	0	1	0	0	0	0	0,00	164,73
96	2	0	0	0	1	0	0	0	0	0,00	149,18