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Fluid ingestion, affective states and perceived exertion
during prolonged exercise

by

Susan Helen Backhouse

A Doctoral Thesis
Submitted in partial fulfilment of the requirements for the award of
Doctor of Philosophy of Loughborough University

January, 2004
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Abstract

The impact of nutritional intervention on affective states has largely been ignored in the exercise-affect literature. For decades the impact of such interventions on perceptions of exertion has been well documented. However, Hardy and Rejeski (1989) assert that 'what' a person feels, as measured by the rating of perceived exertion (RPE) scale, may be very different from 'how' they feel, and that on its own the RPE provides limited information about the subjective experiences of individuals during exercise. This thesis describes a series of studies that assess the influence of various fluid ingestion regimes on both 'how' and 'what' a person feels. Seven studies were undertaken, incorporating a variety of exercise modes, including prolonged running (Study 1, 3 & 7), prolonged cycling (Study 2 & 4) and prolonged intermittent, high intensity exercise (Study 5, 6 & 7).

The relationship between fluid ingestion during exercise and affective states during and following exercise proved to be a complex one. The initial investigation (Study 1) showed that the ingestion of water during prolonged running resulted in an overall improvement in valence during the recovery period. A significant increase in activation was also noted in the water trial only, from pre to post exercise. Furthermore, subjective ratings of energy post-exercise were higher in the water trial, compared to the no water trial. In study 2 the beneficial effects observed in study 1 were not so apparent. In this instance the only significant change of interest was in energetic arousal, which was found to be higher 5 min post exercise in the water trial compared to the no water trial. When the ingestion of a CHO solution during exercise was compared to a placebo or flavoured water solution (Studies 3-7) the findings also varied. However, the observation of an enhanced affective profile following CHO ingestion in Study 4 and Study 5 highlights the importance of considering nutritional status and intervention when investigating the exercise-affect relationship.

These studies have highlighted some important aspects in our understanding of the exercise-affect relationship alone. Firstly, a robust finding across all the studies was the observation of an almost uniformly positive shift in valence from the final
within-exercise assessment to the post exercise assessments. Thus emphasising the
dynamic nature of affect and the importance of repeated within exercise
assessment. Secondly, moderate intensity exercise of a fixed duration was marked
by highly variable inter-individual differences in the response of participants to
the valence and activation dimensions. However, exercise to fatigue elicited a
homogenous valence response as participants came closer to reaching their
exercise capacity.

Keywords

affective states, valence, activation, perceived exertion, fluid ingestion, CHO
solutions, prolonged exercise, dimensional perspective, Circumplex model
For Nana, my inspiration.
Acknowledgements

No thesis is ever the product of one person's efforts, and this one is no exception. There are a number of people I would like to thank for their invaluable contribution and assistance throughout this thesis:

Professor Clyde Williams and Professor Stuart Biddle, my research supervisors and career development officers. Thank you for your continuous support and guidance throughout this PhD. I am indebted to Clyde for encouraging me to embark on this research experience and for his belief in my ability to bring a new dimension to the Sport and Exercise Nutrition research group.

To all the members of the Sport and Exercise Nutrition research group at Loughborough University. Your support, humour and friendship have been invaluable. I would especially like to thank my collaborators in these studies; Dr Lettie Bishop, Mr Andy Foskett, Dr Ajmol Ali & Mr Nick Gant and Mrs Maria Nute for her unrelenting support over the years.

I would like to express my gratitude to all the participants who volunteered for the studies contained in this thesis. Without their help and willingness, its completion would not have been possible.

I would like to thank Glaxo-SmithKline for their financial support throughout these years, in particular Dr. Jacquie Shaw, Professor David Parker and the late Dr. Maarten van den Braak.

To my family and friends with whom I have shared a variety of experiences and feelings throughout this PhD. You have been an amazing pastoral support team. Mum and Dad, you have provided me with selfless support in so many ways to enable me to pursue my educational aspirations. I couldn’t ask for more loving, caring and supportive parents.
Unless otherwise indicated the work contained in this thesis is that of the author and has not been previously submitted for another degree in this or any other University.

Publications

The findings of some of the studies reported in this thesis have been published as follows:


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The challenge for the exercise and sport scientist is clear. Physiologists must reject the view that “the body doesn’t have a head” and psychologists must reject the view that “the head doesn’t have a body” (Morgan, 1981). Indeed, Morgan also posits that the implications for what an individual thinks and feels they are doing are profound for those working in sport and exercise sciences. Profound in the sense that physical performance is not governed by metabolism alone, but perception and cognition as well. Such assertions form the basis of the studies that follow. Previously in the exercise physiology laboratory at Loughborough University, and indeed laboratories throughout the world, the rating of perceived exertion scale (RPE) has been the gold standard measure of the subjective experience elicited during the experimental trials undertaken. Anecdotal reports over the years in our laboratory suggests that participants, when undertaking prolonged exercise protocols ‘feel better’ when they ingest fluid versus no fluid, and also when carbohydrate (CHO) is ingested versus a placebo drink. However, to date no studies have been undertaken that attempt to assess such anecdotal reports.

Although investigations have demonstrated the validity and reliability of the RPE as a measure of ‘what’ the organism is feeling during exercise (Borg, 1985), recent research (Hardy & Rejeski, 1989) suggests this measure on its own, provides limited information, regarding the subjective experiences of the individual. They state that ‘how’ a person feels may be far more important in terms of the decision to maintain a given pace, slow down, speed up or terminate an exercise effort. As Acevedo et al. (1996) state,

“Affective states and the cognitive appraisal of exertion during exercise may determine whether or not an individual will persist at an activity.” (p.286)
Chapter 1 Introduction

If we are to fully understand exercise behaviour, in particular what influence fluid ingestion has on attenuating fatigue and improving exercise capacity and performance, an understanding of how one feels is likely to be important and informative.

There has not been a great deal of research that investigates the possible link between exercise induced changes in the body and affective states, and furthermore no systematic studies have been conducted on the influence of nutrition on such subjective states during exercise. Thayer (1989) asserts that nutrition is likely to be another important determinant of affective responses, in particular, a state that he calls energetic arousal. However, Thayer is clear to emphasise that the exact nature of this relationship is not yet understood. As highlighted, it is perhaps surprising that previous research on nutritional interventions has only focused on one subjective rating, namely Borg's RPE scale. Athletes use a variety of nutritional interventions, such as fluid ingestion, in order to enhance and facilitate performance, and many studies have reported a beneficial effect of such practices. This thesis explores whether or not such strategies can also enhance the athlete's affective responses during exercise. It has long been known that nutritional status can alter a person's affective state such as increased alertness, reduced fatigue and increased self-rated happiness at rest (Smit & Rogers, 2000; Smith, 2002; Zwyghuizen-Doorenbos et al., 1990) and consequently, it is tempting to speculate a possible role for nutrition on such states during and following exercise. This thesis will therefore employ a variety of exercise modes and nutritional strategies in order to examine such potential links. If relationships are found to exist it could add significant knowledge to the literature on the ergogenic benefits of nutritional interventions and to the exercise-affect relationship.

In the literature on the relationship between exercise and affect, there has been a strong advocacy that a unitary phenomenon is in operation and that 'exercise makes people feel better' (Ekkekakis, 2003). However, despite over three decades of research, there has and continues to be a void in the literature that examines prolonged exercise. With this in mind, the investigations that follow will serve to redress the balance and ask the question whether or not prolonged exercise also
elicit positive affective responses. Runners and triathletes, as part of their training and competition, regularly undertake exercise that lasts more than one hour, and indeed, games players also engage in exercise of a long duration. However, little is known about the affective responses that ensue after such involvement. Consequently, the findings could serve to educate athletes of the changes observed in their affective states and what impact nutritional intervention has on improving, or indeed preventing, a decline in such responses.

The investigations undertaken in this thesis, assess affective change using the circumplex model of affect (Russell, 1980). According to the circumplex, affective space is defined by two orthogonal and bipolar dimensions; an affective valence dimension (pleasant-unpleasant) and an activation (high-low) dimension (Larsen & Diener, 1992). A dimensional model was selected because it allows great breadth and scope, which is important at the present time because the affective experience that accompanies exercise has not been thoroughly described (Gauvin & Brawley, 1993). Furthermore, the present research is unique and novel and therefore limiting the investigations to specific emotions would not have been suitable. Focusing on basic affect, which has been adopted in the investigations that follow, allows the detection of any salient changes (Ekkekakis & Petruzzello, 2002). Research to date on the exercise-affect relationship has often been limited to a pre- to post-exercise design, and as Ekkekakis and Petruzzello (1999a) have highlighted recently, this approach often masks the true dynamic changes in affect often observed during exercise. With this in mind, affect will be assessed during exercise using the single item measures of the Feeling Scale (Hardy & Rejeski, 1989) to assess affective valence (pleasure-displeasure) and the Felt Arousal Scale (Svebak & Murgatroyd, 1985) to measure perceived arousal or activation.

1.1 Overview of the Thesis
The aim of the studies presented in this thesis was to examine the influence of fluid ingestion on affective states and perceived exertion during various modes of prolonged exercise (running and cycling). This thesis is presented in ten main chapters. The review of literature (Chapter 2) encompasses the most relevant literature on the assessment of affective states, the exercise-affect relationship and fluid ingestion and exercise. It also highlights some of the mechanisms
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hypothesised to be involved in the exercise-affect relationship as well as the link between nutritional status and affect. The general methods chapter (Chapter 3) describes the method and rationale for the assessment of affect and also the equipment and testing procedures that are common to the experimental tests.

The aim of studies one (Chapter 4) and two (Chapter 5) was to examine the influence of ingesting water versus no water on affective states and perceived exertion during prolonged submaximal exercise. Specifically, we were interested in investigating whether or not affective states could be enhanced by such intervention. Studies three (Chapter 6) and four (Chapter 7) aimed to build upon the information obtained in studies one and two by investigating the influence of a carbohydrate-electrolyte solution (CHO-E) on affect and perceived exertion during prolonged exercise. In Study three, this involved a prolonged run to fatigue, which served as a protocol to determine whether, how and what a person feels could impact on persistence at an exercise task. In study four a continuous cycling protocol was employed.

Studies five (Chapter 8) and six (Chapter 9) were again aimed at investigating the impact of CHO-E solutions on affective states. However, the experimental protocols involved prolonged high intensity intermittent shuttle running, which have been largely ignored in the exercise-affect literature even though this activity pattern is characteristic of many sports undertaken such as football, both at a recreational and elite level.

Study seven (Chapter 10) was designed to examine the impact of continuous and intermittent exercise on affective states and effort sense. An additional stressor was added to this study in order to examine the influence of environmental temperature on the affective states elicited as well as allowing the investigation of fluid ingestion effects.

In all the studies presented, the emphasis is on prolonged exercise. The rationale for this is two fold. Firstly, this aspect of exercise has largely been ignored in the literature and secondly, it allows for a better examination of affective changes during exercise. The studies outlined above serve to explore the exercise-affect
relationship as it pertains to prolonged exercise, and examine the potential effects of various fluid ingestion regimes on such responses.

The final chapter of the thesis (Chapter 11) summaries the findings of all the studies undertaken and addresses potential confounding factors in this type of research, as well as issues for future research.
Chapter II

2.1 Introduction
This review of literature is structured around a number of key areas, which include:
I. The assessment of affect, defining the terms and the approaches to measurement
II. The exercise-affect relationship
III. Nutritional strategies utilised by athletes and their physiological and psychological effects
IV. The mechanisms proposed to account for the exercise-affect relationship and the nutrition-affect connection.

2.2 A misty picture? The definition of key terms and concepts
The definitions of emotion, mood and affect are not universally accepted and have been heavily debated in the literature. Liberal use of terminology exists and theorists caution that the distinctions between affective constructs, although admittedly not perfect or unanimously agreed upon, are important and should be taken into consideration (Ekkekakis & Petruzzello, 2000a). The inconsistent use of terms and the lack of coherence over their definition is problematic. Certainly in the exercise literature, affect, mood, emotion, psychological well-being and feelings are all used interchangeably to refer to a wide range of variables such as anxiety, fatigue and confusion (Tuson & Sinyor, 1993). This review will not extend this debate in great detail as it is covered well elsewhere (Batson, 1992; Ekkekakis & Petruzzello, 2000a). However, some of the key concepts will be highlighted.

Emotions are specific feeling states generated in reaction to certain events or appraisals. They are also typically characterised as being of relatively short duration and high intensity (Lazarus, 1991a; Ortony, 1988). Similarly, moods are also theorised to have a cognitive origin. In contrast to emotions, however, moods
are considered as lacking a specific target (Frijda, 1993, 1994). They are therefore characterised as “diffuse” and contrary to emotions, they are typically associated with low or no action tendencies (i.e., the inclination to “do something about it”). They are thought to be less intense and generally longer lasting compared to emotions (Alpert & Rosen, 1990), although some authors believe that duration is superficial and not an essential distinguishing characteristic (Frijda, 1994; Lazarus, 1994). The most critical difference appears to relate to appraisal. According to Lazarus (1991a) “moods refer to the larger, pervasive, existential issues of one’s life, whereas acute emotions refer to an immediate piece of business, a specific and relatively narrow goal in an adaptational encounter with the environment” (p. 48).

Finally, affect has tone or valence (positive or negative), so in a sense is a measure of pleasure/displeasure and also intensity (weak to strong). According to Batson and his associates (1992) “of affect, mood and emotion, affect is the most general” (p. 298). Likewise, according to Ortony, Clore and Foss (1987) “although the terms “affect” and “emotion” are often used synonymously in the psychological literature, we think it important to make a distinction between them. Affect is a broader construct than emotion. Any valences, judgement or condition implicates affect, whereas emotions are more specific. Consequently, our use of the word “affect” entails that all emotions are affective conditions, but not all affective conditions are emotions” (p. 343). Batson and colleagues (1992) further distinguish mood and affect; “both affect and mood may be instigated by a specific event or experience, such as failure at a task, a pleasant surprise, or remembering a sad event. Simply to experience pleasure or displeasure does not, however, constitute a mood change. One can experience a positive or negative affect, even intense affect, without experiencing a change in mood, as long as the experience is not perceived as portent of things to come. Only when this experience introduces some temporary change in the individual’s expectation of pleasant or unpleasant experiences in the future do we have a change of mood” (p.300). In sum, basic affect appears crucial to motivation and therefore the inclination to move forward or away from anything (Batson et al., 1992).
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It appears that one of the most effective ways to conceptualise the relationships between mood and affect is from a functionalist perspective. The functionalist-evolutionary view of affective phenomena is shared by several theorists (Izard, 1994; Leventhal & Scherer, 1987). Leventhal and Scherer (1987) proposed 3 levels of affective stimulus processing.

1. Sensory-motor level – the evaluation of events involves mainly hard-wired feature detectors.
2. The schematic level – involving solidified memory-based associations between specific stimuli on the one hand and perceptual, behavioural, autonomic and experiential responses on the other.
3. The conceptual level - involving abstract, complex, intentional and reflective modes of processing.

Similarly, Izard (1994) proposed four types of affective information processing (cellular, organismic, biopsychological and cognitive). Exercise has the capacity to induce affective responses emerging from any level of affective processing, from basic affect to specific emotions (Ekkekakis & Petruzzello, 2000a). Ekkekakis and Petruzzello (2000a) use the example that intense physiologic responses elicited during strenuous exercise may be automatically experienced as unpleasant, which would involve what Leventhal and Scherer (1987) described as sensory-motor mode of affect induction. At the same time they suggest that the positive evaluation of one’s own physique may elicit emotional responses, such as pride and improved self-esteem, whereas a negative evaluation may elicit shame and anxiety.

Clearly this leads us to the discussion as to whether researchers in affective changes during exercise should target basic affect or specific emotions. Put simply, the construct that is most relevant to the topic of the investigation should be targeted. Ekkekakis and Petruzzello (2000a) illustrate this with the example that if the aim is to examine the link between exercise-associated affect and exercise adherence (i.e., the hypothesis that people are likely to do what makes them feel good and avoid doing what makes them feel bad), then the appropriate target should be affect (i.e., the ‘goodness’ or ‘badness’ of what people feel). Regardless of whether the affective responses are cognitively mediated (i.e., as
when they are part of a certain emotion) or not, it is the quality of the subjective experience (i.e., the basic affect itself) that would be of interest in this context. On the other hand, they state that if the aim of the investigation is to examine the effects of the social environment on how people feel during exercise, the emotions that are theoretically more likely to be influenced by the manipulation of the social environment (such as self-esteem or social physique anxiety) should be targeted. Researchers should consider this before planning the research protocols and selecting the measurement tools to be used. As there is still a lack of consensus in the literature and the fact that many studies can be termed descriptive, initially focusing on the most general concepts should allow researchers to gain some understanding of how people feel during and following exercise under various conditions.

As already highlighted, the majority of studies in the exercise-affect literature can be termed descriptive, for example they are conducted with the purpose of describing how people feel when exercising. However, the role of cognitive mediators is rarely considered, and the impact of nutritional intervention virtually ignored. This will be addressed in section 2.13.

2.3 The categorical vs dimensional debate
Researchers in the field of exercise psychology and specifically those interested in the influence of exercise on psychological factors can utilise either a categorical or dimensional approach. If one adopts the categorical perspective then affective states are organised into distinct states such as pleasure, fear, happiness, excitement, sadness and pride (Ekman & Davidson, 1994a; Lazarus, 1991a; Ortony, 1988). Each state has different properties and antecedents. In contrast, the dimensional perspective views affective states as inter-related. Their relationships can be modelled by a parsimonious set of dimensions, such as pleasure-displeasure. Both categorical and dimensional conceptualisations have relative strengths and weaknesses depending on the specific research objectives (Lazarus, 1991a). The categorical conceptualisation has the benefit of offering greater specificity, and potentially finer discriminations of psychological meanings. On the contrary, dimensional approaches offer a wide and theoretically unrestricted scope (Ekkekakis & Petruzzello, 2000a). Categorical approaches are often
adopted when researchers are interested in the distinct (cognitive) antecedents of specific emotions, whereas those interested in exploring the general nature and the dynamics of affective responses to environmental stimuli have opted for dimensional models (Feldman Barrett & Russell, 1999). Gauvin and Brawley (1993) present the following argument for adopting a dimensional perspective for the study of affect in the context of exercise:

"Because the affective experience that accompanies exercise has not been thoroughly described, a model of affect that has a wider breadth is more likely to capture the essence of exercise-induced affect than a model that, at the outset, limits the focus of the investigation to specific emotions" (p. 152).

In exercise studies, researchers do not yet have advanced knowledge of the exact nature and direction of responses to the exercise stimulus. Therefore by focusing on basic affect, through a dimensional perspective, the detection of any salient changes is allowed (Ekkekakis & Petruzzello, 2002). Larsen and Diener (1992) and Russell and Feldman Barrett (1999) have covered the categorical versus dimensional debate in detail; therefore the reader is directed to these papers for further detail.

2.4 Generic vs Exercise Specific Measures
There are currently at least three measures of so-called exercise-induced changes in affect or feeling states (Gauvin & Rejeski, 1993; Hardy & Rejeski, 1989; McAuley & Courneya, 1994). The authors of these measures posit that exercise-specific measures can be more sensitive to the stimulus properties of exercise (e.g., profound physiological changes, whole body movement, perception of physical symptoms) (Gauvin & Spence, 1998). However, Stone (1995) argues that the decision to develop an "idiosyncratic" measure of affect must be based on a convincing demonstration that, for some reason, affect within the domain of interest assumes unique characteristics (i.e., content or structure) not captured by existing measurement models. However, evidence is currently lacking to support 'exercise specific' measures. Further, are such measures realistic when one considers the vast array of exercise types (e.g., aerobic vs anaerobic) available and also the various environmental conditions under which exercise can be carried out
(competition vs training vs a walk in the park). In addition, how does the researcher, in adopting such exercise specific measures, deal with the control conditions often employed in such research and also the sampling time points of pre and post exercise, when the participant is not engaging in exercise.

This review will not detail all the assessment tools available to the researcher, as this has been extensively covered elsewhere (Gauvin & Spence, 1998). Further, the reader is directed to a number of critiques on the State-Trait Anxiety Inventory (STAI) (Ekkekakis et al, 1999b), Exercise Induced Feeling Inventory (EFI) (Ekkekakis & Petruzzello, 2001a) and Subjective Exercise Experiences Scale (SEES) (Ekkekakis & Petruzzello, 2001b). Certainly, there are diverse opinions on all these measures, depending on which conceptual view you support, but until the various measures currently used in exercise studies are rigorously tested in a variety of settings, firm conclusions cannot be made.

2.5 The Circumplex Model of Affect: A new tool for exercise psychology?
Schlosberg’s (1941) circular ordering of affective states was followed by Plutchik’s model (1958; 1962) some 17 years later. A further 22 years passed before Russell’s (1980) circumplex model was published. Following on from Russell, a model was presented by Watson and Tellegen (1985).

According to the circumplex model of affect, affective space is defined by two orthogonal and bipolar dimensions, an affective valence dimension (pleasant-unpleasant) and an activation (high-low) dimension (Larsen & Diener, 1992). The relationships among affective states can, therefore, be represented as a circle (see Figure 2.1). The vertical axis of the circle generally marks the activation dimension and the horizontal axis, the valence dimension. Dividing the circle into half differentiates between pleasant and unpleasant states or states characterised by high and low activation. Affective states are construed as combinations of varying degrees of these two dimensions in such a way that they can be conceptualised as located around the perimeter of a circle defined by the valence and activation dimensions. Further, affective states vary along a circular continuum; states closer on the continuum are hypothesised to be more similar, both conceptually and empirically, than those further apart. The centre of the
space establishes a neutral point, and the intensity can be gauged from the distance outward from this point. The circle can be divided into 4 quadrants, producing the following meaningful variants (refer to Figure 2.1):

1. Activated Pleasant (energy, vigour)
2. Activated Unpleasant (distress, tension)
3. Unactivated Pleasant (calm, relaxed)
4. Unactivated Unpleasant (fatigue, boredom)

The circumplex model of affect (Figure 2.1 & 2.2) can organise a large body of known facts in a simple way (Larsen & Diener, 1992). It produces a simple form that maps the affective changes, highlighting the most salient changes.

Although there is some consensus on the basic postulates of the circumplex, authors disagree on a number of factors and the circumplex model is not without its criticisms (for a detailed review, see Larsen & Diener, 1992). One of which is levelled against the claim that the majority of the emotional experience can be captured by two affect dimensions. Russell and Feldman Barrett (1999) emphasise the findings of the circumplex, but at the same time also believe that this dimensional structure represents and is limited to what they term the “core affect” involved (for a detailed review on the nature of core affect, the reader is directed to Russell & Feldman Barrett (1999).

There have also been numerous discussions over the problems inherent in the naming of the circumplex dimensions. Some researchers (Watson & Tellegen, 1985, Meyer & Shack, 1989) have advocated an interpretation of the model that relies on two orthogonal dimensions named Positive Affect (PA) and Negative Affect (NA). However, a number of criticisms have been levelled against such naming. Firstly, the names may be misleading (Larsen & Diener, 1992) because the axes named PA and NA do not necessarily correspond with what other researchers have designated as positive and negative affect. Larsen and Diener (1992) use the example of the PA dimension (as portrayed by Watson and Tellegen (Watson & Tellegen, 1985).
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Figure 2.1. The Circumplex Model of Affect structure. The horizontal axis represents affective valence (negative to positive) and the vertical axis represents the degree of activation (low to high) (Larsen & Diener, 1992).

Figure 2.2. Russell's (1997) facial expression illustration of the circumplex model.
They state that this dimension is anchored at one end by adjectives such as “elated” and “euphoric” and at the other end by adjectives such as “drowsy” and “dull”. The high-end anchors of this dimension do indeed seem positive or pleasant. But this dimension clearly contains a large activation component. However, most investigators label emotions that are pleasant positive affect, regardless of their arousal value. Indeed, the mood adjectives happy, contented and pleased are surprisingly not basic to the dimension labelled “Positive Affect” in Watson & Tellegen’s (1985) interpretation of the circumplex. Further, investigators such as Ortony (1988) consider the positive emotions to include “happiness” as do participants who complete the inventories (Shaver et al, 1987). None of these adjectives fall directly and solely on the dimension named PA by Watson & Tellegen (1985), nor are the adjectives happy, contented, and pleased included in the PA scale developed by Watson, Clark & Tellegen (1988). Thus investigators must be careful when employing this version of Positive Affect, because it is not the emotional state that is usually referred to with this label. Instead, PA is primarily a state of high activation with pleasant hedonic tone.

Another problem that Larsen & Diener (1992) highlight is that the dimension of Positive Affect is in fact a bipolar dimension with a unipolar name. Watson & Tellegen’s (1985) Positive Affect dimension is anchored at one pole by the presence of high activation pleasant adjectives and at the other pole by the presence of low activation unpleasant adjectives, e.g. “sluggish” and “dull”. Clearly this dimension includes both pleasant and unpleasant elements and therefore cannot be justified as being labelled positive affect. In agreement with Larsen and Diener (1992), Thayer (1989) highlights the assertion that the labels of PA and NA do not reflect the large activation components of these dimensions. Thayer replaces the PA dimension with the label ‘energetic arousal’ and the NA dimension with ‘tense arousal’. Yet, such designation is without criticism (Russell, 1989). Still, Thayer’s labels clearly acknowledge the activation content that the PA and NA labels (Watson & Tellegen, 1985) fail to capture. In addition, Larsen and Diener (1992) highlight the PA and NA labels imply that unpleasant emotions are disruptive and disorganising and as such have only counterproductive or negative effects in terms of adaptation on behaviour. Unpleasant emotions are vital to humans because as Nesse (1990; 1998) claims,
affective states represent adaptive responses that have evolved to promote survival with a specific context. Therefore negative affective states, such as fatigue appear vital in preventing any critical disruption to homeostasis so that the individual ceases the activity that the fatigue is the result of. Such a view is also supported by Cabanac (1995) and Damasio (1995).

Russell (1980) reports that the circumplex model accounts for a substantial proportion, but not all of the variance in self-reported affective states. Russell informs that some of the variance is accounted for by the “inevitable errors of measurement”. Further, evidence exists that some of the variance in self-report data is accounted for by individual differences in the use of the rating scale. Johnston and Hackman (1977) reported that affect data showed consistent individual differences in the use of the extreme ends (both positive and negative) of the rating scale.

Surprisingly, “the circumplex has been virtually ignored by researchers in exercise psychology” (Gauvin & Brawley, 1993, p.153), despite requests for the application of the model into investigations on exercise (Biddle & Mutrie, 2001; Biddle et al, 2000; Gauvin & Brawley, 1993). Indeed, in this context the only investigators to employ such a tool are studies by Thayer (1987a) and more recently collaborations between Ekkekakis, Petruzzello and Hall (Ekkekakis et al, 2000b; Ekkekakis & Petruzzello, 1999a). Ekkekakis and Petruzzello (2002) in a recent paper from a four part series in the journal Psychology of Sport and Exercise, dealing with affect measurement highlight an excerpt by Russell (1989), in which he discusses the potential advantages of the circumplex for studying the effects of drugs on mood, and Ekkekakis & Petruzzello recommend substituting the word “exercise” for the word “drug”:

"To understand the mood-altering effects of a drug (or anything else) requires more than experimental evidence that differences in scores on a verbal scale of, say, anxiety are attributable to the drug. As the reader might anticipate by now, each drug seems to produce changes in most of the self-report emotion scales that happen to be included in the experiment...Researchers are thereby forced to list all the emotion scales showing reliable differences due to the drug...it is not
surprising that, despite years of research, the mood-altering effects of even alcohol cannot be clearly stated... As an alternative approach, drug researchers could focus on the change in basic dimensions of mood that is brought about by a drug. A clearer picture of what is going on might emerge if pretest scores and posttest scores, both for the drug group and the placebo group, were taken directly as measures of pleasure-displeasure and arousal-sleepiness. Plotting these scores...[in circumplex space] would not solve all problems, but it should display the basic mood altering effect of the drug. Once this is done, we could then begin to sort out the effects due to setting, cognitive set, prior mood and so on, particularly if they interact with the drug” (pp. 100-101).

This excerpt not only relates to studies on exercise, but also on the influence of nutritional intervention, both at rest, and for the purpose of this thesis, during exercise. Even after decades of research, although we are aware that exercise is often associated with changes in a wide variety of measures of various affective states, we still do not know what the main effects of exercise are on affect and also if any differences exist between different experimental conditions or different exercise modes. Another strength to the circumplex model and its potential beneficial application by exercise psychologists is that it encompasses the entire affective space and therefore individuals are not limited to rate how they feel on a small predetermined set of scales (Ekkekakis & Petruzzello, 2002). Clearly this is important when one considers the issue that a substantial amount of individual variation in affective responses is often reported in exercise studies (Ekkekakis & Petruzzello, 1999a; Gauvin & Brawley, 1993). Finally the circumplex differentiates changes in activation from those of affective valence, which instruments such as the State-trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970) do not allow and which in the past has led to misleading findings (Ekkekakis & Petruzzello, 1999a). Measures such as the STAI do not allow for positively loaded increases in activation or for negatively loaded decreases in activation (Ekkekakis & Petruzzello, 2002). In the context of exercise, however, high activation may indeed be experienced as positive (e.g, vigour and energy). In sum, the circumplex model appears to offer potential strengths in the study of exercise effects and environmental manipulations on affective responses.
2.6 Exercise-affect relationship in acute exercise

While the message emanating from physiological research has supported the general advantages of exercise in terms of physical health, the equivalent psychological literature has revealed a more complex picture. Indeed, the literature on the psychological effects of exercise has grown to the point that even reviews of reviews are now available (Scully et al., 1998). For a critical evaluation on the acute effects of exercise on affective states, the reader is directed to reviews by Tuson & Sinyor (1993), Yeung (1996) and Biddle et al. (2000). Fox (1999) concluded that "both survey and experimental research... provide support for the well publicized statement that 'exercise makes you feel good'" (p.413, italics in the original). However, such assertions of the beneficial effects of engaging in acute exercise on affective states have not been decisively established and results are by no means conclusive. Inherent experimental differences can be pinpointed as hampering such conclusions. Indeed, Morgan and O'Connor (1988) have commented on the lack of rigorous experimental designs, particularly the lack of placebo or control groups and the absence of randomisation procedures. Gauvin and Brawley (1993) have raised the issues of measurement and highlighted the inter-individual variability in affective responses, as well as participant expectancies. Considerable diversity exists in the literature because in some studies trained participants have been used, whereas in others untrained participants have been the focus. Further, there have been numerous self-report tools used to determine affective change, and the two most common are the Profile of Mood States (POMS) and the state form of the State-Trait Anxiety Inventory (STAI). The POMS is heavily skewed towards the assessment of negative mood states, with vigour as the only positive mood state, and the STAI (state scale) only measures state anxiety which is defined as an undesirable mood state (Spielberger et al., 1970). The POMS and the STAI do not sample the full range of the affective experience (Yeung, 1996). Such diversity in methodology is proving to be problematic in the field and makes comparisons across studies very difficult (Tuson & Sinyor, 1993).

The emphasis in the study of the exercise-affect relationship has been almost exclusively on the so called 'feel-better' phenomenon, and the negative findings that sometimes ensue from participation are often ignored. Tuson & Sinyor
(1993), on examination of over 45 studies in the exercise-affect literature up to 1993, revealed that with the possible exception of anxiety, studies conducted had not found a reliable association between acute exercise and improved affective states. However, methodological problems result in caution being required when analysing such studies. If one considers exercise of low intensity, findings on affective responses have often been positive (Bixby et al., 2001; Ekkekakis et al., 2000b). When exercise of a moderate intensity is considered, and the affective responses during exercise are examined, then individual differences in responses are highlighted. For example, in a study undertaken by Van Landuyt and colleagues (2000), participants completed 30 min of cycle ergometry at 60% of estimated maximal oxygen uptake (~141 beats min\(^{-1}\)). They reported a large variability in individual responses, with 44.4% of the participants reporting a progressive improvement, whereas 41.3% a progressive decline in affect. However, when reported as an aggregate score, these variations in response would be masked and a more neutral response pattern would emerge. With increasing exercise intensity, whereby functional limits are increasingly close to being reached, then affective valence is observed to decline (Acevedo et al., 1994; Hall et al., 2002; Parfitt et al., 1996). Further, research is consistently observing something of a “rebound” (Bixby et al., 2001) pattern immediately following exercise that has induced negative responses during exercise (Acevedo et al., 1996; Bixby et al., 2001; Hall et al., 2002). In the case of vigorous exercise, the trajectory of affective valence during and following exercise exhibits two distinct phases. The first phase involves the decline during exercise and the second phase an improvement following exercise (Acevedo et al., 1996; Bixby et al., 2001; Parfitt et al., 1994). The evidence points to an almost instantaneous post-exercise shift from negative to positive affect and, in many cases, this leads to an increase in valence greater than that at baseline levels and hence the well-established post exercise improvements are once again supported. However, if affect had not been sampled repeatedly during exercise, the reader would be led to believe that exercise only exerted positive effects, however, in reality, participants reported negative affect during the bout that had gone unnoticed. Despite over three decades of research on the exercise-affect relationship, consistency in results is lacking and reports are equivocal. Further research is warranted that takes into account the methodological issues already highlighted.
2.7 Mechanisms

There are several processes, both physiological and psychological, that have been proposed to account for the changes in affect following acute exercise. The neural basis for the interaction between exercise and affect are still unknown and only hypotheses can be advanced (Chaouloff, 1997). In section 2.14 the role of serotonin and blood glucose is addressed along with the influence of carbohydrate (CHO) ingestion. This section will deal briefly with the endorphin, thermogenic, distraction, mastery and dual mode hypotheses.

Numerous studies have observed that concentrations of plasma endorphins are elevated following exercise (Goldfarb, 1987; Markoff et al, 1982). In addition although many investigators have found that with exercise, participants became calmer and more relaxed, they have not often been correlated to peripheral β-endorphin levels (Hatfield et al, 1987). Goldfarb and colleagues (1987) have also reported that psychological state was unaffected by maximal intensity exercise despite significant increases in recovery β-endorphin levels. However, when changes in affect have been correlated with endorphin levels, the results have failed to support this hypothesis. Also, the administration of the endorphin antagonist naloxone in exercise studies has shown that an improvement in affect is still reported (Janal et al, 1984). Although animal studies have provided more direct evidence for activation of endogenous opioid systems by long-lasting exercise, this proved equivocal in human experiments. Consequently, in light of the literature, and although an appealing hypothesis that has received a great deal of attention, over the last ten years this attention has declined and, according to Stoll & Alfermann (2003), it can be concluded that the evidence is far from compelling in human studies.

The thermogenic hypothesis proposes that the elevation in deep body temperature during exercise contributes to affective changes following exercise (deVries et al, 1981; Raglin, 1985). The reader is directed to Koltyn (1997) for a detailed review of this mechanism. Examination of various studies designed to test the thermogenic hypothesis leads to the conclusion that compelling evidence is lacking. It appears that the main problem arises as a result of different methodologies in the measurement of body temperature. Petruzzello et al. (1993)
undertook a study comparing the influence of running on a treadmill in warm, cool and normal temperatures and reported that increases in temperature were highly correlated with increases in anxiety. It appears that the anxiety-reducing effects of exercise were only apparent when the body temperature was cooled. Further, the finding that anxiety can be reduced following physical activity even though core temperature does not rise offers good evidence that the anxiolytic effect of exercise is not dependent on increased body temperature (Koltyn & Morgan, 1992). However, Petruzzello and colleagues (1993) caution that the association between post exercise anxiety reduction could be due to brain rather than core body temperature and if this is the case, it will be a very difficult hypothesis to test. In summary, efforts to perform direct tests of the thermogenic hypothesis have not yielded compelling evidence in support of this hypothesis and evidence exists to refute it (Koltyn, 1997).

The distraction hypothesis suggests that it is not the exercise per se that enhances affect, but rather the temporary respite from worrisome thoughts and the stresses of life (Morgan, 1985). This hypothesis is based on the finding that exercise is no more effective than non exercise conditions, such as meditation or quiet rest, in reducing anxiety (Bahrke & Morgan, 1978; Felts, Crouse, & Brunetz, 1988). This hypothesis, however, has not been empirically verified.

The mastery hypothesis maintains that the completion of an effortful or important task may increase people's sense of mastery and hence lead to an improvement in affect (Simons et al, 1985). The work of Bandura (1989) on self-efficacy and Deci and Ryan (1985) on perceived competence highlight the potential this hypothesis may have, however, as with the distraction hypothesis, empirical studies are required.

Recently Ekkekakis (2003) has combined psychological and physiological factors in what he terms the dual mode hypothesis. It has acquired this name because, according to Ekkekakis, affective responses to exercise are influenced by cognitive factors, such as self-efficacy, and interoceptive cues (e.g. muscular or respiratory) that reach the affective centres of the brain via subcortical routes. Exercise intensity is the crucial factor in determining the balance between these
two modes of influence, with cognitive factors hypothesised to dominate at low intensities and interoceptive cues becoming more salient as the participant approaches their functional limit. This is a tentative theoretical model and empirical investigations are now required in order to evaluate the suggestions made.

2.8 CHO ingestion, metabolism and performance
A common practice of endurance athletes is to consume carbohydrate (CHO) before, during and following exercise and there is a large and growing body of knowledge regarding this nutritional strategy (Coggan & Coyle, 1991; Hargreaves, 1996). Studies investigating the type, timing and amount of CHO to be ingested prior to exercise in an attempt to enhance the availability of muscle and liver glycogen and maintain the concentration of glucose in the blood are common. Further, numerous studies have been undertaken on post exercise CHO ingestion to aid recovery by restoring muscle glycogen stores so that future performance can be optimised. However, such strategies are beyond the scope of the present review, but the reader is directed to reviews by Hargreaves (1999) and Coombes & Hamilton (2000) for a more detailed insight into CHO ingestion before and after exercise. This review of literature will focus on the influence of CHO ingestion during exercise and how this relates to exercise performance, perceived exertion and affective states.

Studies looking at the effects of CHO ingestion during exercise on metabolism and performance have produced conflicting findings. In brief, explanations for this could in part be due to inherent differences in study design and type of exercise mode employed, e.g, running versus cycling. In the literature there are many studies on CHO ingestion during prolonged cycling and the majority of the results favour the conclusion of performance enhancement (Coggan & Coyle, 1987; Coyle & Coggan, 1984). Laboratory investigations on CHO ingestion and running performance, however, have proved inconclusive and intermittent exercise protocols have not been as well studied and again equivocal findings reported.
2.9 CHO Ingestion and cycling exercise

Studies indicate that CHO ingestion may have a beneficial effect on endurance performance and this effect is often seen late in exercise of 2h or more in duration. In an often cited study by Coyle and colleagues (1986), 7 well trained cyclists ingested 130g of a glucose polymer in a 50% solution 20 minutes into the exercise to fatigue protocol and 27g CHO in a 10% solution every 20 minutes thereafter. CHO ingestion delayed the onset of fatigue by 1h when compared to the PLA trial. In support of these findings, Coggan and Coyle (1989) reported a 21% increase in time to fatigue during a 70% VO₂ max cycle ergometer ride to fatigue following ingestion of a glucose polymer late in exercise.

Muscle glycogen stores are low late on in exercise of ~2h duration. As a consequence blood glucose oxidation accounts for most of the CHO oxidation (Coggan & Coyle, 1991). Indeed, if muscle glycogen stores are high then blood glucose only provides about 25% of CHO as fuel (Coggan & Coyle, 1991). As observed by Coyle et al. (1986), blood glucose concentration decreases with prolonged cycling exercise and this in turn can lead to a decrement in performance. However, an exogenous supply of CHO may prevent this decrement. Coyle and colleagues as a consequence of numerous studies, suggest that CHO ingestion maintains blood glucose availability and prevents the reduction in CHO oxidation even when muscle glycogen stores are almost depleted (Coyle et al., 1986), thus offsetting the onset of fatigue and enabling exercise to be performed for longer.

In contrast to the findings of Coggan and Coyle (1989) and Coyle et al. (1986), Felig and colleagues (1982) reported only small, insignificant increases in time to fatigue. In this study participants cycled at 60-65% VO₂ max to fatigue when ingesting either 10g or 20g of glucose compared to PLA every 15 min during exercise. In further disagreement with the findings of Coggan & Coyle is a study by Burgess et al. (1991). Nine recreational males cycled at 67% peak VO₂ for 165 min and then undertook a performance ride to fatigue at 80% peak VO₂. Participants ingested either 3.5ml.kg.BW CHO solution or a PLA solution at 20 min into exercise and then every 20 min thereafter, resulting in delivery of CHO of approximately 13g.hour. There was no performance enhancement reported
following ingestion of CHO. A possible explanation for the lack of relationship between CHO ingestion and performance in these studies could be due to the fact that the cyclists were not experienced and therefore could display large variability in their exercise performance as a result of motivation and learning effects. Any potential improvement in performance as a result of CHO ingestion could have been obscured by such variability. In addition, Burgess et al. (1991) also report that the ingestion of CHO at a rate of 13g CHO hr⁻¹ in their study may not have been sufficient as an exogenous supply of CHO and the observation of only a small difference in blood glucose concentration at 158 min and fatigue could support such an assertion. In summary, there is a general consensus that carbohydrate ingestion during prolonged cycling enhances performance (Coggan & Coyle, 1991).

2.10 CHO Ingestion and Prolonged Running
The findings of studies involving the influence of CHO ingestion on running have been far from conclusive. Riley and colleagues (1988) failed to demonstrate an increase in time to fatigue at 70% VO₂ max following ingestion of a 7% CHO solution 20 min before and every 20 min during exercise when compared to a placebo solution. In support, Williams et al. (1990) observed that male distance runners average treadmill time was not different in the CHO trial compared to the placebo trial. In contrast, Wilber and Moffatt (1992) observed that exercise performance improved by 29% when a 7% CHO solution was ingested during a treadmill run at 80% VO₂ max to fatigue. The results of this study are similar to the cycling studies of Coyle et al. (1983, 1986). Tsintzas et al. (1995) studied 11 recreational runners who ingested a 5.5% CHO solution compared to a placebo solution. They observed a 14% improvement in treadmill time to fatigue at 70% VO₂ max. Utilising a similar exercise protocol they also observed a 27% increase in run time to fatigue (Tsintzas et al., 1996).

Such conflicting findings are not readily explainable, however, it is reported that in contrast to prolonged cycling studies, running is not typically associated with a large fall in blood glucose concentration and reduced rates of CHO oxidation at fatigue (Tsintzas et al., 1993; Williams et al., 1990). In contrast to cycling, in the majority of running studies, blood glucose concentration does not decline. Instead,
it appears to be maintained when compared to control conditions (Tsintzas et al., 1995).

Tsintzas and colleagues (1995) investigated the effect CHO ingestion on muscle glycogen utilisation during 60 min of treadmill running. Over the course of the run, they ingested 50g CHO in a 5.5% solution and this resulted in a 28% sparing of muscle glycogen in the vastus lateralis muscle. This sparing was accompanied by an increase in blood glucose concentration. CHO ingestion did not affect CHO oxidation rate and Tsintzas et al. suggest the reduction in glycogen utilisation would be reflected by a greater oxidation in the type I fibres (actually 42%) in the exercising muscles (hence the sparing of muscle glycogen). Therefore it is possible that there is a difference in the relative importance of blood glucose versus muscle glycogen as CHO fuel sources during running and cycling and this can explain the differences in glycogen use with CHO ingestion (Hargreaves et al., 1999). Indeed, Hargreaves suggests differences in muscle mass, recruitment patterns and/or contraction dynamics between running and cycling as possible alternative explanations for such differences.

2.11 CHO ingestion and intermittent exercise

Nicholas and colleagues (1995) reported an improvement in run time to fatigue of 33% following ingestion of a 6.9% CHO drink during the 75 min Loughborough Intermittent Shuttle Running Test (Nicholas et al, 2000) in a run to fatigue protocol that proceeded the LIST. They suggested that this finding was due to a lower utilisation of glycogen during the early part of exercise resulting in the sparing of glycogen in the later run to fatigue. Recently, Davis et al. (1999) supported this finding by reporting a 52% longer run to fatigue when consuming a CHO solution during a similar exercise protocol. In contrast, Mitchell et al. (1989) compared metabolic responses to a 12% CHO solution during 2 h of continuous and intermittent exercise at 70% VO₂ max. The protocol involved 7 x 15 min of exercise with 30 min rest intervals interspersed. They found no differences in blood glucose and insulin concentration between trials and no differences in CHO oxidation and glycogen utilisation rates. The authors concluded that CHO supplementation during intermittent exercise doesn’t provide a performance benefit compared to continuous exercise, nor does it alter muscle glycogen use.
However, the study design could be criticised as resembling a continuous rather than an incremental protocol. Similarly, Nassis et al. (1998) employed a treadmill intermittent protocol. Nine recreational runners undertook repeated bouts of fast running (15 sec) followed by slow running (10 sec). Participants ingested a 6.9% CHO solution at the start (3ml.kg$^{-1}$) and every 20 min thereafter (2ml.kg$^{-1}$) during exercise. There were no performance benefits observed. They conclude that this finding could be the result of the modest delivery of CHO at 30g.h$^{-1}$ and/or the high intensity nature of the protocol.

A study undertaken by Nicholas et al. (1999) gives insight into some of the metabolic differences associated with CHO ingestion during intermittent exercise. Six trained games players ingested 50g.hr$^{-1}$ of CHO or PLA solution of the same volume during the 90 min version of the LIST. They reported a higher insulin response and slightly higher (n.s) blood glucose response. Mixed muscle glycogen utilisation was reduced by 22% and glycogen utilisation decreased in both type I and type II fibres when CHO was ingested during this type of intermittent exercise. In the PLA trial there was a significantly greater glycogen utilisation in the type II fibres than the type I fibres. A possibility exists that CHO ingestion allows glycogen resynthesis to occur during the low intensity exercise periods and rest intervals of the LIST – at least in type II fibres (Tsintzas & Williams, 1998).

In sum, equivocal findings have been reported, however, it appears that CHO ingestion during intermittent exercise may reduce muscle glycogenolysis and therefore spare muscle glycogen during the later stages of exercise. The ingestion of CHO enables the oxidation of this exogenous substrate supply and as a result spares glycogen in the type I fibres.

As discussed, in some studies, CHO ingestion does not improve performance. Such conflicting findings could be due to the fact that many studies use exercise time to fatigue as their measure of endurance capacity and Jeukendrup et al. (1996) argue that this is not a reliable measure of endurance performance, due to the effects of extraneous factors such as motivation and learning effects. Yet, some studies undertake tests that involved recording the fastest time to complete a standard task or work output (e.g Williams et al., 1990; Tsintzas et al., 1993). This
lack of consistency could explain the contradictory findings. The amount of CHO provided is inconsistent across experimental protocols and the majority of studies that have reported a positive effect, have administered generally large amounts of substrate. Also, CHO ingestion during exercise seems to have less of an effect on performance when the duration of exercise is less than 2 h (Ivy et al., 1979). This is probably because CHO availability does not become limiting during this time. Finally, individual differences may play a part. CHO ingestion during exercise doesn’t seem to be beneficial to individuals, who in the absence of CHO supplementation are able to maintain an adequate blood glucose concentration (Coyle et al., 1983). For a more detailed review on the effect of CHO ingestion during prolonged exercise and the influence of CHO type and the optimal amount to be ingested, the reader is directed to a review by Coggan and Coyle (1991).

2.12 CHO Ingestion and Ratings of Perceived Exertion

There are numerous studies in the literature that have investigated the influence of CHO ingestion on ratings of perceived exertion (RPE) during exercise (Burgess et al., 1991; Utter, 1997b, 1999; Wilber & Moffatt, 1992). Table 2.1 illustrates some of these studies and the outcomes reported. To date, the results of these experimental studies have been inconsistent and no firm conclusions made. Some studies have reported that the ingestion of CHO during prolonged exercise reduces the reported perceptions of exertion (Burgess et al., 1991; Coggan & Coyle, 1987) whereas for others, no effects have been found (Ivy et al., 1979, Felig et al., 1982, Tsintzas et al., 1995). Indeed, of the studies highlighted in Table 2.1, 53% reported lower ratings of RPE during the CHO trial compared to the PLA, but 47% reported no differences. Furthermore, of the studies that reported a beneficial effect, 62% involved cycling exercise. Upon a review of the literature and the completion of Table 2.1, it was interesting to note that all the studies used participants under the age of 45 years. Further research on the effects of CHO ingestion on effort sense, in individuals over the age of 45, is warranted.

Coggan and Coyle (1989), Coyle et al. (1986) and Burgess et al. (1991) have all reported a reduction in perceived exertion following ingestion of a CHO solution during prolonged cycling exercise. Burgess et al. (1991) compared the ingestion of an 8% glucose electrolyte solution with a placebo solution on RPE during 180
min of cycling at 70% peak $\dot{V}O_2$. They administered the Borg (1982) category scale (CR-10) and participants were asked to rate their perceived exertion for the legs (RPE-L), chest (RPE-C) and overall (RPE-O). They reported that RPE-L was significantly lower in the CHO trial during the last hour of exercise. In addition they also observed favourable metabolic differences between trials. CHO oxidation rates were higher during the CHO trial at 165 min and 180 min and blood glucose concentration was higher at all time points except 60 and 90 min. Coggan and Coyle (1986) have shown that muscle glycogen depletion and a reduction in the circulating levels of blood glucose are important determinants of fatigue during prolonged cycling (~70% $V_02$ max). The maintenance of blood glucose following CHO ingestion appears to have reduced the peripheral (RPE-L) but not the central (RPE-C) signals of exertion during the later stages of exercise, below lactate threshold (Burgess et al., 1991). The RPE-C originates from the chest and therefore would be unaffected by exercise below the lactate threshold since lactate accumulation and thus shifts in pH would not occur to increase the ventilatory drive (Cafarelli, 1982). Unsurprisingly, the physiological variables associated with this metabolic respiratory rating did not differ between the CHO and PLA trial. Indeed, this study is consistent with the work of Robertson et al. (1982) in that the reduction in peripheral signals of exertion may be a function of the maintenance of blood glucose for oxidation in the muscle (rather than muscle glycogen sharing) and that the elevated blood glucose concentrations and therefore extraction of blood glucose is a mediator of the intensity of peripheral perceptions of exertion (Burgess et al., 1991). Coggan and Coyle (1988) and Coyle and Coggan (1984) have previously shown that blood glucose is associated with a decrease in overall RPE and Burgess et al. (1991) also reported this finding, but as already mentioned, this reduction was largely due to the decrease in RPE-L rather than RPE-C.

Felig and colleagues (1982) and Ivy et al. (1979) found no differences in perception of exertion during prolonged cycling following CHO ingestion. In support of Burgess et al. (1991) and Coggan and Coyle (1988) these authors also observed elevated circulating blood glucose concentrations during exercise following CHO supplementation, however in contrast RPE was similar between
conditions. It is not clear why there is such discrepancy in findings during cycling protocols, but a possible reason could be due to differences in methodology. The study undertaken by Ivy et al. (1979) involved a 2 h self-paced competitive ride and during this time participants were instructed to produce the greatest amount of work as possible by the cessation of the exercise time. As a consequence, the average exercise intensity was slightly higher during the later stages of exercise following ingestion of CHO. If the same intensity had been produced during both trials then differences in RPE may have been observed.

A problem with research on CHO ingestion and RPE is the reliance on cycle exercise (Burgess et al., 1991; Coggan & Coyle, 1987; Coyle et al., 1986; Kang et al., 1996). Only recently has research reported changes in RPE following CHO ingestion during prolonged running and conflicting findings have been produced. Tsintzas and colleagues have undertaken a number of studies investigating the influence of CHO ingestion during prolonged running on performance and metabolism and in the series of studies reported, no reduction in RPE was observed. In 1995, Tsintzas et al. observed no difference in RPE when the ingestion of a 6.9% and a 5.5% CHO solution before and during a 42.2km treadmill time trial compared to a placebo solution. This was despite the fact that during the 5.5% CHO solution trial, participants were better able to maintain their chosen speed throughout the entire time trial and this was reflected in a reduced performance time compared to the other trials. However, no differences in RER were found at any of the sampling time points and CHO oxidation rates were also reported as being similar. In another study by Tsintzas et al. (1996), 11 male subjects ran to exhaustion at 70% VO₂ max. Participants ingested either a 5.5% or a 6.9% CHO electrolyte solution or a placebo solution for the first hour of exercise, and then water throughout the remainder of the run. There were no differences between the two CHO trials in run time, but time to fatigue was longer in the 5.5% CHO trial compared to the placebo trial. In this trial blood glucose concentration was only higher at 20 min compared to the placebo trial, and catecholamines, serum insulin and cortisol concentrations were not different between the trials. If blood glucose concentration is an important mediator in the perception of effort, then it is perhaps unsurprising that again Tsintzas et al. reported no differences in RPE between the trials. Further, in a trial undertaken by
Tsintzas et al. (1993) comparing the ingestion of a 5% CHO solution or a non-flavoured tap water solution on 30km road race performance, similar finding emerged. There were no differences in RPE reported between the trials, despite an enhanced performance time for the CHO trial compared to the water trial and again the metabolic profile was similar between conditions. Blood glucose concentration was not different between the trials.

Utter et al. (1997) out of dissatisfaction with the lack of running studies on this topic conducted a study involving 30 marathon runners. They were divided into groups and undertook a 2.5hr run at 75-80% VO₂ max. One group ingested a 6.5% CHO solution before and every 15 min during the run, and the other group, the same volume of a placebo solution. They observed a reduction in RPE during the CHO trial compared to the PLA trial at 100 min and every time point thereafter. Utter et al. also reported a higher RER, CHO oxidation rate and blood glucose concentration immediately post exercise in the CHO group. This led them to the conclusion that the availability of CHO influences effort sense during the later stages of prolonged submaximal treadmill running. In support of the study on cycling exercise undertaken by Burgess et al. (1991), no differences in Ve were reported and similarly the authors assert that the differences in RPE are not the result of respiratory metabolic factors, caused by the ventilatory drive. In agreement with Burgess et al. (1991) they suggest that the observed differences late on in exercise, are the result of less intense peripheral signals in the exercising muscles. Utter et al. suggest that during the later stages of prolonged exercise, energy substrates such as muscle glycogen decrease significantly, which leads to an interruption of the supply of energy for the contraction of the myofibrils and therefore localised muscular fatigue is induced (For a more detailed overview of this hypothesis the reader is directed to Utter et al., 1999). In addition, Wilber and Moffatt (1992), Riley et al. (1988) and McMurray et al. (1983) also observed the mean RPE to be lower following ingestion of CHO during prolonged running. However, it is important to note that the investigation by Riley and colleagues (1988) followed a one day fast.

Utter et al. (1999) brought the two modes of running and cycling together in one study and compared the effects of CHO ingestion during exercise on these two
types of exercise. Ten triathletes undertook four trials. They ran and cycled for 2.5 h at ~75% VO$_2$ max whilst ingesting either a 6% CHO solution or a placebo solution before (12ml.kg.BM) and during (4ml.kg.BM) exercise. They observed a lower RPE during the later stages of prolonged cycling in participants that ingested CHO compared to PLA. This finding was also associated with higher CHO oxidation rates as well as high blood glucose concentrations immediately post exercise. Further, blood insulin, cortisol and growth hormone concentrations were lower. Interestingly, cortisol has not often been mentioned in studies reporting the influence of CHO ingestion on RPE and since cortisol is often secreted in response to emotional stress and unpleasant sensations, it remains to be determined whether this hormone itself could affect the perception of exertion through a neurological mechanism (Utter et al., 1999). In contrast, RPE did not differ between the CHO and PLA trial during the prolonged running protocol. This was despite a higher CHO oxidation rate and blood glucose concentration in the CHO trial. However, in the PLA trial, blood glucose concentration was fairly well maintained and it is possible that the endogenous supply of energy in the form of CHO substrate to the exercising muscles may not have been reduced sufficiently to intensify the perception of exertion during running (Utter et al 1999). Also, the concentration of cortisol was not different between the two conditions in the running trial, unlike in the cycling trial. In this study the overall RPE was similar between running and cycling during the first 60 min of exercise, but past this time, it began to differ between the modes of exercise, with a larger increase in RPE during the running trial compared to the cycling. A potential explanation for this finding could be as a result of greater sensory input from the torso and arms, as opposed to just the legs in cycling, because muscle contractions in these regions play a stabilising role in maintaining body posture during running (Kreighbaum & Barthel, 1995). This is obviously not important in cycling.

In sum, those studies that have observed a reduction in RPE during exercise following CHO ingestion have generally done so during the later stages of the protocols. For example, Utter et al. (1997) did not see a reduction until the 100th minute of exercise, and similarly Burgess et al. (1991) only reported a reduction during the last hour of the 180 min bout. Further, it appears that when differentiated ratings of perceived exertion are administered, reductions are more
often seen. This is particularly the case in cycling studies, when the majority of studies report a reduction in perceived exertion in the legs following CHO ingestion. However, differences are not as well documented in overall RPE and chest RPE. In the running studies that have found no differences in RPE, such as those undertaken by Tsintzas et al., only the overall traditional measure of RPE was used. During cycling exercise, most studies that have investigated CHO ingestion have documented an improvement in endurance performance, however the benefits during running are not as conclusive as cycling. Similarly, the impact of CHO ingestion on reducing effort perception follows the same trend. The differences in the metabolic responses to running and cycling have been posited (Riley et al., 1988; Hargreaves et al., 1999) as being responsible for the lack of improvement in endurance capacity following CHO ingestion and this explanation could apply for the inconsistent findings on CHO ingestion and effort sense.

This review has highlighted some of the current findings in the literature on the influence of CHO ingestion on perceptions of exertion during various modes of exercise. It has also served to highlight some of the potential mechanisms involved, however, for a more detailed view of some of the proposed sensory mechanisms, the reader is directed to the review by Mihevic (1981) who covers this aspect in great detail.

2.13 CHO ingestion and Affect

While there is a strong theoretical basis for the recommendation of ingesting carbohydrates during prolonged exercise as a consequence of its well documented performance benefits, its effects on affective states and cognitive performance during prolonged exercise are yet to be determined. This is perhaps surprising when we consider the assertion by Acevedo (1996) that “affective states and the cognitive appraisal of exertion during exercise may determine whether or not an individual will persist at an activity”. Young (1975) reinforces this suggestion with the declaration that feelings are central to everything we are and do. Clearly the decision about whether or not to carry on with an activity should be viewed as a “cognitive-perceptual process” whereby the organism processes a variety of cues (Morgan, 1981). According to Morgan, this cognitive-perceptual process is involved in effort sense, in other words effort sense is based upon the “physiological cost, cognition (thinking) and perception (feeling)” (p.385). So all
these factors should be considered when studying human behaviour. A general consensus exists that CHO ingestion improves performance during prolonged submaximal (Costill, 1988; Coyle, 1991; Ivy, 1999) and intermittent, high intensity (IHI) exercise (Hargreaves, 1984; Nicholas, 1995). However, can it be used as a tool to maintain positive affective states during exercise, which is important when optimal performance is required. Further, Thayer (1989) emphasises the limited amount of scientific research on the relationship among affect, exercise and food – the likelihood of an important relationship is strong.

Lieberman (2001) also emphasises the fact that the brain requires a continuous supply of glucose in order to function adequately and during prolonged submaximal exercise, peripheral glucose requirements increase and consequently CHO ingestion has been observed to enhance endurance performance, as previously outlined. The brain’s utilisation of blood glucose also increases during endurance exercise, however, the effects of CHO supplementation on affective states during such activity are not well documented.

This review will begin with only a limited overview of studies investigating the effect of CHO ingestion on affect in resting individuals because such studies have been reviewed elsewhere (Benton, 2002; Christensen, 1997; Spring, 1987). Further, these authors also give a detailed account of some of the physiological and psychological mechanisms that have been proposed to explain a carbohydrate-induced behavioral effect, so this review will not cover these proposed mechanisms in detail. The influence of CHO feeding in non exercising participants is more readily available in the literature, however, its impact is still controversial (Bellisle et al., 1998). Several studies (Smith et al., 1988; Spring et al., 1989) have revealed that a CHO rich meal increases perceptions of sleepiness and calmness in healthy adults when compared with a protein rich or no meal condition.
Table 2.1. Summary of studies examining the effects of acute exercise on ratings of perceived exertion.

<table>
<thead>
<tr>
<th>Authors</th>
<th>N</th>
<th>Mean age</th>
<th>Sex</th>
<th>Fitness Level</th>
<th>Exercise Type</th>
<th>Exercise Intensity</th>
<th>Exercise Duration</th>
<th>Fluid Ingestion</th>
<th>Outcome</th>
</tr>
</thead>
</table>
| Ivy et al. (1979)  | 9  | 22.7     | 7M  | Trained       | Bicycle ergometer (80rpm) | Self-paced (work production) | 2 h               | Glucose polymer; 12.8g/15min of exercise | - No differences in RPE  
- No effects on total work production, but reduced rate of fatigue over last 30min in CHO  
- Maintained blood glucose levels |
| Felig et al. (1982)| 19 | M        |     |               | Bicycle ergometer | 60-65% VO₂ max | To fatigue         | Glucose; 40/80g.h | - No difference in RPE  
- Independent of alterations in blood glucose concentration  
- No delay in fatigue |
| Hargreaves et al. (1984) | 10 | 21.8     | M   |               | Bicycle ergometer | 30min blocks - 20min @50%, followed by 10 min intense (30s @100% then 2 min rest -sprint to fatigue | 4h               | Feedings at 0, 1, 2 & 3h of exercise  
Solid CHO: 43g sucrose, 9g fat, 3g protein with 400ml of drink  
PLA: 400ml drink | - No differences in RPE between treatments  
- Improved sprint ride to exhaustion at the end of the trial |
| Coyle et al. (1986) | 7  | 26       | M   |               | Bicycle ergometer | 71% VO₂ max | To fatigue         | Glucose polymer solution: 2.0g.kg@20min then 0.4g/kg every 20min thereafter | - No difference in RPE during first 2.5hr exercise  
- At fatigue in PLA trial, RPE higher compared to 175min in PLA trial  
- Fatigue delayed by 1h following CHO ingestion |
Table 2.1 cont.d. Summary of studies examining the effects of acute exercise on ratings of perceived exertion.

<table>
<thead>
<tr>
<th>Coggan &amp; Coyle (1987)</th>
<th>7</th>
<th>23</th>
<th>M</th>
<th>Endurance trained VO(_2\max): 4.62 ± 0.2 l.min(^{-1})</th>
<th>Bicycle ergometer</th>
<th>70% VO(_2\max)</th>
<th>Bout 1: to fatigue</th>
<th>Following bout 1: (1) Intravenous infusion of 20% dextrose (2) CHO soln; 3g.kg BW in 50% soln (3) PLA</th>
<th>- Bout 1: No difference between 3 trials with no treatment - Bout 2: RPE decreased in the infusion and feeding trials compared to the end of bout 1, this was not observed in the PLA trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murray et al. (1987)</td>
<td>13</td>
<td>30.6</td>
<td>M</td>
<td>Moderate VO(_2\max): 45.1 ± 7.7 ml.kg.min(^{-1})</td>
<td>Bicycle ergometer Intermittent exercise</td>
<td>55 &amp; 60% VO(_2\max) in heat (33°C) interspersed with 5 min rest periods</td>
<td>1.6h ride followed by a 480 revolution cycling task</td>
<td>During rest periods: 5% glucose; 6% sucrose/glucose; 7% glucose polymer/fructose</td>
<td>- No differences in RPE between trials - CHO trial – higher plasma glucose following 1h cycling - 6% &amp; 7% improved 480 revolution cycling task</td>
</tr>
<tr>
<td>Murray et al. (1989)</td>
<td>12</td>
<td>30.7</td>
<td>7M 5F</td>
<td>Moderate VO(_2\max): 42.8 ± 1.8 ml.kg.min(^{-1})</td>
<td>Bicycle ergometer Intermittent exercise</td>
<td>65% VO(_2\max) in heat (33°C) interspersed with 5 min rest periods</td>
<td>1.25h (3x20min bouts@65% then timed cycling task (1200rpm))</td>
<td>Pre and during rest periods: 2.5ml.kg.BW, PLA, 6%, 8% and 10% sucrose</td>
<td>- No differences in RPE - 6% soln enhanced 1200rpm cycling task - Compared to PLA, higher blood glucose &amp; insulin concentration during the final 20 min of ex</td>
</tr>
<tr>
<td>Coggan &amp; Coyle (1989)</td>
<td>6</td>
<td>24</td>
<td>M</td>
<td>Endurance trained</td>
<td>Bicycle ergometer</td>
<td>70% VO(_2\max)</td>
<td>To fatigue</td>
<td>After 135min of ex, ingestion of (1) glucose polymer 3g.kg-1 in a 50% soln (2) equal vol of PLA</td>
<td>- No significant effect of CHO feedings on RPE - 21% increase in time to fatigue following CHO ingestion</td>
</tr>
<tr>
<td>Study</td>
<td>Subjects</td>
<td>Age</td>
<td>Minutes</td>
<td>VO₂max</td>
<td>VO₂peak</td>
<td>Energy Source</td>
<td>Duration</td>
<td>Exercise Mode</td>
<td>Outcome</td>
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<tr>
<td>Robertson et al. (1990)</td>
<td>M</td>
<td>23.5</td>
<td>8</td>
<td>73g peak VO₂</td>
<td>26.8 ± 1.3 ml·kg⁻¹·min⁻¹</td>
<td>60% peak VO₂</td>
<td>7 day diet containing: (1) 75g dl-hydroxyacetone &amp; 25g sodium pyruvate, (2) isocitrate, glucose polymer, PLA</td>
<td>To fatigue</td>
<td>No differences in RPE up to 50min</td>
</tr>
</tbody>
</table>
| Burgess et al. (1991) | M | 9 | 10 | 4.3 ± 0.2 l·min⁻¹ | 70% peak VO₂ | Bicycle ergometer | 165min | 20min every 2hr by 2 stage ride to fatigue | No differences in RPE 
Glucose higher at all time points except 60 & 90 min |
| W.A. et al. (1991) | M | 24-30 | 8 | 58.4 ± 1.4 ml·kg⁻¹·min⁻¹ | 67% peak VO₂ | Bicycle ergometer | 15min | CHO & PLA, every 15miner delivered at 1g·h⁻¹ | Higher blood glucose at 158min and fatigue |
| Wilber & Maffet (1992) | M | 10 | 30 | 4.5 | 80% VO₂ | Treadmill | To fatigue | 7% CHO & PLA Pre: 250ml & CHO trial higher BG conc |
| Tsintzas et al. (1995) | M | 44.5 | 7 | 42.6km | Self Paced | Treadmill | 42.6km | 6.6% CHO, 5.5% CHO, PLA, 3ml·kg⁻¹·BM before, 2ml·kg⁻¹·BM every 5km | Performance time faster in 5.5% CHO oxidation rates similar |

Table 2.1 cont'd. Summary of studies examining the effects of acute exercise on ratings of perceived exertion.
Table 2.1 cont.d. Summary of studies examining the effects of acute exercise on ratings of perceived exertion.

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Gender</th>
<th>Age</th>
<th>Exercise Type</th>
<th>VO₂ max</th>
<th>Intensity</th>
<th>Time to Fatigue</th>
<th>Metabolite Response</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsintzas et al.  (1996)</td>
<td>11 male, 27 female</td>
<td>M</td>
<td>20-25</td>
<td>Treadmill</td>
<td>70% VO₂</td>
<td>To fatigue</td>
<td>6.9% CHO, 5.5% CHO, PLA</td>
<td>- No differences in RPE - 5.5% CHO increased run time to exhaustion</td>
<td></td>
</tr>
<tr>
<td>Kang et al. (1996)</td>
<td>7 male, 29 female</td>
<td>M</td>
<td>25-30</td>
<td>Bicycle ergometer</td>
<td>70% peak VO₂</td>
<td>To fatigue</td>
<td>6% glucose/sucrose soln &amp; PLA; 0.6g.kgBW.h every 20min</td>
<td>- RPE-L &amp; RPE-O reduced in CHO trial - Increased concentration of blood glucose and rate of CHO oxidation in CHO trial</td>
<td></td>
</tr>
<tr>
<td>Utter et al. (1997)</td>
<td>30 (17 CHO, 13 PLA)</td>
<td>M</td>
<td>25-30</td>
<td>Treadmill</td>
<td>75-80% VO₂</td>
<td>2.5 hr</td>
<td>6% CHO (Gatorade) Pre: 0.75L During: 0.25L every 25min</td>
<td>- RPE lower in CHO at 100, 120, 140, 160min - Higher blood glucose, RER and CHO ox rates post ex in CHO trial - No differences in Ve</td>
<td></td>
</tr>
<tr>
<td>Utter et al. (1999)</td>
<td>10 male, 34.2 female</td>
<td>M</td>
<td>25-30</td>
<td>Bicycle ergometer &amp; Treadmill</td>
<td>~75% VO₂</td>
<td>2.5 hr</td>
<td>6% CHO (Gatorade) Pre: 12ml.kg..BM During: 4ml.kg..BM every 15min</td>
<td>- Lower RPE during later stages of cycling in CHO trial - Higher blood glucose levels in this trial post exercise - No differences in running on RPE between CHO and PLA</td>
<td></td>
</tr>
</tbody>
</table>
Other studies (Christensen & Redig, 1993; Lieberman, 1986; Smith et al., 1988) have found no effects of either a CHO rich meal or a sucrose beverage (Brody & Wolitzky, 1983; Reid, 1995) on affective states. In contrast a study undertaken by Benton and Owens (1993) reported that subjective energy increased after a sugar containing drink. The discrepancy between this finding and those reported could be explained by the timing of assessment of affect. In the majority of studies affect is measured about 2 h after ingesting CHO. Indeed this is the case with all the studies that have reported an association between decreased subjective energy and the consumption of a meal (Benton, 2002). However in the Benton and Owens' study they measured affect after 14 or 30 min. This is consistent with the study of Thayer (1987a) who observed that following a sugar snack, a short term increase in subjective energy was followed by a longer term fall in energy. Research suggests that the response involves a two stage effect (Benton, 2002). In conclusion, the relationship between CHO intake and affective states in healthy adults at present is at best a weak one. The majority of studies have been driven by the hypothesis that ingestion of carbohydrate will lead to an associated decrease in subjective energy. The studies discussed have examined this relationship in participants who were sitting quietly, however more significant results could be observed when sustained demands are placed upon the individual, such as those induced by prolonged exercise. The possibility that raising blood glucose during such activity could have an impact on affect has been little considered.

In the few studies that have investigated the influence of CHO ingestion on affective states during exercise, results have proved equivocal and it is clear that more research is required. Such discrepancies probably reflect differences in methodology and as a result, conclusions cannot be made as readily. Further, to date only one or two studies have examined responses to an acute bout of exercise, the other studies, albeit limited, have focused on the responses to chronic feedings.

CHO ingestion has been reported to improve mood states as measured by the POMS (McNair et al., 1981) during prolonged training periods in elite female cyclists and hockey players (Keith, 1991; Kreider, 1995) and during sustained
exercise interspersed with rest (Lieberman et al., 2002). However, these findings have not been conclusive. Kreider et al. (1995) assessed whether or not a dietary supplementation of a CHO solution (4g.kg.day CHO) during a period of intense training would affect among other things, the psychological status of elite female hockey players. The dietary availability of CHO was 82% greater in the CHO group compared to their matched counterparts, who ingested a placebo solution, during days one to six of training. However, despite this increased availability of CHO, only a limited impact on psychological status was observed. Participants completed the POMS immediately before and following each training session and used the 'right now' time set (McNair et al., 1981). Indeed, only post exercise fatigue-inertia scores were lower in the CHO group, and post hoc analysis highlighted this to have occurred following the first practices on days one and four. The authors conclude that increased dietary availability of CHO during heavy training may reduce the perception of fatigue and increase time to exhaustion following intense training, however it did not appear to affect overall psychological status as measured by the POMS.

Lieberman and colleagues (2002) observed that participants who received a CHO solution during a 10 h study that included a 19.3km road march and two 4.8km runs interspersed with rest, reported less confusion and greater vigour than those who received the placebo solution. A dose response relationship was also found with the 12% CHO solution resulting in greater improvement than the 6% CHO solution.

Keith et al. (1991) administered three diets to seven female cyclists over the course of 1 week. They each ingested a diet that was either low (25%) moderate (50%) or high (75%) in CHO. The POMS (McNair et al., 1981) was administered at the end of each week and then prior to cycling to fatigue. They found that following one week ingestion of a low CHO, high protein and high fat diet mood states as measured by the POMS were adversely affected. Cyclists had significantly greater scores for tension, depression and anger and less vigour compared to the moderate CHO diet. Further, total mood score was significantly greater than the scores obtained for the moderate and high CHO diet. However, these results should be interpreted cautiously. The participants were not fed the
diets under controlled conditions and although the authors felt that compliance was satisfactory, the actual compliance to the prescribed diets could be questioned. In contrast some studies that have compared CHO ingestion with protein ingestion in ‘none exercising’ individuals have as mentioned previously found that perceptions of energy decreased (Christensen & Redig, 1993; Lieberman et al, 1986). The observation of enhanced vigour in the study by Keith et al (1991) following CHO ingestion could be due to the exercising element of the protocol. During prolonged or intense exercise, it may be more difficult to maintain the central requirements for energy due to the peripheral demands in order to maintain energy expenditure. The brain utilises glucose as its main energy substrate (Evans et al, 1998) and this organ is highly metabolic. A study by Ide et al. (2000) involving regional blood flow investigations has shown that exercise increases the brain’s metabolic requirements in certain regions and as a consequence central energy requirements are increased. As glucose is the brain’s principal energy provider, carbohydrates are the optimal nutrients for sustaining exercise during periods of rapid energy depletion (Coyle et al., 1991) and they are probably the optimal substrate for supporting central metabolic requirements under these conditions (Lieberman et al., 2002).

Morgan et al (1988) found that runners who had undergone a significant increase in training mileage, reported significant mood disturbances, eliciting a negative mood profile and that a diet relatively low in CHO did not alter the distress produced during an increased training load over a 5-d period. This study again does not concur with the study by Keith et al. (1991) who found increased vigour following increased CHO ingestion during an intense training programme.

Only two studies to date have investigated the effects of CHO ingestion on an acute bout of exercise and consequently firm conclusions cannot be made. Welsh et al. (2002) investigated the influence of ingesting an 18% and 6% CHO solution before and during an IHI shuttle running protocol, which was designed to simulate the demands of a basketball game. The total exercise time was 60 min, split into four 15 min quarters, with a 20 min half time rest period. A run to fatigue then followed. The POMS was used to assess changes in affect during exercise. Welsh et al. observed a 37% longer run time to fatigue following CHO ingestion.
compared to the PLA trial. There were significantly greater negative mood states reported at half time and at fatigue compared to the pre exercise time point. However, the only difference observed between the CHO and PLA trials was upon fatigue when the fatigue subcomponent of the POMS was lower in the CHO trial (p=0.048). The authors suggest that this represents a lower self-report sensation of fatigue in participants ingesting the CHO solution, however, they were unable to maintain the shuttle running speeds. They also noted that blood glucose was higher and FFA lower during the second half of the exercise protocol and such a blood profile has been suggested as being possible mediators of enhanced CNS function during heavy exercise with CHO ingestion (Davis, 2000). Glucose is clearly an important energy source for the brain, especially in those areas most active during strenuous exercise (Welsh et al., 2002). Paul (1996) concluded that pre-exercise CHO meal consumption (90min before) affected tryptophan:LNAA ratio before, during, and after cycling exercise, but these changes were not sufficient to alter physical and cognitive performance.

As highlighted throughout this section differences in methodologies make comparisons difficult. Some studies assess affect in excess of 2h postprandially (Keith et al, 1991; Smith et al., 1988) whereas others report the acute effects and measure affect within 30-90 min of ingestion (Benton & Owens, 1993). Further in the case of the exercising studies some participants were asked to report how they had felt during the previous week (Keith et al, 1991) whereas in others they were asked to respond to how they had felt at that moment (Welsh et al., 2002). Further, it is difficult to compare studies that don’t have a physical activity element with those that do. There may also be differences in the responses between males and females. Keith et al. (1991) and Kreider et al. (1995) used females, whereas the study by Morgan et al. (1988) used male participants. Spring et al. (1989) have reported that males respond differently to CHO feedings when compared with females, at least in acute feeding studies. Further differences in the amount of CHO supplemented, particularly in the chronic feeding studies, could have a significant impact.

In sum, clearly more evidence is required from controlled laboratory studies utilising a variety of exercise modes (prolonged running/cycling, IHI exercise) in
order to examine the influence of CHO ingestion on affective states during and following exercise. Further, previous studies have relied on the negative scoring POMS, which provides five negative affective responses and only one positive measure in the form of vigour. Therefore participants are being restricted in their response to the exercise session and the nutritional manipulation. Employing a categorical model is at the outset limiting the investigative scope to distinct affective states and missing other aspects of affect. Considering the lack of knowledge on the effect of consuming CHO during exercise on affective states and the potential for altered mood to affect performance, this PhD was designed to determine the effects of fluid ingestion during various modes of exercise.

2.14 CHO ingestion: Biochemical mechanisms and affect

The various mechanisms proposed to underlie the connection between CHO ingestion and affect have either received little support from empirical studies or few data currently exist to either support or refute them (Christensen, 1997). Further, many of the studies to which strong evidence exists of a connection have been undertaken on animals and not human participants. A number of physiological mechanisms have been proposed and the one that has received the most attention involves the neurotransmitter serotonin. The reader is directed to recent reviews (Benton, 2002; Christensen, 1997) and to the book by Wurtman and Wurtman (1977) for more detail on the actions and production of serotonin. Wurtman and Wurtman (1995) propose that CHO intake in resting individuals, acting via insulin secretion and what they term the ‘plasma tryptophan ratio’ increases brain serotonin. When a high CHO meal increases the tryptophan to large neutral amino acids (LNAAA) ratio, relatively more tryptophan is transported into the brain and because the transforming enzyme tryptophan hydroxylase is not normally fully saturated (Benton, 2002), any increased availability of tryptophan results in an increased synthesis of serotonin. However, there is an issue with this mechanism. Research has shown that if protein accounts for as little as 5% of the caloric intake, then increased provision of tryptophan will be prevented (Benton & Donohoe, 1999). This observation has blunted the enthusiasm for this mechanism by which CHO consumption affects behavior. Consequently, apart from in controlled laboratory conditions or following very selective and restrictive diets, it is incredibly difficult to regularly increase the availability of tryptophan.
However, it has been reported that carbohydrates do not elevate plasma tryptophan in humans engaged in prolonged exercise, and it has been hypothesised that they will therefore have beneficial effects on centrally mediated fatigue (Davis et al., 1992). Certainly the role of fatigue regulation by brain serotonin may be more significant in exercising individuals (Davis et al., 2000). Indeed, Segura & Ventura (1988) report that tryptophan supplementation improved endurance capacity, suggesting that increased brain serotonin may be beneficial to exercising individuals. Further research is required in order to arrive at conclusions regarding the role of serotonin in regulating alertness and fatigue at rest and exercise performance during exercise. Although there is evidence for central serotonergic systems playing a key role in the etiology of depression and anxiety, it remains to be shown whether such a contribution is significant in exercising participants (Chaouloff, 1997). Indeed, Chaouloff asserts that this question can only be answered if an integrative approach is combined with a suitable animal model.

Hypoglycemia has also been suggested as a possible mechanism used to account for a lowering of affect. This is a metabolic disturbance characterised by low blood sugar and an episode is characterised with symptoms such as hunger, nervousness and fatigue. Such symptoms arise because of the counterregulatory hormones (e.g. adrenaline, cortisol) produced to prevent the decline in glucose levels below baseline (Messer et al., 1990). In clinical practice, patients frequently report feeling miserable or tearful during or after an episode of acute hypoglycemia (Gold et al., 1995). Yet there have been few studies performed during acute hypoglycemia that have assessed any changes in psychometric affect dimensions. Further, in non-exercising individuals most studies (Messer, 1990; Spring et al., 1987) conclude that hypoglycemia does not represent a viable mechanism for the CHO-affect connection. However, its impact on affective states during prolonged exercise has not received much attention.

A number of psychological hypotheses are also present in the literature. The potential impact of expectancy effects has been repeatedly discussed (Christensen, 1991) and is a factor that must be considered and recognised. However, investigators, certainly in diet-behaviour research, employ controls in order to avoid such confounding effects (Spring et al., 1987). Finally, CHO's could
influence behaviour and affective states through its effects on perceptions of fatigue. A CHO rich, protein poor meal can increase feelings of sleepiness or fatigue (Spring et al., 1989). However, it appears the effect is a two stage one. The immediate response to CHO ingestion is to report increased feelings of vigour and energy, however this enhanced affective response is often short lived and is followed by an increase in fatigue (Christensen, 1991). Thayer (1987a) offers support to this assertion as he reported an immediate increase in energy following a sugar snack, but then a decline in energy was seen to be the longer term effect. Indeed, the inconsistency in research led Reid and Hammersley (1995) to conclude that the effects of CHO on affect and behavior are influenced by psychological factors.

Therefore, the aim of this thesis is to investigate the influence of various fluid regimes during running, cycling and high intensity intermittent prolonged exercise in order to assess not only 'what' the participant feels during exercise, which has been the dominant focus to date, but also 'how' they feel. As this review of literature has highlighted, there have been many studies undertaken on the influence of fluid ingestion on perceived exertion during exercise, and researchers have examined its influence during rest on affective states, however, such approaches have not been investigated together in an exercise protocol. Furthermore, some of the methodological issues highlighted and the recommendations made will be adopted in the studies that follow. Specifically, due to the nature of the research to be conducted, a dimensional approach to the measurement of affect will be adopted, and repeated measures on in-task affect will be sought, which will add to the extensive literature that has utilised a pre to post design. Finally, this research will investigate the influence of prolonged exercise on affective states, which has previously been ignored.
Chapter III

General Methods

3.1 Introduction
This chapter describes the equipment and methodological procedures which are common to each study. Specific experimental procedures pertaining to each study will be detailed within the methods section of each experimental chapter.

All procedures undertaken had approval from the Loughborough University Ethical Advisory Committee. All participants were informed of the nature, purpose and possible risks of each experiment before obtaining written informed consent. Participants were also required to complete a medical history questionnaire and detail their current training status.

3.2 Assessment of self reported affect
A lack of consensus still exists in the exercise psychology literature on the approach to affective change assessment. In light of this and the recent reviews undertaken by Ekkekakis et al. (2000a), affect in the studies that follow will be assessed from the point of view of the affect circumplex (Russell, 1980; 1989). Reviewers (Biddle, 2000; Biddle & Mutrie, 2001; Gauvin & Brawley, 1993) have called for the application of this potentially useful measurement approach to the study of the exercise-affect relationship because, despite three decades of research, we are no closer to identifying the stimulus properties of exercise with any certainty. The circumplex model is a suitable method in the study of the influence of fluid ingestion on affective responses during prolonged exercise because it is domain-general, therefore not likely to produce assessments that are biased against or in favour of a certain treatment (Ekkekakis & Petruzzello, 2002).

As this area of research is in its infancy, this model is ideal as it targets basic affect, which is the simplest and broadest concept. This is crucial when no previous evidence exists regarding which affective states may be influenced following various fluid regimes during exercise and breadth and scope is one of its
greatest assets. Clearly, how good or bad and how aroused/activated a person feels are highly relevant to exercise and valence and activation underpin basic affect. The studies undertaken are based along similar approaches suggested by Scherer (1984) and Ekkekakis and colleagues (2000b; 2002) by using affective states as a "generic term" (p.298), that refers to all varieties of states that contain the ingredient of basic affect. An important point that Ekkekakis (2003) raises is that "although basic affect (such as pleasure or displeasure, tension or relaxation) can exist as a component of emotions, there can also be basic affective responses to specific stimuli that occur independently of emotions." (p.5).

Numerous psychometric measures exist in the literature to assess affective responses and there is a growing debate among researchers regarding the measurement approach in the study of affective change during and following exercise. As Gauvin and Brawley (1993) noted:

"...a dimensional approach seems better suited to the study of exercise and affect because the models stemming from it are intended to be broad, encompassing conceptualisations of affective experience. Because the affective experience that accompanies exercise has not been thoroughly described, a model of affect that has a wider breadth is more likely to capture the essence of exercise-induced affect than a model that at the outset limits the focus investigation to specific emotions" (p.152).

As highlighted in the review of literature in Chapter 2, during the late 1960s and early 1970s, studies relied heavily on categorical measures of affect such as the Profile of Mood States (McNair et al., 1981) and the State Trait Anxiety Inventory (Spielberger et al, 1970). Yet, in the context of exercise, formal psychometric evaluation has not been undertaken on these two measures, and they have been the source of much criticism. To date no evidence exists that the most salient changes in affect associated with exercise are anxiety and depression and therefore, the narrow focus that has previously been adopted, limited the ability to capture the impact of exercise on affect in general (Ekkekakis & Petruzzello, 1999a).
As outlined, a dimensional perspective will be adopted, namely the circumplex model. This model targets basic affect, which is the simplest and broadest concept and this is important in research that is new and cannot draw on previous findings. It is a very influential dimensional conceptualisation, where two dimensions are crossed; an affective valence dimension and an activation dimension. Affective states are construed as combinations of varying degrees of these two constituent dimensions, such that they can be conceptualised as located around the perimeter of a circle (Hall et al, 2002). Stone (1995) uses the analogy of colour hues to illustrate this representation of affect. The circumplex model can be conceptualised as a colour circle, where discrete colour labels (red, blue) are viewed as mixtures of more primary colours, affect can be conceptualised in much the same way. A division of the circle into quadrants produces the following meaningful variants;

(i) unactivated pleasant affect (relaxation, calmness)
(ii) unactivated unpleasant affect (boredom, fatigue)
(iii) activated unpleasant affect (tension, distress)
(iv) activated pleasant affect (excitement, enthusiasm)

Refer to figure 2.1 to view the circumplex model of affect.

In all the studies, repeated measures of affect were sought before, during and following the exercise bout because participants may feel both good and bad a number of times during this period. This is a relatively new approach in the study of the exercise-affect relationship. With this in mind a combination of multi-item and single item dimensional assessment instruments were selected.

In order to obtain repeated measures of on-task exercise related affect, the Feeling Scale (Hardy & Rejeski, 1989) was used as a single item measure of affective valence and the Felt Arousal Scale (Svebak & Murgatroyd, 1985) selected as a single item measure of perceived activation. These scales will assess the unrotated dimensions of the affect circumplex. Single item measures can offer the advantage of being able to be used repeatedly during an experimental trial with only a small risk of respondent overload and inducing reactivity to testing (Ekkekakis & Petruzzello, 2002). Indeed, the wealth of studies that have employed Borg’s single item Rating of Perceived Exertion scale as a measure of effort sense, allows us to
appreciate the potential value of such single item measures. However, there is always the potential for random measurement error when utilising such measures, compared to multi-item measures. In view of this, the Activation-Deactivation Adjective Checklist (Thayer, 1989) was used as a multi-item measure of affect and administered before and following the exercise bout. In line with Ekkekakis et al. (2000b; 2002) and Watson et al. (1999) this questionnaire will be plotted in a circumplex model that has been rotated 45°.

Hardy & Rejeski (1989) have demonstrated the reliability and validity of the Feeling Scale (FS). It is an 11-point single-item bipolar measure of pleasure-displeasure. This scale was developed specifically for use in an exercise setting. The scale ranges from -5 to +5 (Appendix A). Anchors are provided at the 0 point (‘neutral’) and at all odd integers, ranging from ‘very good’ (+5) to ‘very bad’ (-5). Participants were asked to rate how they felt at that particular moment. The instructions were,

“It is quite common to experience changes in mood while participating in exercise. Some individuals find exercise pleasurable, whereas others find it to be unpleasurable. Additionally feelings may fluctuate across time. That is one might feel good and bad a number of times during exercise. Scientists have developed a scale to measure such responses. Select the number that best represents your true feelings using the FS”

The FAS is a 6-point, single-item measure of perceived activation. The scale ranges from 1 to 6, with anchors at 1 (“Low arousal”) and 6 (“High Arousal”) (Appendix B). The FAS has been extensively used in the context of reversal theory research, including exercise related studies (Kerr, 1993). Again, participants were asked to rate how they felt at that particular moment. The instructions were,

“Estimate here how aroused you actually feel. Do this by pointing to the appropriate number. By “arousal” here is meant how “worked-up” you feel. You might experience high arousal in one of a variety of ways, for example as excitement or anxiety or anger. Low arousal might also be
Chapter III

General Methods

experienced by you in one of a number of different ways, for example as relaxation or boredom or calmness”.

The FS and FAS are plotted on the circumplex in an unrotated fashion, along the dimensions of valence and activation.

The AD-ACL is a self-report measure of the bipolar dimensions of Energetic Arousal (EA) and Tense Arousal (TA) (Thayer, 1989). Ten, 4-point, Likert-type items represent each dimension (Appendix C). EA and TA are composed of two 5-item subscales. The EA dimension ranges from energy to tiredness and the TA dimension ranges from tension to calmness. Although not originally designed and validated as a measure of circumplex dimensions, some authors propose that the structure of the AD ACL can be represented as an affective circumplex (Russell & Feldman Barrett, 1999; Yik, 1999). The AD ACL items, EA and TA, are theorised to represent 45° rotational variants of the dimensions of valence and activation of the affect circumplex. The AD ACL can be scored either in terms of the bipolar dimension of EA and TA (represented by 10 items each) or in terms of four unipolar scales: Energy, tiredness, tension and calmness (represented by 5 items each). The energetic arousal scale is used to tap the dimension that extends from high-activation pleasant affect to low-activation unpleasant affect and the tense arousal scale taps the dimensions that extends from high-activation unpleasant to low-activation pleasant affect (Yik, 1999). The AD ACL has been extensively validated and tested for its reliability by Thayer (1986, 1989) and it is theoretically based on an activation model that is relevant in the exercise context. It has been used in several studies examining affective responses to exercise (Ekkekakis, 1999c; Ekkekakis et al., 2000b; Tate, 1995; Thayer, 1987a).

Finally the Rating of Perceived Exertion scale (Borg, 1982) was used as a measure of perceived effort during exercise. The RPE is a 15-point scale, which has been found to be a valid and reliable measure of perceived exertion during exercise (Borg, 1982a). The scale ranges from 6 to 20, with anchors ranging from “very, very light” to “very, very hard” (Appendix D).
3.3 Body mass and height
In all studies nude body mass was determined to the nearest 0.1kg using beam balance scales (Model 3306ABV, Avery Industrial Ltd, UK). Body mass was recorded before exercise, and immediately post-exercise, after sweat had been removed from the skin. Height was evaluated to the nearest 0.1cm using a wall-mounted stadiometre (Holtain Ltd, Crymych, UK).

3.4 Measurement of gas exchange
In all studies the collection of expired air samples was carried out using the Douglas bag method. Expired air was collected through a low resistance respiratory valve and lightweight, wide bore (40mm) tubing (Falconia Ltd) into a 150-litre Douglas bag through a two-way tap (Harvard Equipment). During the intermittent running tests (the LIST, see section 3.11 for full description) expired air was collected using the modified Douglas bag technique. A 200-litre capacity Douglas bag was attached to a rucksack frame by plastic reinforcers for carriage during the protocol, with the total weight of the equipment amounting to 2.4 kg. This method is similar to the one described by de Groot et al. (1983), however in the present study the subject had no control over the opening or closing of the valves for gas collection. One complete cycle of shuttle running exercise was undertaken for the participant to become familiar running with the Douglas bag before the valve was opened to allow gas collection (i.e., on the next walk phase) for the subsequent cycle.

Resting and exercising samples were collected for 5 minutes and 1 minute respectively. Oxygen and carbon dioxide content were analysed using a single unit incorporating both a paragmagnetic oxygen analyser, operating on the basis of the susceptibility of oxygen to a paragmagnetic gas and an infra-red carbon dioxide analyser (Servomax, Model 1440C, Crowborough, Essex). The instruments were calibrated against nitrogen and known gas mixtures (16% O₂ & 4% CO₂) before and between a series of gas analyses. A dry gas meter (Harvard Apparatus Ltd, Edenbridge, Kent) calibrated against a 600-litre Tissot spirometer (Collins Ltd, USA) and a thermometer (Edale Instruments, Model C) was used to measure the volume and temperature of the expired air samples. Barometric pressure was obtained from a barometer (Griffin and George Ltd). Using the Haldane...
transformation formula, all gas volumes were corrected to STPD conditions. Minute oxygen uptake ($\dot{V}O_2$), carbon dioxide expired ($VCO_2$), ventilation rate ($VE$) and RER were calculated. Whole body percentage substrate oxidation rates were calculated using indirect calorimetry (Frayn, 1983).

3.5 Measurement of maximal oxygen uptake on a treadmill

In studies 1, 3 and 7 participants undertook two preliminary tests to determine:

1) The relationship between running speed and oxygen uptake using a 16 min incremental submaximal running test,

2) The maximal oxygen uptake ($\dot{V}O_2_{max}$) using an uphill treadmill running test to exhaustion.

The $\dot{V}O_2_{max}$ of each subject was determined during an uphill treadmill running test (Taylor et al, 1955). The treadmill speed was kept constant throughout the test and the inclination was increased from an initial gradient of 3.5% by 2.5% every 3 min. Expired air samples were collected during the 1:45-2.45min of each 3 min stage. A final expired air sample was taken during the last minute of the test immediately after the participant signalled that the running speed could be maintained for one final minute. Verbal encouragement was given throughout this test. The highest value for oxygen uptake during this test was considered to be the $\dot{V}O_2_{max}$ of the participant. Values for $\dot{V}O_2_{max}$ were verified according to the criteria defined by Howley et al. (1995).

3.6 Familiarisation run

In the running studies (Studies 1, 3 and 7), on a separate occasion at least 3 days before the first main trial, participants completed a 45 min run at the speed corresponding to the experimental requirement to familiarise them with the procedures and measurements to be used during the main trials. During this test, participants followed the drinking pattern to be used during the main exercise trials.
3.7 Treadmill calibration
Prior to each treadmill study, the treadmill was calibrated by measuring both the treadmill belt length and the time required to complete 50 revolutions at various speeds. The speed shown on the treadmill display was validated against the actual calculated speeds of the treadmill.

3.8 Measurement of maximal oxygen uptake on a cycle ergometer
Maximal oxygen uptake in the cycling studies (Studies 2 and 4) was estimated by means of a continuous incremental exercise test on an electro-magnetically braked cycle ergometer (Load Excalibur, Groningen, Netherlands), thus exercise intensity was independent of pedal frequency. The test was carried out in accordance with the British Association of Sport and Exercise Sciences (BASES) guidelines (Hale et al, 1988). Participants began cycling at 95W, with increments of 35W every 3 min. During the 3rd minute of each work rate increment, expired air was collected by the Douglas bag method (see section 3.4 for details). Heart rate was also recorded during this minute (see section 3.12). As with the treadmill studies, the test progressed until participants signalled by raising one finger indicating that they could only continue for one further minute, at this point a further 60-second gas collection took place. Participants were given strong verbal encouragement at this time in order to complete the last minute. From the \( \dot{V}O_2 \) work relationship, the work rate equivalent to the required % \( \dot{V}O_2 \) max was extrapolated. Linear regression was used to calculate the oxygen uptake required to elicit the required % \( \dot{V}O_2 \) max from the \( \dot{V}O_2 \) max data for the isokinetic ergometer. Therefore, the wattage was calculated in order to elicit this and used as the work rate for the isokinetic bike.

3.9 Cycle ergometer familiarisation
Participants completed a one-hour familiarisation trial. This served the purpose of ensuring that each participant would be working at the correct % \( \dot{V}O_2 \) max for the main trial and to verify that participants would be able to sustain the required work load to undertake the protocol in the main trials. It also served to familiarise the participants of the procedures and measures involved in the trials. If
participants were working below or above the required % $\dot{V}O_2$ max, the work rate was adjusted accordingly.

3.10 Measurement of maximal oxygen uptake for the intermittent studies

In studies 5 & 6 maximal oxygen uptake was estimated during a progressive shuttle running test, developed at Loughborough University by Ramsbottom et al. (1988). The test consists of shuttle running between two markers placed 20m apart, at increasing speeds. The pace was controlled by an audio signal from a CD player. Participants were reminded that the test was maximal and progressive and that they should continue to run at the required pace for as long as possible. Participants dropped out of the test or were withdrawn by the investigators when they failed to keep up with three successive bleeps. The level obtained was used to find the participants $\dot{V}O_2$ max from the table of predicted values in the authors manual (Ramsbottom et al., 1988). This value was then used to calculate the shuttle speeds corresponding to 55% and 95% of $\dot{V}O_2$ max for the main experimental trials.

3.11 The Loughborough Intermittent Shuttle Running test (LIST)

The LIST was designed to simulate the activity pattern characteristic of a game of football (Nicholas et al., 2000). The structure of the protocol is depicted below in Figure 3.1. The LIST is performed on a wooden sprung floor, between 20m apart markings. The total exercise time of the LIST is 90 minutes, with a total rest time of 15 minutes. The varying running and walking speeds are dictated by an audio signal by a computer programme developed at Loughborough University. Over the course of the LIST individuals cover a total distance of 12.5km, sprinting approximately 1km, and changing direction 624 times, with an estimated total energy expenditure of approximately 1300kcal.
3.12 Measurement of heart rate

In the continuous running and cycling studies (Studies 1, 2, 3, 4 and 7) heart rate was monitored using short-range telemetry and recorded at 15 second intervals during the expired air collection (Sportester, Polar Electro, Kempele, Finland). In the IHI studies (Studies 5 and 6) the same watches were used, but the data were stored in memory mode. The data were then downloaded using the appropriate computer software (Polar HR analysis software, version 5.04).

3.13 Experimental controls

The following chapters will correct for some of the potential deficits of earlier research in the exercise-affect relationship. Firstly, all of the studies will be controlled for the time of day in which they are completed. Specifically, all the studies will be completed in the morning, with participants arriving in the laboratory between 08:00 and 10:00 am. This control was deemed necessary in order to ensure that the potential confounding effects of time of day on affect were minimised. To date some authors (Hill & Hill, 1991; Thayer, 1987) have reported
an influence, whereas others do not support such assertions (Koltyn, 1998; Trine & Morgan, 1995). Secondly, because all the studies are within-participant designs, they will act as their own controls and as such will complete their experimental trials on the same day each week. Additionally, due to the contradictory findings on potential gender differences (Hansen et al., 2001), only males will be used in the studies that follow.

3.13.1 Nutritional control
Participants reported for each experimental trial following an overnight fast of between 10 and 12 h. This was to ensure that participants began each trial with an empty stomach, thus eliminating any negative effect a previous meal might have, both on exercise metabolism and gastric emptying. For the 48 h prior to the experimental trial, participants refrained from any strenuous physical activity. Participants consumed their normal diet, but weighed and recorded their food eaten in a food diary during this time period before the first trial. This diet was then replicated during the corresponding period prior to any other further trials. In addition caffeine and alcohol were also prohibited during the 48 h prior to the trial because both have been found to have transient effects on affective states (Rogers et al., 1992).

3.14 Ambient temperature, humidity and barometric pressure
Dry and wet bulb temperatures were measured using a whirling hygrometer (Brannan Thermometers Ltd, Cumberland). Humidity was then calculated from these measurements using conversion tables. Barometric pressure was measured using a wall mounted barometer (Fisher Scientific UK, Loughborough, Leicestershire) prior to the onset of the trials.

3.15 Composition of the test drinks
During studies 4 and 5, participants ingested a 6.4% isotonic carbohydrate electrolyte solution, which is a commercially available sports drink (Lucozade Sport, GlaxoSmithKline) and an artificially sweetened placebo (GlaxoSmithKline). In study 7 the same 6.4% CHO-E solution was administered, along with a commercially available “No added sugar concentrated orange drink” diluted 1:4 with tap water; 46mOsmol.kg-1 (Robinsons No Added R). In studies 3
and 6 a 6.5% hypotonic CHO-E solution (GlaxoSmithKline) and an artificially sweetened placebo (GlaxoSmithKline) was administered. The administration of the drinks in each study is described in the relevant chapters. The prescribed volume of fluid was measured using a measuring cylinder and stored in separate plastic drinking bottles, in order to avoid spillage and ensure the correct amount was consumed. Table 3.1 shows the composition of the drinks.

Table 3.1. Composition of the test drinks.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Commercially available Lucozade Sport</th>
<th>Hypotonic CHO-E Solution</th>
<th>GSK Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO content (%)</td>
<td>6.4</td>
<td>6.5</td>
<td>0</td>
</tr>
<tr>
<td>CHO type</td>
<td>Glucose syrup and maltodextrins</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Sodium (mg/100ml)</td>
<td>49.45</td>
<td>50.4</td>
<td>1.97</td>
</tr>
<tr>
<td>Potassium (mg/100ml)</td>
<td>10.28</td>
<td>10.32</td>
<td>11.16</td>
</tr>
<tr>
<td>pH</td>
<td>3.45</td>
<td>3.86</td>
<td>2.86</td>
</tr>
<tr>
<td>Acidity (% w/w CAMH)</td>
<td>0.50</td>
<td>0.44</td>
<td>0.29</td>
</tr>
<tr>
<td>Osmolality (mOsm)</td>
<td>287</td>
<td>115</td>
<td>26</td>
</tr>
</tbody>
</table>

3.16 Blood sampling
In studies 3, 5 and 6 blood samples were taken from a forearm vein using an indwelling cannula (Venfoln, 18G, BOC Ohmeda, Sweden) at pre-determined times (see specific chapters for details). The cannula was inserted under local anaesthetic (1% lignocaine, Antigen Pharmaceuticals Ltd, Ireland) and flushed with non-heparinised saline solution (0.9% Sodium chloride, Steripak Ltd, UK). For the cycling studies (Studies 2 and 4), samples were drawn into a monovette tube (evacuated blood collection tubes, Sarstedt, Leicester, UK) containing lithium heparin (1.5 IU heparin.ml⁻¹ blood). Finger prick capillary blood samples (Study 7) were obtained using a lancet (Autoclix, Roche, Germany) and 20 µl micropipettes.

In the fatigue studies (Studies 3 and 6) 5 ml of blood was allowed to clot for 30 min and then centrifuged at 4000 rev.min⁻¹ for 10 min (4°C) to obtain serum.
Serum was dispensed and stored at -80°C for further analysis. For the cycling studies, (Studies 2 and 4), blood collected into the lithium heparin monovette was centrifuged at 3000 rev.min⁻¹ for 10 min (4°C) to obtain plasma that was immediately stored at -80 °C prior to analysis for cortisol, as outlined below.

3.17 Blood analysis
Analysis of blood samples was conducted in the School of Sport and Exercise Science at Loughborough University.

3.18 Blood glucose and lactate
Blood glucose and lactate concentrations were determined from whole blood (20 µl) deproteinised with 200µl perchloric acid (2.5%). Prior to analysis samples were mixed, centrifuged at 5000 rev.min⁻¹ for 2 min (Eppendorf, 5414C, Germany) and stored at -20°C prior to analysis. Blood glucose concentration was determined by photometric analysis on the 20 µl aliquots of perchloric acid extract using the G.O.D period method (GOD-PAP kit, Randox Laboratories, CO.Antrim, N Ireland) and plasma glucose was determined using the same kit and an automated system (COBAS Mira Plus, Roche Diagnostic Systems, Switzerland). Blood lactate concentration was determined by fluorimetric analysis on 20 µl aliquots of perchloric acid extract using a method adapted by Maughan (1982).

3.19 Serum cortisol
In the prolonged run and LIST to fatigue studies (Studies 3 and 6 respectively) serum was obtained by centrifuging 5 ml of coagulated whole venous blood for 10 min at 4000 rev.min⁻¹ at 4°C. It was then stored at -70°C for subsequent analysis of cortisol using a commercially available radioimmunoassay (Coat-A-Count Cortisol, DPC kit, Caernarfon, UK). Radioactivity was measured using an automated gamma counter (cobra II, Packard Instruments Co.Inc.,USA).

3.20 Plasma cortisol
For the cycling and LIST study (Studies 2, 4 and 5) aliquots of heparinised plasma were analysed to determine the concentration of plasma cortisol using radioimmunoassay (ICN Pharmaceuticals, Costa Mesa, CA).
3.21 Intra-assay variation
Intra-assay coefficient of variation (SD/mean*100) was determined for each assay and is given in table 3.2. Each coefficient of variation was determined using at least 20 samples.

Table 3.2. Intra assay variation.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Intra Assay Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood glucose</td>
<td>mmol.l⁻¹</td>
<td>1.2</td>
</tr>
<tr>
<td>Plasma glucose</td>
<td>mmol.l⁻¹</td>
<td>1.4</td>
</tr>
<tr>
<td>Blood lactate</td>
<td>mmol.l⁻¹</td>
<td>1.6</td>
</tr>
<tr>
<td>Serum Cortisol</td>
<td>µg.dl⁻¹</td>
<td>3.4</td>
</tr>
<tr>
<td>Plasma Cortisol</td>
<td>nmol.l⁻¹</td>
<td>1.8</td>
</tr>
</tbody>
</table>

3.22 Statistical analysis
A two-way analysis of variance for repeated measures on two factors (experimental condition and sampling time) was used to examine the affective, physiological, metabolic and subjective rating data. Two separate analyses were conducted for the affective states data; pre to post analysis and during exercise analysis. Significant main effects were further analysed using paired t-tests, using the Bonferroni adjustment for the number of pairwise comparisons. Greenhouse-Geisser epsilon corrections were used when the sphericity assumption was violated. Statistical significance was set at the 0.05 level, apart from the Bonferroni analyses.

3.23 Plotting of AD ACL subscales in circumplex space
The circumplex is rotated 45° to allow plotting of the AD ACL subscales. In order to calculate the new co-ordinates after the co-ordinate system has been rotated by this angle, the following formula was applied:

\[ x' = x \times 0.707 + y \times 0.707 \]
\[ y' = y \times 0.707 - x \times 0.707 \]
This formula applies when the co-ordinate system has an origin of 0,0. However, the AD ACL has a range from 10 to 40 for EA and TA. So the point where the two dimensions intersect is at 25. Therefore, before the trigonometric formulas are applied, the scores have to be recalibrated relative to the middle of the ranges (25, 25). Therefore, 25 was subtracted from each score.
Chapter IV

Study One

The influence of fluid ingestion during prolonged running on affective states and effort sense

4.1 Introduction

Over the years numerous physiological experiments have been conducted on prolonged exercise and have examined the influence of nutritional interventions, such as fluid ingestion before, during and following exercise. Consequently, the beneficial effects on performance have been extensively reported (Coggan & Coyle, 1991; Hargreaves, 1996). Borg’s (1982) rating of perceived exertion (RPE) scale has been used for decades by researchers undertaking such trials, in order to assess ‘what’ the participants feel during exercise in an attempt to supplement the physiological observations made. Indeed, much information has been gleaned from this single item scale.

Recently, Hardy and Rejeski (1989) have posited that the RPE on its own provides limited information and that a combination of measures during exercise is necessary if we are to obtain a true reflection of the exercise experience. For example, two individuals may rate a given exercise intensity as hard, or 15 on the RPE scale, but despite reporting the same level of exertion, one may feel good and the other bad. In light of such assertions, this study will assess both ‘what’ and ‘how’ the participant feels during a 90 min run on a motorised treadmill. This will serve to facilitate the examination of the influence fluid ingestion exerts on such responses by utilising a variety of self-report measures.

Dehydration is a decrease in total body water, which occurs anytime that fluid intake does not keep up with fluid loss. When an individual does not consume fluid during prolonged exercise to match fluid losses a reduced blood flow to the periphery is observed, thus hindering the major mechanism of heat dissipation
within the body (Montain & Coyle, 1992). Indeed, an elevation in body
temperature places increased stress upon the body and this may be reflected in the
participant’s appraisal of the exercise stimulus, in terms of the pleasure they
obtain from undertaking the work. The influence of fluid ingestion on endurance
capacity has been studied in runners (Fallowfield et al., 1996) and in this case
endurance capacity was extended by 26 minutes when fluid was ingested
compared to the no fluid trial. In studies on prolonged cycling, the influence of
fluid ingestion on perceptions of exertion have proved equivocal and it would
seem that during a fixed duration protocol in a moderate environment, the body is
not placed under enough stress for differences to be observed (McConnell et al.,
1999; Robinson et al., 1995), however further research is required in order for
firm conclusions to be established.

Whilst participants often report ‘feeling good’ during and after exercise (Leith,
1994), this has been limited to exercise of durations in the region of ~30 min.
There is a void in the literature that addresses prolonged exercise, and therefore
we have few empirical studies that detail changes in affective responses during
such exercise durations. Finally, Kerr and Kuk (2001) argue that no attempt is
made to match the exercise mode utilised in the laboratory studies undertaken
with the participants usual mode of exercise, which may result in the experimenter
altering the participants’ affective responses inadvertently (Daley & Maynard,
2003).

Therefore, the present study attempts to examine the influence of fluid ingestion
on affective response and effort sense during a prolonged running protocol, using
participants that regularly undertake running activity. The present study also aims
to address the balance in the exercise-affect relationship by exploring the affective
responses elicited during such a protocol. It was hypothesised that if the
participants’ hydration status is maintained during the prolonged exercise bout,
this could manifest itself in a more pleasant exercise experience.
4.2 Materials and Methods

4.2.1 Participants
Fifteen male university athletes (mean ± SEM: age 21 ± 0.5 yr; body mass 69.5 ± 1.4 kg; \( \overline{\text{VO}_2\text{max}} \) 65.0 ± 1.2 ml.kg\(^{-1}\).min\(^{-1}\)) took part in this study; all were involved in endurance training on a regular basis.

The participants were informed of the demands of the study and the possible risks and discomforts prior to receiving their written consent. The study had the approval of the Ethical Advisory Committee of Loughborough University. Prior to testing, participants were informed that the purpose of the study was to examine the influence of ingesting fluid on the sweating responses and fluid loss during a 90 min run. No mention was made of the potential for positive/negative psychological outcomes following the exercise task.

4.2.2 Measures of affect
The Feeling Scale (FS: (Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: (Svebak & Murgatroyd, 1985) and the Activation-Deactivation Adjective Check List (AD ACL; Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered before exercise, every 20 min during the 90 min run, upon cessation of exercise and 5 min, 15 min and 30 min post exercise. The AD ACL was administered before exercise and 0 min, 5 min, 15 min and 30 min post exercise. These time points were chosen because in general affective states appear to be most positive 10-15 min after completion of exercise (Dyer & Crouch, 1988) when the physiological processes have settled and by sampling at regular intervals following exercise, a more complete picture of affective responses can begin to be developed.

4.2.3 Perception of exertion
The Rating of Perceived Exertion scale (RPE; (Borg, 1982) was used as a measure of perceived effort during exercise, as previously described (Chapter 3).
4.2.4 Preliminary procedures

The participants undertook two preliminary tests to determine: 1) the relationship between running speed and oxygen uptake using a 16 min incremental submaximal running test, 2) their maximal oxygen uptake (\(\bar{VO}_2\) max) using an uphill treadmill running test to fatigue (Taylor, 1955). These procedures have previously been described (Chapter 3).

Before the first experimental trial the participants undertook a 45 min treadmill run at 70% \(\bar{VO}_2\) max to familiarise themselves with the experimental procedures.

4.2.5 Experimental procedures

In a randomised, counter balanced design participants completed two exercise trials; each separated by at least 7 d. On each occasion participants consumed either fluid or no fluid. In the fluid trial participants ingested water immediately before exercise (5ml.kg\(^{-1}\) body mass) and every 20 min during (2ml.kg\(^{-1}\) body mass). In the no fluid trial an ice bucket was provided to allow participants to cool themselves (in order to prevent overheating) during the 90 min exercise period. Participants were asked to refrain from heavy exercise for 2 days prior to each trial and their dietary intake was monitored during the 48 h preceding each trial using a food diary. This was completed prior to the first trial itemising the foods consumed and estimated portion sizes. The participants followed the same diet during the 48 h prior to the second trial. In addition caffeine and alcohol were also prohibited during the 48 h prior to the trial because both have been found to have transient effects on mood (Rogers, Edwards, Green, & Jas, 1992).

Figure 4.1 shows a schematic representation of the 90 min run protocol. On the morning of each trial participants arrived at the laboratory between 08:00h and 09:00h following an overnight fast of 10 hours. All participants were instructed to ingest \(\frac{1}{2}\) pint (approx. 300ml) of water when they woke in the morning prior to each trial, in an attempt to standardise each participant’s hydration status prior to exercise. On arrival participants were asked to rate their responses on the FS, FAS and AD ACL. Nude body mass was measured on a beam balance (Avery, Birmingham, UK). Participants were then given a 5ml.kg\(^{-1}\) body mass bolus of the
Chapter IV Water Ingestion and Prolonged Running

test solution and then the participants completed a 5 min warm up at 60% \( \text{VO}_2 \text{ max} \). Once the warm up was completed, the participants stretched for 5 min. Then following the standardised warm up, the participants returned to the treadmill and the speed was increased to a pace which initially elicited an oxygen consumption equivalent to 70% \( \text{VO}_2 \text{ max} \).

Expired air samples were collected over 60s intervals after 20 min of exercise, and every 20 min thereafter. At the same time, RPE values were obtained and heart rate recorded at 15s intervals using short-range telemetry. The administration of the FS and FAS preceded these measures. Following expired air sampling the participant ingested 2ml.kg\(^{-1}\) body mass of the test fluid delivered in two 100ml syringes.

Upon cessation of exercise, participants immediately responded to the FS and FAS. Participants then had their post exercise body mass recorded before they were taken to a quite area in the laboratory to sit comfortably and the affect measures were assessed as described earlier.

4.2.6 Statistical analysis

Results were analysed as described under statistical analysis (Chapter 3). Values are presented as mean (SEM).
Figure 4.1. Schematic representation of the 90 min run protocol.
4.3 Results

4.3.1 Changes in affective valence and activation

Table 4.1 shows the changes in FS before, during and following the 90 min run. There was a main effect of time ($F_{2, 33} = 4.672, p<.05$) and condition ($F_{1, 14} = 6.782, p<.05$) for valence when pre to post exercise time points were considered. Overall, during the recovery period valence ratings were higher in the fluid trial ($2.98 \pm 0.3$) compared to the no fluid trial ($1.87 \pm 0.5$). As Figure 4.3 illustrates, in the fluid trial valence ratings were in line with pre exercise values upon completion of the run and continued to rise during the recovery period. In the no fluid trial, valence ratings fell below pre exercise levels upon completion of the run, but returned back to baseline levels following the recovery period.

Table 4.1. Descriptive statistics (Means ± SEM) of the FS and FAS before, during and following the 90 min run.

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th></th>
<th>FAS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fluid (M ± SEM)</td>
<td>No Fluid (M ± SEM)</td>
<td>Fluid (M ± SEM)</td>
<td>No Fluid (M ± SEM)</td>
</tr>
<tr>
<td>Pre</td>
<td>1.7 ± 0.3</td>
<td>1.7 ± 0.3</td>
<td>2.2 ± 0.2</td>
<td>2.6 ± 0.2</td>
</tr>
<tr>
<td>17 min</td>
<td>2.3 ± 0.3</td>
<td>2.0 ± 0.5</td>
<td>3.1 ± 0.2</td>
<td>3.3 ± 0.2</td>
</tr>
<tr>
<td>37 min</td>
<td>2.1 ± 0.4</td>
<td>2.4 ± 0.4</td>
<td>3.5 ± 0.2</td>
<td>3.5 ± 0.3</td>
</tr>
<tr>
<td>57 min</td>
<td>2.7 ± 0.4</td>
<td>1.9 ± 0.4</td>
<td>3.5 ± 0.3</td>
<td>3.6 ± 0.2</td>
</tr>
<tr>
<td>77 min</td>
<td>2.2 ± 0.5</td>
<td>1.5 ± 0.6</td>
<td>3.8 ± 0.3</td>
<td>3.6 ± 0.3</td>
</tr>
<tr>
<td>Post 0</td>
<td>2.5 ± 0.5</td>
<td>1.1 ± 0.6</td>
<td>3.5 ± 0.3</td>
<td>3.1 ± 0.3</td>
</tr>
<tr>
<td>Post 5</td>
<td>3.0 ± 0.3</td>
<td>1.8 ± 0.5</td>
<td>3.2 ± 0.3</td>
<td>2.7 ± 0.2</td>
</tr>
<tr>
<td>Post 15</td>
<td>3.1 ± 0.3</td>
<td>2.1 ± 0.4</td>
<td>2.8 ± 0.3</td>
<td>2.3 ± 0.3</td>
</tr>
<tr>
<td>Post 30</td>
<td>3.3 ± 0.2</td>
<td>2.4 ± 0.5</td>
<td>2.7 ± 0.3</td>
<td>2.4 ± 0.3</td>
</tr>
</tbody>
</table>

Analysis on the FAS pre to post exercise showed a main effect of time ($F_{4, 56} = 4.483, p<.05$) and an interaction of condition x time ($F_{3, 35} = 3.260, p<.05$). Activation increased from pre to post exercise and post hoc analysis revealed that this increase was only observed in the fluid trial. Specifically activation remained elevated in the fluid trial until 15 min after the exercise was completed and
activation was higher in the fluid trial (2.8 ± 0.3) 15 min post exercise, compared to the no fluid trial (2.3 ± 0.25); (p<.05).

Figure 4.2. Changes in affective valence (FS) and activation (FAS) before, during and after the 90 min run plotted in circumplex space.

Figure 4.3. Changes in affective valence (FS) before, during and following the 90 min run.
4.3.2 Changes in energetic and tense arousal

Table 4.2 shows the changes in EA, TA and the subscales before and following the 90 min run. The Cronbach alpha coefficient for the EA scale was 0.86 and for the TA scale 0.77 indicating satisfactory internal consistency. The alpha coefficients of the energy, tiredness, tension and calmness subscales were 0.71, 0.86, 0.92, 0.74 respectively.

Analysis on the AD ACL subscales revealed that the only significant pre to post exercise change was limited to the energy subscale. Indeed there was an interaction of condition x time ($F_{2,26} = 4.244, p<.05$) and energy was higher 5 min ($p<.05$) and 15 min ($p<.05$) post exercise in the fluid trial compared to the no fluid trial.

Table 4.2. Descriptive statistics (Means ± SEM) of the AD ACL items and subscales before and following the 90 min run.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>23.5 ± 1.5</td>
<td>17.9 ± 1.2</td>
<td>10.1 ± 0.6</td>
<td>11.6 ± 1.0</td>
<td>6.4 ± 0.7</td>
<td>13.5 ± 0.6</td>
</tr>
<tr>
<td>Post 5</td>
<td>29.7 ± 1.5</td>
<td>19.6 ± 1.0</td>
<td>13.1 ± 0.1</td>
<td>8.4 ± 0.8</td>
<td>6.2 ± 0.4</td>
<td>11.6 ± 1.1</td>
</tr>
<tr>
<td>Post 15</td>
<td>27.2 ± 1.7</td>
<td>18.3 ± 0.9</td>
<td>11.6 ± 0.9</td>
<td>9.4 ± 1.1</td>
<td>6.3 ± 0.4</td>
<td>13.0 ± 0.8</td>
</tr>
<tr>
<td>Post 30</td>
<td>27.3 ± 1.8</td>
<td>17.3 ± 0.8</td>
<td>10.9 ± 1.0</td>
<td>8.7 ± 1.1</td>
<td>5.9 ± 0.4</td>
<td>13.6 ± 0.7</td>
</tr>
<tr>
<td>No Fluid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>25.2 ± 0.5</td>
<td>19.7 ± 1.0</td>
<td>11.5 ± 0.7</td>
<td>11.3 ± 0.9</td>
<td>6.3 ± 0.7</td>
<td>11.6 ± 0.7</td>
</tr>
<tr>
<td>Post 5</td>
<td>25.3 ± 1.8</td>
<td>21.4 ± 1.3</td>
<td>10.5 ± 1.2</td>
<td>10.2 ± 1.2</td>
<td>7.2 ± 0.6</td>
<td>10.8 ± 1.2</td>
</tr>
<tr>
<td>Post 15</td>
<td>24.7 ± 1.4</td>
<td>17.4 ± 1.0</td>
<td>9.9 ± 1.0</td>
<td>10.1 ± 1.1</td>
<td>6.3 ± 0.5</td>
<td>13.9 ± 0.9</td>
</tr>
<tr>
<td>Post 30</td>
<td>24.7 ± 1.7</td>
<td>18.1 ± 0.8</td>
<td>9.9 ± 1.0</td>
<td>10.2 ± 1.3</td>
<td>6.3 ± 0.4</td>
<td>13.2 ± 0.8</td>
</tr>
</tbody>
</table>
4.3.3 Individual responses

Change scores were compared for the FS and FAS from the 17th minute (i.e. the first during exercise assessment) to the 77th minute of exercise (when all participants are still exercising), from the 17th minute to the 37th minute of exercise (the mid-point of exercise) and from pre exercise to post 0'. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response with each category are shown in Table 4.3.

The results indicate that the only pattern of homogeneity in the individual change trends was for the FAS from pre to immediately post exercise in the fluid trial, when 87% reported an increase in activation (Table 4.3). For the remaining time
Chapter IV Water Ingestion and Prolonged Running

points a varied response pattern for the FS and FAS was found. Specifically for the FS, from the 17th minute to the 37th minute, in the fluid trial, 60% reported no change in valence, 20% an increase and 20% a decrease. Similar values were observed for the no fluid trial. Indeed, differences were highlighted between conditions between 17th and 77th minute of exercise when the changes were tabulated because 53% of participants in the no fluid trial reported a reduction in valence, in contrast to 13% in the fluid trial. The lack of homogeneity in individual responses is also evident in Figure 4.3. Further, in graph a) of Figure 4.5, which depicts the fluid trial it can be seen that the majority of the lines display a positive directional change, whereas in graph b) which illustrates the no fluid trial, the opposite is true.

Across both conditions, the responses to the FAS were similar between trials, but responses varied within these conditions. For example, from the 17th minute to the 37th minute of exercise, 40% of participants in both trials reported an increase in valence, and 60% in the fluid trial and 53% in the no fluid trial reported no change, and the only decrease was seen in the no fluid trial.

![Graph of individual responses to the FS](image)

**Figure 4.5.** Individual responses to the FS represented graphically. a). Fluid trial, b). No fluid trial.
Table 4.3. Frequency and magnitude of individual affective responses to the 90 min run.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Fluid</th>
<th>No fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling Scale (17th minute-37th minute)</td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Increase</td>
<td>3 (20%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>9 (60%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>3 (20%)</td>
<td>1</td>
</tr>
<tr>
<td>(17th minute-77th minute)</td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Increase</td>
<td>9 (60%)</td>
<td>2-3</td>
</tr>
<tr>
<td>No change</td>
<td>4 (27%)</td>
<td>0</td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (13%)</td>
<td>2-4</td>
</tr>
<tr>
<td>(Pre to post 0)</td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Increase</td>
<td>9 (60%)</td>
<td>2-3</td>
</tr>
<tr>
<td>No change</td>
<td>4 (27%)</td>
<td>3 (20%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (13%)</td>
<td>2-4</td>
</tr>
<tr>
<td>Felt Arousal Scale (17th minute-37th minute)</td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Increase</td>
<td>6 (40%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>9 (60%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (7%)</td>
<td>1</td>
</tr>
<tr>
<td>(17th minute-77th minute)</td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Increase</td>
<td>7 (47%)</td>
<td>1-3</td>
</tr>
<tr>
<td>No change</td>
<td>7 (47%)</td>
<td>7 (47%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (7%)</td>
<td>2 (13%)</td>
</tr>
<tr>
<td>(Pre to post 0)</td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Increase</td>
<td>13 (86%)</td>
<td>1-3</td>
</tr>
<tr>
<td>No change</td>
<td>1 (7%)</td>
<td>4 (27%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (7%)</td>
<td>4 (27%)</td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).
4.3.4 Rating of perceived exertion
There was a main effect for time (F (2, 24) = 18.680; p<.001) for the RPE scores. Across both conditions, RPE increased as the run progressed (Figure 4.6).

![Figure 4.6 Rating of perceived exertion during the 90 min run.](image)

4.3.5 Correlations between the FS and RPE scale
Table 4.4 displays the correlations between the FS and the RPE scale at the various time points sampled during the 90 min run. Significant correlations were noted at 20 min and 80 min only.

<table>
<thead>
<tr>
<th>Time</th>
<th>Fluid Trial</th>
<th>No Fluid Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 min</td>
<td>-.66**</td>
<td>-.53*</td>
</tr>
<tr>
<td>40 min</td>
<td>-.46 (ns)</td>
<td>-.44 (ns)</td>
</tr>
<tr>
<td>60 min</td>
<td>-.41 (ns)</td>
<td>-.40 (ns)</td>
</tr>
<tr>
<td>80 min</td>
<td>-.54*</td>
<td>-.65 **</td>
</tr>
</tbody>
</table>

** Correlation is significant at the p<.01 level; * Correlation is significant at the p<.05 level.
4.3.6 Physiological responses to the exercise protocol
Oxygen uptake, heart rate and %VO₂ max did not differ between trials demonstrating that participants were exercising at the same relative exercise intensity in both conditions. Heart rate during exercise ranged from approximately 155-162 beats.min⁻¹.

4.3.7 Environmental conditions
There was no difference between trials in the dry and wet bulb temperature and relative humidity during the study. The laboratory temperature across both trials averaged 19.7 ± 0.3°C, with a relative humidity of 47.4 ± 1.7%. All participants consumed the prescribed volume of fluids. After correcting for fluid intake, body mass decreased by −1.9 ± 0.08 kg in the fluid trial and by −1.9 ± 0.08 kg in the no fluid trial, equivalent to reductions in body mass of 1.4 ± 0.1% and 2.7 ± 0.1% respectively (p<0.01). Thirst ratings were obtained during exercise at 40 min and 70 min and analysis revealed that ratings were higher (F(1, 4) = 99.024; p<.001) in the no fluid trial compared to the fluid trial.

4.3.8 Diet
A nutrient analysis of the 2-day food records prior to each of the two exercise sessions revealed no differences in the energy intake and nutrient composition between conditions. The mean energy intake of the participants was 2674 kcal/day, with the proportion of energy being 59% from CHO, 25% from fat and 16% from protein.
4.4 Discussion

The purpose of this study was to investigate the influence of ingesting fluid during a prolonged 90 min treadmill run on affective states and effort sense. Research on prolonged exercise and nutritional interventions has been limited to investigating such interventional effects on physiological and metabolic parameters, and the few studies that have examined changes in affect that occur as a result of engaging in prolonged exercise (Acevedo et al., 1996) have ignored the influence nutrition may impose. A large body of evidence exists that suggests fluid ingestion during prolonged exercise attenuates dehydration (Hamilton et al., 1991; Montain & Coyle, 1992). Consequently such prevention could exert a beneficial influence on the affective responses during exercise.

This study sought to obtain repeated in-task assessments of affect, facilitated by the administration of single-item scales. Such a methodology has not been readily adopted in the exercise psychology literature (Ekkekakis & Petruzzello, 1999a; Hall, 2002). To date the prime focus has been on the pre to post exercise changes. Subsequently affect, was plotted onto a two-dimensional Circumplex model, with the aim of recognising any salient changes occurring during and following the 90 min run. Consistent with the work of Ekkekakis and Petruzzello (1999a), a diversity of patterns and responses emerged as the exercise bout continued. As Figure 4.2 illustrates, participants did not remain in one quadrant during the experimental protocol, but in fact shifted between two of the circumplex quadrants. Prior to exercise, a deactivated pleasant state was reported, and immediately following the cessation of exercise, participants had reached an activated pleasant state. Indeed, this was also evidenced from the data obtained from the multi-item AD ACL questionnaire (Figure 4.4), however, as a consequence of only pre to post exercise assessment this was to a lesser extent.

Fluid ingestion had little effect on ratings of perceived exertion, however it did influence a number of the affective measures. An overall main effect of condition was observed for the FS, with valence ratings being higher during the recovery period in the fluid trial compared to the no fluid trial. A time effect was also noted for the FS, and as Figure 4.3 illustrates, the temporal patterning of change from
pre to post exercise differs between the two trials. The beneficial effects of ingesting fluid during prolonged exercise was further evidenced by the fact that 5 min and 15 min post exercise self reported energy, as assessed by the AD ACL (Thayer, 1989) was higher following that trial compared to the no fluid trial. Energy increased from pre exercise to 5 min and 15 min post exercise in the fluid trial, and was higher than self reported energy in the no fluid trial at these time points. In addition, activation, as assessed by the FAS, was only seen to increase in the fluid trial from pre to post exercise and activation remained elevated in the fluid trial until 15 min after the exercise was completed. Further, activation was higher in the fluid trial at this time point. Rogers, Kainth and Smit (2001) reported that consumption of water during an experiment conducted at rest investigating mental performance, led to an immediate, but not sustained ‘alerting’ and ‘revitalising’ effect on participants, irrespective of their initial level of thirst. To my knowledge, the present study is the first to show that fluid ingestion enhances affective responses following a prolonged exercise bout. This is an interesting finding when one considers that the participants indicated that they perceived themselves to be working at an average intensity of 12 (moderate) across both conditions. So even though they did not perceive the exercise to be less effortful in the fluid trial, they reported enhanced activation and energy post exercise, as well as an overall enhancement of valence during the recovery period. Thus supporting the assertions of Hardy and Rejeski (1989), that ‘how’ and ‘what’ one feels may differ.

Although there was a significant increase across time in ratings of perceived exertion, no significant differences emerged between conditions. Such findings are consistent with previous research by Dengel et al. (1993) who observed that even hypohydration of up to 5.6% body weight following fluid restriction and exercise, did not alter RPE during submaximal cycling. Indeed, several of its important correlates, including $V_E$, blood lactate and heart rate were unchanged by hypohydration. This present study supports such findings because cardiovascular function was not altered in this study either. Such maintenance of function could be attributed to the experimental protocol not reducing blood volume to the point at which stroke volume was compromised and heart rate increased. In contrast Riebe and colleagues (1997) observed that RPE responses were lower in the re-
hydration trial than in the no fluid trial. In the present study it could be argued that the body was not placed under enough stress for differences to be observed (McConell et al., 1999; Robinson et al., 1995).

The findings of the correlational analysis between the FS and the RPE scale revealed a moderate relationship during the first and last during exercise assessment (Table 4.4). The correlations were not significant at 40 and 60 min. The findings confirm the conclusions of Hardy and Rejeski (1989) in that the data indicates "although the RPE and the FS do share some commonality, they are not isomorphic constructs. That is, from a phenomenological perspective, there is a difference between what one feels and how one feels at varying intensities of work" (p.310). Further research should utilise both measures to fully understand the exercise effect.

Subjective thirst ratings were significantly higher during the no fluid trial compared to the fluid trial. It is therefore possible that feelings of thirst are associated with a negative affective state. The fact that the athletes thirst mechanism appeared to be more switched on during the no fluid trial, suggests that the water deficit is acting as a potential cue in eliciting a more negative affective profile. Furthermore, the sensation of thirst may have served to inhibit the sensation of energy and the increase in activation from pre to post exercise, which was noted in the fluid trial only. One could argue that there were no differences in oxygen uptake or heart rate between the trials and indeed, RPE did not differ between conditions, and therefore the subjective thirst responses should be interpreted cautiously. However, according to Engell and colleagues (1987) the subjective sensation of thirst accompanies fluid deficits greater than 1% of body-weight and there is a linear relationship between hypo-hydration levels and thirst sensations. In the no fluid trial, participants were found to have a reduction in body mass of $2.7 \pm 0.1\%$ compared to $1.4 \pm 0.1\% (p<0.01)$ in the fluid trial. Such a deficit supports the participants increased sensation of thirst in the no fluid trial and this may have led to the gradual decrease in affective valence which reached its lowest level immediately post exercise when dehydration would have been at its greatest. Rogers et al. (2001) also suggest that functionally, perceived thirst is a
good measure of hydration status and that the ability of physiological measures to
detect subtle differences in hydration status is questionable (Shirreffs, 2000).

One must consider that a Hawthorne effect could be in operation in this study
because it is quite possible that the participants may perceive that they are
receiving a beneficial treatment by ingesting fluid during the trial, and this in turn
could influence the affective responses reported. The enhancement of affective
states following fluid ingestion might simply reflect an improvement resulting
from special attention afforded by the intervention versus no intervention in the no
fluid trial. The participants used in this study were all keen endurance runners or
triathletes and it could be argued that as such are likely to have an awareness of
the importance of fluid ingestion during exercise. However, even if they were
aware of the benefits of fluid ingestion during exercise, an enhanced affective
profile resulted, which in itself is important in terms of performance, motivation
and task persistence. In order to minimise the Hawthorne effect, participants were
told that the purpose of the experiment was physiological in nature. Indeed, mere
expectations about the exercise and treatment may have produced the rating
change, even without any conscious awareness on the part of the individuals.
However, one could counter this argument through the lack of difference observed
in the ratings of perceived exertion, which surely would also be subject to the
same expectancies and bias. Furthermore, all participants were explicitly advised
to be completely honest with all their ratings, and that there were no right or
wrong responses. Also, in my opinion, it seemed that the rating task became quite
automatic and the participants appeared to give little consideration to anything
except the immediate ratings.

Previously, research has focused on the nomothetic approach in the study of the
exercise-affect relationship, however, this assumes that all individuals respond to
the same exercise stimulus in a uniform manner, for example that exercise of a
moderate intensity will produce positive affective responses in all or most
individuals. In contrast, this study supports a recent study by Van Landuyt and
colleagues (2000) who observed that 44% reported a progressive improvement in
valence, whereas 41% reported a progressive decline. This divergent trend when
presented as the traditional group mean response, leads one to believe that the
participants' responses remain unchanged during exercise. In the present study the only homogeneous trend was observed in the fluid trial, where 86% of participants reported an increase in activation from pre to post exercise. However, for the remaining time points, a variety of responses were reported, specifically, in the fluid trial from the 17 min to the 37 min of exercise 60% reported no change in valence, 20% an increase and 20% a decrease. Such inter-individual variability poses a challenge in terms of explanation, and this study has not made the picture any clearer. In fact, the relevant literature on this phenomenon remains limited. However, a number of variables, primarily from social-cognitive theories, have been shown to be related to affective responses to moderate exercise. These variables include attributions and goal orientations. Self-efficacy has been studied most extensively and has been shown to be consistently associated with affective responses in a variety of samples is (e.g., (McAuley & Courneya, 1992; McAuley, Talbot, & Martinez, 1999). However, even the studies that have studied self-efficacy have produced conflicting findings, particularly regarding the intensity of exercise when self-efficacy exerts its greatest influence on affective responses. This, as in much of the research on affective responses, can be attributed to differences in the measurement approach and also the physical fitness and demographics of the participants. To examine the relationship between self-efficacy and affective valence across a greater range of intensities, Ekkekakis, Hall, and Petruzzello (1999) used an exercise protocol in which the speed and grade of a treadmill were increased every minute, from a slow jog to the point of volitional exhaustion. The results showed significant positive correlations between self-efficacy and affective valence near the middle of the range of the test, but not in the early stages or at the point of volitional exhaustion. Supporting the hypothesis that the relationship should be stronger at moderate levels of intensity. Further, individual differences are likely to play a role, but there is a void in the literature in addressing this relationship. Ekkekakis et al. (2001c), in a series of studies on the role of exercise-specific sensory modulation, found that preference for and tolerance of exercise intensity accounted for approximately 25% and 20%, respectively, of the variance in valence during moderate exercise. In order to prevent the possible influence of environmental factors on the affective responses elicited, the experimental environment was well controlled. For example, the music, which the participants were allowed to listen to, was kept constant across
trials, as it has been found to influence affective responses (Boutcher & Trenske, 1990). Further, social influences were minimized as far as possible because the investigators were the only contact the participants had during the experiment.

In conclusion, it can be inferred that fluid ingestion should be considered as an important facet in the exercise-affect relationship. This study adds to the abundance of literature available to athletes on the performance benefits of fluid ingestion because there also appears to be psychological benefits of ingesting fluid during exercise. Furthermore, there is a case for this element to be considered in studies investigating the influence of exercise on sedentary participants because the influence nutrition exerts on such responses has not previously been highlighted. The mechanisms underlying the improved affective responses following fluid ingestion are unclear, and therefore further studies are required in order to explore the relationship between nutritional interventions and affective responses.
Chapter V

Study Two

The influence of fluid ingestion during prolonged cycling on affective responses and effort sense

5.1 Introduction

Athletes are constantly reminded that hypohydration impairs both physical and mental performance, however, it can be avoided by appropriate drinking strategies during exercise. Hypohydration by as little as 2% of body weight has been reported to compromise exercise performance (Armstrong et al., 1985; Buskirk et al., 1958), and increase the participants perception of effort (Armstrong et al., 1985). There have been numerous studies investigating the effects of hypohydration on physiological functions (Dengel et al., 1992; Sawka et al., 1985) and considering these findings and as highlighted in the preceding chapter, there have been few studies investigating the influence of maintaining fluid balance on affective states during prolonged exercise. In the previous study on prolonged running (Chapter 4) and in studies by Robinson (1995) and McConell (1999) on cycling, there was no benefit on ratings of perceived exertion when fluid was ingested in a moderate environment for a fixed duration. However, in the previous study (Chapter 4), although it supported the conclusion of Robinson and McConell in respect to the RPE responses, the trial in which fluid was prescribed resulted in enhanced affective valence and self-reported feelings of energy compared to the no fluid trial.

Therefore, the purpose of this study was to extend previous research undertaken on running exercise by examining the effects of fluid ingestion on affective responses and ratings of perceived exertion during 120 min of cycling.
5.2 Materials and Methods

5.2.1 Participants
Nine recreationally active males (mean ± SEM; age 21 ± 0.2 yr; height 179 ± 2 cm; body mass 73.2 ± 1.6 kg; \( \dot{V}O_2 \) max, 55.2 ± 1.8 ml.kg\(^{-1}\).min\(^{-1}\)) volunteered to participate in this study. All participants were fully informed of the nature and purpose of the study before signing a statement of informed consent. All participants were experienced at exercising for a total of one to three hours. The study had the approval of the Ethical Advisory Committee of Loughborough University.

5.2.2 Measures of affect
The Feeling Scale (FS; Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: Svebak & Murgatroyd, 1985) and AD ACL (Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered before exercise, every 15 min throughout the prolonged cycle, upon cessation of exercise and 5 min, 15 min, 30 min and 60 min post exercise. The AD ACL was administered before exercise and then at post 5 min, 15 min, 30 min and 60 min post exercise.

5.2.3 Perceived exertion
The rating of perceived exertion scale (RPE; (Borg, 1982) was used as a measure of perceived exertion during exercise, as previously described (Chapter 3).

5.2.4 Preliminary procedures
Maximal oxygen uptake was estimated by means of a continuous incremental exercise test on an electrically braked cycle ergometer (Load, Excalibur, Groningen, The Nederlands) to volitional fatigue. This procedure has previously been described in Chapter 3. From the \( \dot{V}O_2 \) work relationship, the work rate equivalent to 65% \( \dot{V}O_2 \) max was interpolated.
5.2.5 Familiarisation
Participants completed a one-hour familiarisation trial as previously described (Chapter 3).

5.2.6 Experimental procedures
In a randomised, counter balanced design participants completed two exercise trials; each separated by at least 7 d. On each occasion participants consumed either fluid or no fluid. In the fluid trial participants ingested water immediately before exercise (5ml.kg⁻¹ bodymass), every 15 min during (2ml.kg⁻¹ bodymass) and 5 min post exercise (5ml.kg⁻¹ bodymass). In the no fluid trial an ice bucket was provided to allow participants to cool themselves (in order to prevent overheating) during the 120 min exercise period.

The schematic representation of the protocol is shown in Figure 5.1. Participants arrived at the laboratory between 8.15-8.30am following an overnight fast of between 10 and 12 hours. All participants were instructed to ingest ½ pint (approx 300ml) of water when they woke up in the morning prior to each trial, in an attempt to standardise each participant’s hydration status prior to the exercise bouts. Participants responded to the FS and FAS and completed the AD ACL. They were then asked to empty their bladder and then have their nude body mass measured. Participants then rested quietly for 15 minutes before an initial blood sample was obtained from an antecubital vein by venopuncture. In the fluid-ingestion trial, following the pre-exercise blood sample, participants consumed 5ml.kg body mass of water.

Participants then performed a 120 min cycle ergometer ride on an electronically braked ergometer (Lode Excalibur) at 65% VO₂ max. The FS and FAS scales were administered at intervals of 15 min, the first set being administered during the 14th min of the test. Expired air samples were obtained using the standard Douglas bag method as previously described (Chapter 3) at min 20 and 80 during the exercise period to verify that the relative exercise intensity was 65% of the participants maximal oxygen uptake. Heart rates were recorded every 15 min during exercise
as previously described (Chapter 3). RPE and thirst ratings were also obtained at 15 min intervals throughout the cycle (Chapter 3).

Upon cessation of the exercise task, participants immediately responded to the FS and FAS. Participants once again responded to these measures along with the AD ACL at 5 min, 15 min, 30 min and 60 min post exercise. Following the 120 min exercise period, a post exercise blood sample was obtained and then participants were required to consume 5ml.kg⁻¹ body mass of fluid, after which nude body mass was recorded. The post exercise mass was corrected for the fluid that had been consumed throughout the exercise period, thus enabling changes in body mass occurring as a result of the experimental conditions to be calculated. A further blood sample was taken at 1 h post exercise. No food was consumed during this period.

5.2.7 Blood analyses
Blood samples were collected into vacutainer (Becton Dickinson, Oxford, UK) and monovette (Sarstedt, Leicester, UK) tubes. For further details of blood storage and analysis, refer to chapter 3.

5.2.8 Statistical analysis
Results were analysed as described under statistical analysis (Chapter 3). Values are presented as mean (SEM).
**Figure 5.1.** Schematic representation of the 2 h cycling protocol.
5.3 Results

5.3.1 Affective responses to the exercise protocol

Table 5.1 reports the descriptive statistics of the FS before, during and following exercise. Analysis on the FS from pre to post exercise revealed an overall main effect for time (F (5, 40) = 3.684; p<.05). Post hoc analysis revealed this change to be limited to the post exercise time points. There was no interaction of condition x time, therefore, averaged across conditions, a rebound effect was observed from immediately post exercise to 5, 15, 30 and 60 min post (0.94 ± 0.7 (P0) vs 1.72 ± 0.5 (P5); 2.28 ± 0.4 (P15); 2.22 ± 0.4 (P30); 2.44 ± 0.4 (P60); Figure 5.3). During exercise, a main effect for time (F (7, 56) = 7.894; p<.01) was found with valence decreasing with the duration of the cycle. Although not statistically significant, there was a trend for valence to be better maintained during the fluid trial compared to the no fluid trial (0.33 ± 0.6 vs 2.0 ± 0.4, Fig. 5.3).

Table 5.1. Descriptive statistics (mean ± SEM) of FS and FAS before, during and following the 120 min cycle.

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th>FAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fluid</td>
<td>No Fluid</td>
</tr>
<tr>
<td></td>
<td>(M ± SEM)</td>
<td>(M ± SEM)</td>
</tr>
<tr>
<td>Pre</td>
<td>2.1 ± 0.5</td>
<td>1.6 ± 0.5</td>
</tr>
<tr>
<td>14 min</td>
<td>1.7 ± 0.5</td>
<td>1.6 ± 0.5</td>
</tr>
<tr>
<td>29 min</td>
<td>1.3 ± 0.3</td>
<td>1.2 ± 0.3</td>
</tr>
<tr>
<td>44 min</td>
<td>1.7 ± 0.3</td>
<td>0.9 ± 0.3</td>
</tr>
<tr>
<td>59 min</td>
<td>1.6 ± 0.4</td>
<td>0.6 ± 0.4</td>
</tr>
<tr>
<td>74 min</td>
<td>1.6 ± 0.5</td>
<td>0.4 ± 0.5</td>
</tr>
<tr>
<td>89 min</td>
<td>1.1 ± 0.5</td>
<td>0.2 ± 0.5</td>
</tr>
<tr>
<td>104 min</td>
<td>0.6 ± 0.6</td>
<td>-0.1 ± 0.6</td>
</tr>
<tr>
<td>119 min</td>
<td>-0.1 ± 0.5</td>
<td>-0.8 ± 0.5</td>
</tr>
<tr>
<td>Post-0</td>
<td>1.6 ± 0.6</td>
<td>0.3 ± 0.6</td>
</tr>
<tr>
<td>Post-5</td>
<td>2.1 ± 0.5</td>
<td>1.3 ± 0.5</td>
</tr>
<tr>
<td>Post-15</td>
<td>2.6 ± 0.4</td>
<td>2.0 ± 0.4</td>
</tr>
<tr>
<td>Post-30</td>
<td>2.3 ± 0.5</td>
<td>2.1 ± 0.5</td>
</tr>
<tr>
<td>Post-60</td>
<td>2.4 ± 0.4</td>
<td>2.4 ± 0.4</td>
</tr>
</tbody>
</table>
Figure 5.2. Changes in affective valence (FS) and activation (FAS) before, during and following the 120 min cycle, plotted in circumplex space.

Figure 5.3. Changes in the FS before, during and following the 120 min cycle.
Affective valence displayed a temporal pattern characteristic of a rebound pattern (Figure 5.4) from the final during exercise assessment and immediately post exercise assessment, to all time points post exercise.

![Graphical representation of a rebound model](image)

Figure 5.4. Graphical representation of a rebound model (Bixby, Spalding, & Hatfield, 2001).

Activation as assessed by the FAS increased from pre exercise to immediately post exercise across both trials (Fluid: 2.22 ± 0.5 vs 3.22 ± 0.6, NF; 2.0 ± 0.2 vs 3.7 ± 0.6, F (7, 56) = 7.894; p<.01). During exercise, a main effect for time (F (7, 56) = 2.593; p<.05) was observed with activation increasing as the exercise progressed across both trials.

### 5.3.2 Changes in energetic and tense arousal

Table 5.2 illustrates the changes in EA, TA and the subscales before and following 2 h cycling. The Cronbach alpha coefficient for the EA scale was 0.76 and for the TA scale 0.68 indicating satisfactory internal consistency. The alpha coefficients of the energy, tiredness, tension and calmness subscales were 0.81, 0.43, 0.81, 0.71 respectively. Analysis on the EA subscale revealed a treatment (F (1, 8) = 5.852; p<.05) and interaction (F (4, 32) = 2.706; p<.05) effect. EA was lower 5 min post exercise following the NF trial compared to the F trial (22.7 ± 1.9 vs 17.0 ± 1.9, F vs NF, p<.05) (Figure 5.5). A main effect of time was found for energy (F (3, 29) = 3.969; p<.05). Subjective energy was reduced following the 90 min cycle compared to the pre exercise time point across both conditions.
Similarly a treatment ($F(1, 8) = 6.160; p<.05$) and interaction ($F(4, 32) = 2.703; p<.05$) effect were also observed for the other component of EA, that of tiredness. Post hoc analysis revealed that tiredness was higher in the NF trial 5 min post exercise, compared to the F trial ($11.56 \pm 1.1$ vs $14.8 \pm 1.3$, F vs NF, $p<.05$).

Table 5.2. Descriptive statistics (mean ± SEM) of the AD ACL items and subscales before and following the 120 min cycle.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fluid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>25.3 ± 2.3</td>
<td>17.3 ± 1.0</td>
<td>12.1 ± 1.3</td>
<td>11.8 ± 1.0</td>
<td>6.4 ± 0.5</td>
<td>14.1 ± 0.8</td>
</tr>
<tr>
<td>Post 5</td>
<td>22.7 ± 1.9</td>
<td>18.1 ± 0.8</td>
<td>9.2 ± 1.0</td>
<td>11.6 ± 1.1</td>
<td>6.2 ± 0.3</td>
<td>13.1 ± 0.9</td>
</tr>
<tr>
<td>Post 15</td>
<td>22.8 ± 1.4</td>
<td>17.0 ± 0.8</td>
<td>8.8 ± 1.0</td>
<td>11.0 ± 0.7</td>
<td>6.1 ± 0.4</td>
<td>14.1 ± 0.7</td>
</tr>
<tr>
<td>Post 30</td>
<td>24.3 ± 1.8</td>
<td>15.7 ± 0.7</td>
<td>9.3 ± 1.2</td>
<td>10.0 ± 0.7</td>
<td>5.4 ± 0.2</td>
<td>14.7 ± 0.7</td>
</tr>
<tr>
<td>Post 60</td>
<td>23.3 ± 1.8</td>
<td>16.2 ± 0.8</td>
<td>8.6 ± 1.0</td>
<td>10.2 ± 0.9</td>
<td>5.3 ± 0.2</td>
<td>14.1 ± 0.7</td>
</tr>
<tr>
<td><strong>No Fluid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>26.3 ± 2.3</td>
<td>19.1 ± 1.5</td>
<td>12.2 ± 1.4</td>
<td>10.9 ± 1.1</td>
<td>8.4 ± 1.0</td>
<td>14.3 ± 0.9</td>
</tr>
<tr>
<td>Post 5</td>
<td>17.0 ± 1.9</td>
<td>17.3 ± 1.0</td>
<td>6.8 ± 0.8</td>
<td>14.8 ± 1.3</td>
<td>6.2 ± 0.5</td>
<td>13.9 ± 1.2</td>
</tr>
<tr>
<td>Post 15</td>
<td>19.6 ± 1.2</td>
<td>15.9 ± 0.8</td>
<td>7.1 ± 0.8</td>
<td>12.6 ± 1.1</td>
<td>5.6 ± 0.3</td>
<td>14.7 ± 0.8</td>
</tr>
<tr>
<td>Post 30</td>
<td>20.2 ± 1.8</td>
<td>16.6 ± 0.7</td>
<td>7.8 ± 0.9</td>
<td>12.6 ± 1.4</td>
<td>5.6 ± 0.2</td>
<td>14.0 ± 0.7</td>
</tr>
<tr>
<td>Post 60</td>
<td>21.6 ± 1.4</td>
<td>16.3 ± 1.0</td>
<td>8.3 ± 1.1</td>
<td>11.8 ± 0.6</td>
<td>5.4 ± 0.2</td>
<td>14.1 ± 1.0</td>
</tr>
</tbody>
</table>

For TA, there were no significant effects observed. However, tension, a subcomponent of TA, displayed a main effect for time ($F(2,14) = 6.967; p<.05$) and an interaction effect ($F(2,14) = 5.763; p<.05$). Tension was higher in the NF trial pre exercise compared to the F trial ($6.44 ± 0.5$ vs $8.44 ± 1.0$, F vs NF, $p<.05$). A reduction in tension was observed only in the NF trial 30 min and 60 min post exercise ($p<.05$).
5.3.3 Individual responses

Change scores were compared for the FS and FAS from the 14th minute (i.e. the first during exercise assessment) to the 60th minute (the mid-point of the protocol) of exercise, from the 14th minute to the 119th minute (i.e. the last minute of exercise) of exercise and from pre exercise to post 0'. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response with each category are shown in Table 5.3.

The results indicate that the individual change trends were varied across the FS and FAS scales. From 14 min to 60 min during exercise 67% of individuals in the no fluid trial reported a reduction in FS, which is in contrast to 33% in the fluid
trial. Across both trials, 22% reported an increase in FS, and in the fluid trial 45% reported no change compared to 11% in the no fluid trial. A similar pattern can be observed from pre to post exercise (Table 5.3). Such a diversity of responses was not as pronounced from the 14th min of exercise to the 119th. The only increase in valence, of 11%, was seen in the fluid trial, however both trials saw a large reported decrease. Specifically, 67% in the fluid trial and 78% in the no fluid trial. In FAS most participants (78% in the fluid trial and 67% in the no fluid trial) reported increases pre to post exercise, but during exercise results were mixed between the subgroups. For example between the 14 min and 119 min, 89% of participants observed an increase and 11% a decrease in the fluid trial compared to 67% that observed an increase, 22% no change and 11% a decrease in the no fluid trial.

5.3.4 Rating of perceived exertion

Rating of perceived exertion increased over time ($F(7, 56) = 45.055, p<.001$) across both conditions. RPE was consistently higher throughout exercise in the NF trial, but this did not reach statistical significance (Figure 5.6).

![Figure 5.6 Rating of perceived exertion during the 120 min cycle](image)
Table 5.3 Frequency and magnitude of individual affective responses to the 120 min cycle.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Fluid</th>
<th>No fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td><strong>Feeling Scale</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(from 14^{th} min of ex to 60^{th} min)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>2 (22%)</td>
<td>1-1</td>
</tr>
<tr>
<td>No change</td>
<td>4 (45%)</td>
<td>1</td>
</tr>
<tr>
<td>Decrease</td>
<td>3 (33%)</td>
<td>1</td>
</tr>
<tr>
<td><em>(from 14^{th} min of ex to 119^{th} min)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>1 (11%)</td>
<td>1-1</td>
</tr>
<tr>
<td>No change</td>
<td>2 (22%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>6 (67%)</td>
<td>1-7</td>
</tr>
<tr>
<td><em>(from pre to post 0)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (33%)</td>
<td>1-1</td>
</tr>
<tr>
<td>No change</td>
<td>1 (11%)</td>
<td>2 (22%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>5 (56%)</td>
<td>1-3</td>
</tr>
<tr>
<td><strong>Felt Arousal Scale</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(from 14^{th} min of ex to 60^{th} min)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>2 (22%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>6 (67%)</td>
<td>7 (78%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (11%)</td>
<td>1</td>
</tr>
<tr>
<td><em>(from 14^{th} min of ex to 119^{th} min)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>8 (89%)</td>
<td>1-4</td>
</tr>
<tr>
<td>No change</td>
<td></td>
<td>2 (22%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (11%)</td>
<td>1-1</td>
</tr>
<tr>
<td><em>(from pre to post 0)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>7 (78%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>2 (22%)</td>
<td>3 (33%)</td>
</tr>
<tr>
<td>Decrease</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).
5.3.5 Physiological responses to the exercise protocol

Oxygen uptake, heart rate and %\(\text{VO}_2\max\) did not differ between trials demonstrating that the participants were exercising at the same relative exercise intensity in both conditions. Heart rate during exercise ranged from approximately 153-172 beats.min\(^1\) (Figure 5.7). HR during the NF trial were elevated during the later stages compared to the F trial, but this was not statistically significant. Body mass, when corrected for fluid intake fell similarly.

![Figure 5.7 Heart rate during the 120 min cycle.](image)

5.3.6 Thirst scale

The rating of perceived thirst reported by the participants was higher at 30 minutes in the NF trial compared to the F trial and this persisted throughout exercise (condition x time interaction; 15.5 ± 0.3 vs 11.6 ± 0.2, NF vs F, F \(_{(2,12)}\) = 10.32, \(p<.01\)) (Figure 5.8).

5.3.7 Plasma cortisol

Plasma cortisol concentrations were higher immediately post exercise compared to pre exercise values (F \(_{(2,16)}\) = 26.89, \(p<.01\)) in the F and NF trials (Figure 5.9). There were no significant differences between conditions.
Figure 5.8 Thirst ratings during the 120 min cycle (n=7); * p<.05

Figure 5.9 Changes in plasma cortisol concentration (nmol.l⁻¹) upon cessation of exercise and 1 h post.
5.3.8 The relationship between the pre to post difference scores of plasma cortisol and the FS and FAS

FS and plasma cortisol

In the fluid trial, the correlation between the change scores in plasma cortisol and the FS was a weak one (.23, ns), however, the same was not observed in the no fluid trial. Indeed a strong negative correlation (-.67, p<.05) was found with larger decrements in valence ratings accompanying the highest increases in plasma cortisol levels.

FAS and plasma cortisol

In support of the above finding, strong and significant correlations were only observed in the no fluid trial. Specifically, a strong positive relationship (.76, p<.05) was found between the changes in plasma cortisol and changes in FAS during the no fluid trial. A moderate relationship was observed during the fluid trial, but this was not significant (.56, ns)

5.3.9 Correlations between the FS and RPE scale

Table 5.4 illustrates the correlations observed between the FS and RPE scale. There were no significant correlations during the no fluid trial, however significant correlations were noted during the final two sampling time points in the no fluid trial.

Table 5.4 Correlations between the FS and RPE scale

<table>
<thead>
<tr>
<th>Time</th>
<th>Fluid</th>
<th>No fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 min</td>
<td>0 (ns)</td>
<td>0 (ns)</td>
</tr>
<tr>
<td>30 min</td>
<td>-.35 (ns)</td>
<td>-.53 (ns)</td>
</tr>
<tr>
<td>45 min</td>
<td>-.30 (ns)</td>
<td>-.24 (ns)</td>
</tr>
<tr>
<td>60 min</td>
<td>-.09 (ns)</td>
<td>-.16 (ns)</td>
</tr>
<tr>
<td>75 min</td>
<td>-.55 (ns)</td>
<td>-.35 (ns)</td>
</tr>
<tr>
<td>90 min</td>
<td>-.25 (ns)</td>
<td>-.57 (ns)</td>
</tr>
<tr>
<td>105 min</td>
<td>-.26 (ns)</td>
<td>-.70 *</td>
</tr>
<tr>
<td>120 min</td>
<td>-.01 (ns)</td>
<td>-.67*</td>
</tr>
</tbody>
</table>

* Correlation is significant at the p<.05 level
Chapter V  Water Ingestion and Prolonged Cycling

5.4 Discussion

The purpose of this study was to investigate the influence of fluid ingestion during prolonged cycling exercise on affective states and effort sense. Therefore this study was concerned with measuring both 'how' and 'what' the participant feels before, during and following the exercise session. This follows the assertion of Hardy and Rejeski (1989) when they suggest that RPE on its own provides limited information. In the previous study (Study 1) we examined such responses during a 90 min run at 70% VO₂ max. This study serves to explore and compare the affective responses elicited as a result of prolonged cycling exercise and to assess whether or not the beneficial effects observed on the affective responses reported during and following running exercise, extends to cycling exercise.

In support of the previous study (Study 1), fluid ingestion had an impact on the affective responses reported. Energetic arousal was higher 5 min post exercise in the fluid trial compared to the no fluid trial. Indeed, in the trial where fluid was not ingested, energy, a subscale of EA was found to decreases as a result of exercise and this decrement was reported 5 min and 15 min post exercise. Previously (Study 1) it was demonstrated that fluid ingestion during a prolonged 90 min run resulted in higher feelings of energy 5 min and 15 min post exercise when compared to the no fluid trial. In the present study tiredness was also higher 5 min post exercise in the no fluid trial compared to the fluid trial. However, it is important to note that this finding should be interpreted cautiously because the Cronbach alpha coefficient for tiredness was low at 0.43 and it is not clear why this result occurred. It appears that the strategy of ingesting fluid during exercise appeared to maintain feelings of energy and prevent feelings of tiredness developing following a prolonged cycling protocol. There were no improvements in EA or its subscales, as a consequence of prolonged cycling exercise, but a maintenance effect was found. This supports previous findings during prolonged running (Study 1). Previous research that has observed an enhancement in EA following exercise has typically used exercise of shorter duration and lower intensity, such as the 10 min walks of Ekkekakis and colleagues (2000b) and Thayer et al. (1987a). There have been no studies to date that have measured
changes in EA following prolonged exercise. Consequently, comparisons are difficult to make. However, it appears when participants engage in prolonged exercise, such as a 120 min cycle at 65% VO₂ max, EA and its subcomponents are not enhanced. This study and the previous study on prolonged running (Study 1) present new findings to the affective literature because it was found that their decline is prevented by the consumption of fluid throughout the exercise session. This finding is certainly important to both elite athletes and those that take part in exercise to keep fit because such a strategy can be employed by anyone and an enhancement to the affective experience, by such a simple strategy, is of significance.

The sampling of affective states before, during and after exercise revealed that the temporal dynamics of affective change differed according to the condition in which exercise was undertaken. The ingestion of fluid during exercise did not enhance affective valence, rather it prevented its decline. In the no fluid trial the reduction in valence was more pronounced (Figure 5.3).

Self-reported activation increased from pre to immediately post exercise across both the fluid and no fluid trials. The same increase in activation was also observed in the prolonged running and hydration study (Study 1), however, significant increases in activation were limited to the trial in which fluid was consumed. During exercise, activation was observed to increase as the exercise progressed across both trials. A similar trend was not observed in the trial where no fluid was consumed.

As exercise continued, perceptions of exertion also increased and this occurred independent of the trial undertaken. Therefore, in the present study exercise did not have an influence on the individual’s perception of exertion during the 120 min cycle at a moderate exercise intensity, which supports the findings of the previous study involving prolonged running (Study 1). It is also in agreement with the findings of Robinson (1995) and McConnell (1999) in their studies on fluid ingestion during 1 h of exercise in a neutral environment. If the trial was carried out in a hot environment, differences may have emerged. The central
physiological parameters that have been linked to RPE include HR, $V_E$ and $\dot{V}O_2$ (Mihevic, 1981; Pandolf, 1982). There were no significant differences observed in these parameters as a result of the fluid intervention and this would support the similar perceived exertion findings.

In support of the running and hydration study (Study 1), the subjective thirst rating reported by the participants was significantly higher at 30 minutes and all time points thereafter in the no fluid ingestion trial. The subjective sensation of thirst accompanies fluid deficits greater than 1% of body weight (Greenleaf, 1992) and there is a linear relationship between hypohydration levels and thirst sensations (Engell et al., 1987). Rogers et al. (2001) suggest that functionally, perceived thirst is a good measure of hydration status and that the ability of physiological measures to detect subtle differences in hydration status is questionable (Shirreffs, 2000). Therefore, the results from this and the previous running study (Study 1) suggest that thirst may be an underlying cue in the affective responses elicited. Indeed, a lessened perception of thirst could in part explain the more positive EA responses. A heightened perception of thirst could have a detrimental effect on this subscale and, as observed by Rogers et al. (2001), the ingestion of fluid could be revitalising and alerting to the participants, which could manifest itself in enhanced feelings of EA. Further investigation is warranted.

As highlighted previously (Study 1), there could be other factors beyond the control of the experimenter that could have played a role in the responses observed. The main factor brought to the readers' attention is that of participant expectancy and bias. The Hawthorne effect, which is based on the tendency for participants in an experiment to improve following the manipulation of a selected independent variable (in this case fluid ingestion), could have been in operation in the present study. In other words, the improvement in affective states following fluid ingestion might simply reflect an improvement resulting from special attention afforded by the intervention. However, if such an effect was in operation, one would expect significant differences to report in a wider range of subjective variables. Orne (1962) suggests a problem solving behaviour occurs on the part of the individuals completing the studies, whereby they try to determine
the true purpose of the study, and then respond in accordance with the perceived hypothesis. The underlying hypothesis was not stated to the participants and an attempt to mask such a scheme of research was made, however, it is possible that the repeated administration of questionnaires and scales before, during and after the exercise session would generate expectancies. In summary, an expectancy effect on the part of the individuals, on the beneficial merits of ingesting fluid during prolonged exercise, based on their own cognitions and perceptions, cannot be eliminated. However, every attempt was made to minimise the influence of demand characteristics and the Hawthorne effect by the methodologies employed, particularly through collaboration with an exercise immunology experiment. Finally, one would expect a more consistent improvement across the range of subjective experiences to have taken place if this effect had occurred.

In support of the assertions of Bixby and colleagues (2001) the pattern of affective change from the final during exercise assessment to the post exercise time points (Figure 5.3) was similar to that of a rebound model (Figure 5.4) (Bixby et al., 2001). This trend occurred regardless of the exercise condition. Valence was found to decrease as the exercise bout progressed, again highlighting the importance of repeated within exercise assessments of affect. If one was to sample only pre and post exercise, the shift towards negative affectivity would not have been observed and the true nature of the subjective exercise experience falsely reported. In the present study, the exercise protocol was of a long duration and therefore the rebound pattern may have stemmed from the athletes realising a sense of relief that they had completed such strenuous exercise bout. One could also speculate that it may also reflect a sense of accomplishment. Further research should examine the relationship between the rebound model and social cognitive factors such as self-efficacy and attributions.

Figure 5.2 illustrates the shift in affect throughout the experimental protocol, as measured by the single item scales, from a deactivated pleasant state at the onset of exercise up to a more neutral activated state in the fluid trial towards the later stages of exercise and a shift into the deactivated unpleasant quadrant in the no fluid trial. Finally, as the recovery period progressed, mean participant responses were again located in the deactivated pleasant quarter. By mapping such responses
in circumplex space, the truly dynamic nature of affect can be clearly seen, and this has been reported elsewhere (Hall et al., 2002). A finding that is important to note is that the pattern of mapping between the single item scales and the multi-item AD ACL differed and it appeared to do so along the activation dimension. For example in the no fluid trial, pre to immediately post exercise, the single item scales showed a positive movement towards a more activated state, but the multi item questionnaire suggests affect moved in the opposite direction. Such contrasting findings could be due to the fact that the participants did not associate the sensations of increased activation that they reported on the single item scale with the choice of words offered by the AD ACL questionnaire. If the participants do not find them to be meaningful and relevant to the process of activation from exercise, then such conflicting findings should not be surprising. Indeed Thayer (1989) has commented that some participants are uncertain how to make discriminations between still and quite, and I would add placid to this list also. Therefore, the inabilities of some, in making discriminations between states of calmness, could have led to the differences observed.

The present study supports the conclusion from study 1 and the assertions of Hardy and Rejeski (1989) that the RPE and FS are not isomorphic constructs. Indeed the only significant correlations between the two scales were reported during the latter stages of the no fluid trial. Specifically a strong correlation was observed at 105 min (\(r = .70, p<.05\)) and 120 min (\(r = .67, p<.05\)), with decreasing valence ratings being associated with a concomitant increase in the RPE. It is interesting to note that the only significant associations were seen late in exercise during the no fluid trial because such a pattern also manifested itself in other correlational analyses undertaken. Indeed correlations were conducted between the change scores from pre to post exercise for plasma cortisol and the FS and FAS and the only significant correlations were found in the no fluid trial. Correlations between the change scores in the FS and plasma cortisol concentrations revealed a weak, insignificant relationship in the fluid trial but a strong negative relationship (\(r = .67, p<.05\)) in the no fluid trial, with larger decrements in valence ratings accompanying the highest increases in plasma cortisol concentrations. A similar trend was also noted when the change scores for the FAS were correlated with the change scores for plasma cortisol. Specifically, a
strong positive relationship (.76, p<.05) was found in the no fluid trial, but the relationship was not significant in the fluid trial. It is possible that participants in the no fluid trial were subject to stronger physiological cues, particularly as the exercise progressed, which resulted in the relationships discussed. However, this conclusion would be strengthened if significant differences had been noted between the trials for some of the physiological measurements, particularly plasma cortisol concentration.

In support of Davidson & Irwin (1999), this study demonstrated the variability among individuals in the direction and intensity of their response to the exercise stimulus. For example, during the fluid trial, between minutes 14 and 60, 22% reported an increase in valence, 45% no change and 33% a reduction. So even though participants are experiencing the same exercise stimulus, a variety of responses are reported. The same variability was true for the trial where participants did not ingest fluid; 67% reported a decrease, 11% no change and again 22% reported an increase in valence. It was interesting to note that the variety of responses was not as pronounced between minutes 14 and 119. In fact, a large percentage of participants reported a reduction in valence between these time points, across both trials, with the largest percentage coming from the trial when fluid was not provided. A more homogenous response could have come about at this time point because the body will be more stressed at 120 min into exercise, compared to 60 min into the bout. The heart rate responses support this statement. In the no fluid trial the heart rate increased from 162 ±3 beats.min⁻¹ at 60 min to 172 ±3 beats.min⁻¹ at 120 min illustrating the increased demands on the body to maintain energy expenditure. Ekkekakis (2003) hypothesises that a homogeneous response set is more likely to occur when participants are moving closer to their functional limits. This study offers some support for this suggestion. As researchers, we often ignore the idiographic approach and take a nomothetic perspective when addressing such responses. However, such variability in individual responses is important and should always be considered when undertaking research of this nature. Indeed, this finding highlights the issue that the traditional nomothetic assumptions of the exercise-affect relationship, i.e. most participants are expected to experience similar changes in affect in response to the
same exercise stimulus, is indeed questionable. The current findings and those from the previous study, offer support to Van Landuyt and colleagues (2000) who have provided evidence that questions the assumption of a homogenous response. In their study approximately half of the sample exhibited progressive improvements and half progressive deterioration during exercise. Our studies also have highlighted the varied responses elicited during the early stages of prolonged exercise that can be classified as of a moderate intensity.

In conclusion, fluid ingestion during prolonged cycling did not lessen the perception of effort or enhance valence of activation. However, it did exert a beneficial effect on the EA subscale. Furthermore, the only significant correlations between the subjective scales and plasma cortisol, which is a stress hormone, occurred in the no fluid trial. The mechanisms responsible for an enhanced affective profile are not entirely clear, however, it appears that thirst may be an underlying cue. These results support the importance of drinking fluid before and during exercise and add a new perspective to the literature concerning fluid ingestion and exercise, as well as knowledge to the relationship between exercise and affect.
The influence of carbohydrate ingestion during a prolonged run to fatigue on affective states and effort sense

6.1 Introduction

As highlighted in the previous studies investigating water ingestion and affective responses, there has been limited research undertaken on prolonged, moderate to high intensity exercise. Further, the influence of nutritional factors, such as carbohydrate ingestion, on such responses has been largely ignored. In addition the majority of researchers have limited the assessment of affective states to the period just before and following exercise. Such limited sampling may mask the truly dynamic nature of affect during exercise, as reported by Hall et al. (2002) and such a methodology fails to capture the in-task fluctuations (Bixby et al., 2001).

Numerous studies have explored the effects of carbohydrate (CHO) substrate availability on ratings of perceived exertion (RPE) (or “what” a person feels) during exercise. However, few studies have examined the impact of CHO on affective responses (or “how” one feels) during exercise (Hardy & Rejeski, 1989) and in those studies that have been conducted at rest, the impact of carbohydrate and placebo solutions on affect has been inconsistent and the findings equivocal (Benton & Owens, 1993). My hypothesis is that affect may be influenced by the supply of glucose when performing a metabolically demanding task, such as a prolonged run to fatigue. Maintenance of blood glucose is important because it is the main fuel for the central nervous system as well as providing substrate for muscle metabolism. Therefore the aim of this study was to examine “what” and “how” a person feels before, during and following a prolonged run to fatigue. In
order to address this question, we assessed affect from a dimensional perspective (as previously discussed in chapter 3), obtained ratings of perceived exertion and measured a number of physiological and metabolic indices of exertion.
Chapter VI

CHO Ingestion and Prolonged Running to Fatigue

6.2 Materials and Methods

6.2.1 Participants
Thirteen male university athletes (mean ± SEM: age 20 ± 1 yrs; body mass 72 ± 3.5 kg; \( \dot{\mathrm{V}} \mathrm{O}_2 \) max 63.9 ± 2.3 ml.kg\(^{-1}\).min\(^{-1}\)) took part in this study; all were involved in endurance training on a regular basis.

The participants were informed of the demands of the study and the possible risks and discomforts prior to receiving their written consent. The study had the approval of the Ethical Advisory Committee of Loughborough University. Prior to testing, participants were informed that the purpose of the study was to examine the influence of ingesting CHO-electrolyte solutions on endurance capacity. No mention was made of the potential for positive/negative psychological outcomes following the exercise task.

6.2.2 Measures of affect
The Feeling Scale (FS: (Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: (Svebak & Murgatroyd, 1985) and the Activation-Deactivation Adjective Check List (AD ACL; Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered before exercise, every 20 min during the prolonged run, at fatigue and then 15 min and 45 min post exercise. The AD ACL was administered before exercise and 15 min and 45 min post exercise. These time points were chosen because in general affective states appear to be most positive 10-15 min after completion of exercise (Dyer & Crouch, 1988) when the physiological processes have settled and as mentioned previously, sampling following exercise, as well as during allows a more complete picture of affective responses to be developed.

6.2.3 Perception of exertion
The Rating of Perceived Exertion scale (RPE; (Borg, 1982) was used as a measure of perceived effort during exercise, as previously described (Chapter 3).
6.2.4 Preliminary procedures
The participants undertook two preliminary tests to determine: 1) the relationship between running speed and oxygen uptake using a 16 min incremental submaximal running test, 2) their maximal oxygen uptake (VO₂ max) using an uphill treadmill running test to fatigue (Taylor, 1955). These procedures have previously been described (Chapter 3).

Before the first experimental trial the participants undertook a 45 min treadmill run at 70% VO₂ max to familiarise themselves with the experimental procedures and the measures of affect (Chapter 3).

6.2.5 Experimental procedures
In a double-blind randomised cross-over design, participants performed two prolonged runs to fatigue on the treadmill at 70% VO₂ max with at least 7 days in between each trial. On each occasion participants consumed either a water placebo (PLA) that had been artificially sweetened and coloured (Glaxo-SmithKline) or a 6.5% carbohydrate-electrolyte solution (CHO) (Lucozade Sport, Hypotonic Solution, Glaxo-SmithKline), immediately before the run (5ml.kg⁻¹ body mass) and every 20 min during exercise (2ml.kg⁻¹ body mass). Participants were asked to refrain from heavy exercise for 2 days prior to each trial and their dietary intake was monitored during the 48h preceding each trial using a food diary. This was completed prior to the first trial itemising the foods consumed and estimated portion sizes. The participants followed the same diet during the 48h prior to the second trial. In addition caffeine and alcohol were also prohibited during the 48h prior to the trial because both have been found to have transient effects on mood (Rogers, Edwards, Green, & Jas, 1992).

Figure 6.1 shows a schematic representation of the run to fatigue protocol. On the morning of each trial participants arrived at the laboratory between 08:00h and 09:00h following an overnight fast of 10 hours. On arrival participants were asked to rate their responses on the FS, FAS and AD ACL. Nude body mass was measured on a beam balance (Avery, Birmingham, UK) and a cannula (Venflon,
16-18G, Ohmeda, Hatfield, Herts, UK) was inserted into an antecubital vein and kept patent by frequent flushing with sterile saline. Following 10 min of passive standing, a 5 min resting expired air sample was collected, immediately followed by a 10ml resting venous blood sample. Participants were then given a 5ml.kg.BM bolus of the test solution and then the participants completed a 5 min warm up at 60% \( \dot{V}O_2 \) max. Once the warm up was completed, the participants stretched for 5 min. Immediately following the standardised warm up, the participants returned to the treadmill and the speed was increased to a pace which initially elicited an oxygen consumption equivalent to 70% \( \dot{V}O_2 \) max.

Expired air samples were collected over 60s intervals after 20 min of exercise, and every 20 min thereafter and finally during the last minute of the run. At the same time points, RPE values were obtained and heart rate recorded at 15s intervals using short-range telemetry. The administration of the FS and FAS preceded these measures. Following expired air and blood sampling the participant ingested 2ml.kg\(^{-1}\).BM of the test fluid delivered in two 100ml syringes. The participants ran to volitional fatigue, which was defined as the point at which the required running pace could no longer be maintained. No information regarding their exercise time was provided until both trials had been completed.

Upon fatigue and the cessation of the test, participants immediately responded to the FS and FAS. Participants then had the cannula removed and their post exercise body mass recorded before they were taken to a quiet area in the laboratory to sit comfortably and the affect measures were assessed as described earlier.
Warm up 60% $\dot{V}O_2$max

Blood and expired air sample

+ every 20 minutes until fatigue

Main Trial 70% $\dot{V}O_2$max

FATIGUE

-30 -5 0 20 40 60 80 + every 20 minutes until fatigue

Fluid, HR, RPE

FS/FAS FS/FAS FS/FAS FS/FAS FS/FAS FS/FAS FS/FAS FS/FAS FS/FAS FS/FAS

AD ACL AD ACL

Figure 6.1. Schematic representation of the run to fatigue protocol.
6.2.6 **Blood analyses**

Venous blood samples collected throughout the main trials were dispensed as follows: 5ml was put in an EDTA coated tube and centrifuged (Bukard) for 10 min at 6000rpm. The plasma samples were then stored at -70°C and later analysed for glucose and cortisol as described previously (Chapter 3).

6.2.7 **Statistical analysis**

Statistical analysis of the data was complicated by the fact that each participant exercised for a different duration. Therefore complete sets of data were obtained only at 0, 20, 40, 60, 80, fatigue and then the post exercise time points. Results were analysed as described under statistical analysis (Chapter 3). Times to fatigue were analysed using t-tests for paired data. Values are presented as mean (SEM).
6.3 Results

6.3.1 Affective responses to the exercise protocol

There was a significant increase in negative affect from pre- to post- exercise, as shown by changes on the FS (F (2,22) = 24.210; p < .001) across both conditions (Figure 6.2). Affective valence had improved and was in line with pre exercise values 30 min after exercise (Table 6.1).

Table 6.1. Descriptive statistics (means ± SEM) of the FS and FAS before, during and following the prolonged run to fatigue.

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(M ± SEM)</td>
<td>(M ± SEM)</td>
</tr>
<tr>
<td></td>
<td>CHO</td>
<td>PLA</td>
</tr>
<tr>
<td>Pre</td>
<td>1.2 ± 0.6</td>
<td>1.2 ± 0.5</td>
</tr>
<tr>
<td>17 min</td>
<td>2.0 ± 0.5</td>
<td>1.2 ± 0.5</td>
</tr>
<tr>
<td>37 min</td>
<td>1.2 ± 0.7</td>
<td>0.5 ± 0.6</td>
</tr>
<tr>
<td>57 min</td>
<td>0.9 ± 0.7</td>
<td>0.2 ± 0.6</td>
</tr>
<tr>
<td>77 min</td>
<td>0.1 ± 0.6</td>
<td>-0.9 ± 0.6</td>
</tr>
<tr>
<td>Post 0</td>
<td>-2.9 ± 0.6</td>
<td>-3.7 ± 0.3</td>
</tr>
<tr>
<td>Post 15</td>
<td>0.9 ± 0.6</td>
<td>0.5 ± 0.5</td>
</tr>
<tr>
<td>Post 30</td>
<td>1.5 ± 0.5</td>
<td>1.5 ± 0.4</td>
</tr>
<tr>
<td>Post 45</td>
<td>2.0 ± 0.5</td>
<td>1.9 ± 0.4</td>
</tr>
<tr>
<td>FAS</td>
<td>Pre</td>
<td>3.2 ± 0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0 ± 0.3</td>
</tr>
<tr>
<td>17 min</td>
<td>3.9 ± 0.3</td>
<td>3.9 ± 0.3</td>
</tr>
<tr>
<td>37 min</td>
<td>3.8 ± 0.2</td>
<td>3.6 ± 0.2</td>
</tr>
<tr>
<td>57 min</td>
<td>3.8 ± 0.2</td>
<td>3.9 ± 0.2</td>
</tr>
<tr>
<td>77 min</td>
<td>3.9 ± 0.3</td>
<td>3.7 ± 0.3</td>
</tr>
<tr>
<td>Post 0</td>
<td>2.9 ± 0.5</td>
<td>3.2 ± 0.5</td>
</tr>
<tr>
<td>Post 15</td>
<td>3.1 ± 0.4</td>
<td>2.9 ± 0.4</td>
</tr>
<tr>
<td>Post 30</td>
<td>3.4 ± 0.3</td>
<td>2.8 ± 0.3</td>
</tr>
<tr>
<td>Post 45</td>
<td>3.3 ± 0.3</td>
<td>2.9 ± 0.3</td>
</tr>
</tbody>
</table>
Affective valence during exercise decreased (p<.05) from the 17th minute of exercise to the 37th and 77th minute of the prolonged run in both the CHO and PLA trials. There was a non-significant increase in activation at the onset of exercise and this remained stable across both trials during the prolonged run (Figure 6.2).

Figure 6.2 Changes in affective valence (FS) and activation (FAS) before, during and following the prolonged run to fatigue plotted in circumplex space.

6.3.2 Changes in energetic and tense arousal
Table 6.2 illustrates the changes in EA, TA and the subscales before and following the prolonged run to fatigue. The alpha coefficient for the EA scale was 0.89 and for the TA scale 0.73 indicating high internal consistency. The alpha coefficients of the energy, tiredness, tension and calmness subscales were 0.90, 0.81, 0.73, 0.64 respectively.
Table 6.2 Descriptive statistics (mean ± SEM) of the AD ACL items and subscales before and following the prolonged run to fatigue.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>21.2 ± 1.8</td>
<td>21.2 ± 1.3</td>
<td>9.2 ± 1.1</td>
<td>13.0 ± 0.9</td>
<td>8.2 ± 0.9</td>
<td>12.0 ± 0.7</td>
</tr>
<tr>
<td>Post 15</td>
<td>18.5 ± 1.7</td>
<td>18.2 ± 1.0</td>
<td>7.2 ± 0.7</td>
<td>13.7 ± 1.1</td>
<td>6.7 ± 0.5</td>
<td>13.5 ± 0.9</td>
</tr>
<tr>
<td>Post 45</td>
<td>20 ± 1.9</td>
<td>18.0 ± 1.2</td>
<td>8.3 ± 1.0</td>
<td>13.3 ± 1.2</td>
<td>6.2 ± 0.5</td>
<td>13.2 ± 1.2</td>
</tr>
<tr>
<td><strong>PLA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>21.1 ± 1.9</td>
<td>21.4 ± 0.9</td>
<td>9.3 ± 1.0</td>
<td>13.2 ± 1.2</td>
<td>8.5 ± 1.0</td>
<td>12.1 ± 0.9</td>
</tr>
<tr>
<td>Post 15</td>
<td>18.5 ± 2.1</td>
<td>19.0 ± 1.6</td>
<td>7.5 ± 1.2</td>
<td>14 ± 1.1</td>
<td>6.7 ± 0.6</td>
<td>12.8 ± 1.3</td>
</tr>
<tr>
<td>Post 45</td>
<td>18.3 ± 2.0</td>
<td>17.7 ± 1.0</td>
<td>7.5 ± 1.0</td>
<td>14.2 ± 1.2</td>
<td>5.9 ± 0.4</td>
<td>13.2 ± 0.9</td>
</tr>
</tbody>
</table>

Analysis on the EA scores revealed no significant main effect for time or condition. For TA, the analysis revealed a significant effect of time ($F_{(2, 24)} = 4.998; p < .05$). Across conditions, paired t-tests, corrected to Bonferroni showed that TA decreased 15 min and 45 min post exercise. There was a main effect for time ($F_{(1, 15)} = 7.443; p < .05$) on the subscale tension. Again, tension decreased from pre exercise to 15 min and 45 min post exercise. Figure 6.3 illustrates the changes reported on the AD ACL pre and post exercise.
6.3.3 Individual responses

Change scores were compared for the FS and FAS from the 17th minute (i.e. the first during exercise assessment) to the 77th minute of exercise (when all participants were still exercising) and from pre exercise to post 0'. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response within each category are shown in Table 6.3.
Table 6.3. Frequency and magnitude of individual affective responses to the prolonged run to fatigue.

<table>
<thead>
<tr>
<th>Scale</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Feeling Scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(from 17th min of ex to 77th min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>1 (8%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>1 (8%)</td>
<td>1</td>
</tr>
<tr>
<td>Decrease</td>
<td>11 (84%)</td>
<td>1-3</td>
</tr>
<tr>
<td>(from pre to post 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>1 (8%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>1 (8%)</td>
<td>1</td>
</tr>
<tr>
<td>Decrease</td>
<td>12 (92%)</td>
<td>1-10</td>
</tr>
<tr>
<td>Felt Arousal Scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(from 17th min of ex to 77th min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>5 (38%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>5 (38%)</td>
<td>1-2</td>
</tr>
<tr>
<td>Decrease</td>
<td>3 (24%)</td>
<td>1-2</td>
</tr>
<tr>
<td>(from pre to post 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>1 (8%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>8 (61%)</td>
<td>1-2</td>
</tr>
<tr>
<td>Decrease</td>
<td>4 (31%)</td>
<td>1</td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).

The results indicate that the individual change trends were essentially homogenous with respect to the FS. Almost all participants (92%) showed a decrease in FS from pre to immediately post exercise but they differed in the magnitude of the change, ranging from 1 to 10 points. During exercise, the results were similar, with 84% of participants in the CHO trial, and 77% of participants in the PLA reporting a decline in affect. For the FAS, there was a divergent response during exercise, with participants reporting a variety of change within the three subgroups. In the CHO trial, 38% of individuals reported an increase in activation,
38% no change and 24% a decrease. A similar response pattern was observed in the PLA trial.

6.3.4 Rating of perceived exertion

Rating of perceived exertion increased over time ($F (2,30) = 18.286; p<.001$) across both conditions. No significant differences were found between conditions (Figure 6.4).

![Figure 6.4 Rating of perceived exertion during the prolonged run to fatigue.](image)

6.3.5 Physiological responses to the exercise protocol

Oxygen uptake, heart rate and $\% VO_2\text{max}$ did not differ between trials demonstrating that the participants were exercising at the same relative exercise intensity in both conditions. Heart rate during exercise ranged from approximately 158-170 beats.min$^{-1}$. 


6.3.6 Plasma glucose

An interaction of drink x time (F (3, 25) = 4.672; p< .05) was observed with plasma glucose concentration being lower at 20 min in the CHO trial compared to the PLA trial. However, no other differences were observed (Figure 6.5).

![Plasma Glucose Concentration](image)

Figure 6.5 Changes in plasma glucose concentration (mmol.l⁻¹) during the prolonged run to fatigue; * p<.05 CHO vs PLA.

6.3.7 Serum cortisol

Serum cortisol concentrations increased (F (2, 14) = 9.755; p< .05) by 42% during the CHO trial (24.9 ± 2.7 mmol.l⁻¹ to 35.3 ± 3.9 mmol.l⁻¹) and by 25% (25.1 ± 2.8 mmol.l⁻¹ to 31.3 ± 2.3 mmol.l⁻¹) during the PLA trial. At 60 min, serum cortisol concentration was higher (interaction of time x treatment; (F (3, 23) = 4.890; p< .05) during the PLA trial (Figure 6.6).

6.3.8 Environmental conditions

There was no difference between trials in the dry and wet bulb temperature and relative humidity during the study. The laboratory temperature across both trials averaged 21.1 ± 0.4°C, with a relative humidity of 43.0 ± 1.6%.
Figure 6.6. Serum Cortisol Concentration (mmol.l⁻¹) during the prolonged run to fatigue: * p<.05 CHO vs PLA; (n=9)

All participants consumed the prescribed volume of fluids. After correcting for fluid intake, body mass decreased by 0.60 ± 0.6kg in the CHO trial and by 0.43 ± 0.52 in the PLA trial, equivalent to reductions in body mass of 0.84 ± 0.9% and 0.61 ± 0.8% respectively (ns).

6.3.9 Diet

A nutrient analysis of the 2-day food records prior to each of the two exercise sessions revealed no differences in the energy intake and nutrient composition between conditions. The mean energy intake of the participants was 2489 kcal/day, with the proportion of energy being 59% from CHO, 26% from fat and 15% from protein.

6.3.10 Exercise time to fatigue

The run time to fatigue was 147 ± 32.13 min in the CHO trial and 129.8 ± 30.2 min in the PLA trial (ns).
6.3.11 Correlation between the FS and RPE scale

Table 6.4 illustrates the correlations observed between the FS and RPE scale. An inconsistent pattern emerged, however the correlations that were significant indicated a moderate to strong negative relationship between the two scales. As RPE increased, valence ratings decreased.

Table 6.4. Correlations between the FS and RPE scale

<table>
<thead>
<tr>
<th>Time</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>-.55*</td>
<td>-.68*</td>
</tr>
<tr>
<td>40</td>
<td>-.50 (ns)</td>
<td>-.45 (ns)</td>
</tr>
<tr>
<td>60</td>
<td>-.72**</td>
<td>-.48 (ns)</td>
</tr>
<tr>
<td>80</td>
<td>-.75**</td>
<td>-.57*</td>
</tr>
</tbody>
</table>

* Correlation is significant at the p<.05 level; ** correlation is significant at the p<.01 level.
6.4 Discussion

The aim of the present study was to examine the effects of ingesting a carbohydrate-electrolyte solution on affective responses and perceived exertion during a prolonged run to fatigue.

Results indicated that affect, as measured by the FS, was not enhanced and RPE not reduced by the ingestion of a CHO-electrolyte solution. Under both conditions a prolonged run to fatigue elicited negative affective changes, characterised by an unpleasant deactivated state, confirming the fatiguing nature of this protocol (Figure 6.2). This is in contrast to the positive affect that Morgan (1985) suggests is experienced by some runners after the first hour of a run. Indeed, Morgan describes the enhanced effect as a “profound alteration in one’s emotional state” (p.95). However, it must be cautioned that this suggestion is based on introspective accounts. Reports of negative affect during prolonged submaximal running have only previously been shown by Acevedo et al., (1996). They reported a decrease in affect, as measured by the FS, following a 2 h run at 70% \( \dot{VO}_2 \) max. It is not entirely clear from the literature how aerobically fit the participants in this study were, making comparisons difficult, however, it could be speculated that their characteristics were similar to those in the present study because they were described as distance runners, and they were able to complete a 2 h run at 70% \( \dot{VO}_2 \) max which requires a substantial level of fitness. This study is the first to describe the dynamic changes in affect as participants exercise at a constant intensity until fatigue. Hall et al. (2002) also reported a shift towards negative affect, culminating at the point of fatigue following a treadmill test to fatigue, however, their test was incremental and as a result, time to fatigue occurred much sooner (~11 mins). It was interesting to note that Hall et al.,’s participants reached fatigue at the upper left hand quadrant of the circumplex model (activated unpleasant), whereas in the present study participants first went through the activated unpleasant quadrant, but reached fatigue in the deactivated unpleasant quadrant. This might indicate the workings of a different fatiguing process.
Such negative affective responses could be due to the claim by Nesse (1998) that affective responses represent adaptive reactions that have evolved to promote survival in a specific context. The increased physical stress that the body is placed under during a run to fatigue protocol will alter the body’s homeostasis. As this disruption enters consciousness (Cabanac, 1995; Damasio, 1995) the adaptive responses elicited are those of negative affect which serves as an alarm to stop the individual and withdraw them from the activity that is affecting their homeostasis (Hall et al., 2002).

Despite the ingestion of a 6.5% carbohydrate-electrolyte solution before and during the prolonged run to fatigue, blood glucose concentrations were not elevated when compared to the placebo trial. It was hypothesised that the ingestion of a CHO-E solution would lead to an elevation in blood glucose concentration and this in turn may improve the affective responses reported during this trial compared to the placebo trial. However, in the present study, blood glucose concentration did not increase and self-reports of affect were similar across conditions. Few studies have examined the influence of CHO intake on affective responses and therefore results are by no means conclusive. Welsh and colleagues (2002) reported enhanced self perceptions of fatigue, as measured by the POMS (McNair, Lorr, & Droppleman, 1981), during the second half of an intermittent running protocol, when their participants ingested a CHO-electrolyte solution. In this instance, blood glucose concentrations were elevated following ingestion of a 6% CHO-E solution. Kreider and co-workers (1995), by means of a training study on elite cyclists, showed that despite an increase of 82% in CHO consumption over a six day training period, only a limited improvement occurred in psychological status as assessed by the POMS. Benton (2002) has undertaken a substantial amount of research on the influence of carbohydrate intake on mood at rest. He concludes that in studies comparing sugar-containing drinks, with placebos at rest, the influence on mood is inconsistent. Indeed when glucose and sucrose containing drinks were observed to influence mood, the effects were small. Further research on the influence of CHO ingestion on affective states during acute exercise is warranted. In particular, the influence of different types of exercise (intensity and mode) and volume and concentration of fluid ingested. In
our own laboratory, athletes often provide anecdotal reports that they "feel better" following ingestion of a CHO solution during and following prolonged exercise.

As expected, perceptions of exertion increased as the exercise bout continued and this finding has previously been documented during prolonged submaximal exercise (Acevedo et al., 1996; Coggan & Coyle, 1989; Murray et al., 1987). This finding can be explained as a result of the increase in physiological stress placed on the participant towards the end of the run, leading to a heightened perception of effort. This was shown by the progressive increase in heart rate, which responds linearly to the energy demands of physical activity. As with the affective responses, no differences were found in the perception of exertion, as measured by the RPE, between treatments. The metabolic data also supports this finding. Elevated concentrations of blood glucose have previously been associated with a suppressed perception of effort (Coggan & Coyle, 1989) and, as mentioned earlier, blood glucose concentrations were similar between trials in the present study. CHO oxidation rates were not different between trials. Furthermore, no differences existed in the central sensory variable of HR between treatments, which has previously been linked to mediating the perception of effort (Mihevic, 1981). In summary, the above findings, along with the similar run times recorded, support the similarity in RPE observed in the present study. My findings further support previous work (Felig et al., 1982; Ivy et al., 1979; Murray et al., 1987), which observed no differences in the RPE between the CHO and PLA conditions.

This study did pose a challenge in how the data were handled, due to the variable duration of the experimental protocol (variable times to fatigue across participants). All participants had measurements at least until the 80th minute of the exercise bout, and therefore complete data sets were obtained for variables assessed pre exercise, at 20 min, 40 min, 60 min and 80 min during exercise, upon fatigue and for two time points sampled following fatigue. Handling the data in this way poses a problem because it cannot be assumed that the responses (including both the physiological and subjective ones) are the same. For example, the 80th minute for the individual who fatigued at the 91st minute may not elicit the same responses as the individual sampled at this time that fatigued at the 187th minute. An attempt was made to compare the participants in a relative fashion, on
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CHO Ingestion and Prolonged Running to Fatigue

the basis of a physiologically meaningful landmark that the participants passed on their way to fatigue, such as an RER of 1.0, or a blood lactate concentration of 4.0 mmol.l⁻¹. However, when the data were reviewed, this was not possible, because these landmarks were not obtained in most of the individuals sampled. Therefore, in light of this finding, data were reduced in the way previously described.

Sampling affective states before, during and following the prolonged run to fatigue, offered support to Bixby and co-workers’ (2001) assertion that the temporal dynamics of the affective responses to acute exercise are more complex than has been previously assumed. Participants in the present study reported a negative shift in affect as the prolonged run continued, reaching a nadir upon fatigue. These highly negative responses were markedly improved 15 min post-exercise, which is characteristic of Bixby and colleagues’ (2001) rebound model. This is similar to Solomon’s (1980) Opponent-Process theory. This post exercise shift from a negative to a positive trend has also been observed by Acevedo et al. (1996), Bixby et al. (2001) and Hall et al. (2002). Indeed the shift returned participants to pre-exercise levels of affective valence, however, in the present study it did not lead to improvements in affective valence. If affect had not been assessed repeatedly during the run, such dynamic responses would have been missed and pre- to post- results would suggest that the run to fatigue had not led to a negative change in affective responses, but had remained stable throughout.

In the present study, the majority of participants upon fatigue reported a state of deactivated unpleasantness, with extreme negative ratings on the valence and activation dimensions. Indeed, 92% of participants across both trials reported highly negative affective valence, and this finding is supported by a study undertaken by Hall et al. (2002) as a homogenous trend for negative affect was reported at the level of individuals when they were close to reaching their functional limits. There was an almost universal trend for participants to respond negatively as the exercise became overwhelming, upon fatigue. However, the individual responses prior to arrival at this end point were varied. Indeed, Davidson and Irwin (1999) state “one of the most striking features of emotion is the profound variability among individuals in the quality and intensity of response to the identical stimulus” (p.16). This study supports what Van Landuyt et al.
Chapter VI  
CHO Ingestion and Prolonged Running to Fatigue

(2000) terms the bi-directional effects on affect. Specifically, this run to fatigue protocol led to both negative and positive changes in the same individual and between individuals. Further, during exercise, across both conditions 8 (62%) participants exhibited changes along the valence dimension, but not the activation dimension. This finding offers support for Van Landuyt et al. (2000) and Feldman-Barrett's (1998) indications that there appears to be complex individual differences in the manner in which affective response are generated. Some participants may be activation focused, reporting little change in affective valence during exercise, or as appears to be the case in the present study, valence focused, placing a greater emphasis on the positive and negative stimulus properties of exercise.

In the present study it appears that the prolonged run to fatigue exerted an influence on self-reported feelings of tense arousal because it was found to be lower 15 min and 45 min following exercise, across both conditions. This supports the assertion of Thayer (1989) that a reduction in tense arousal often follows exercise that is vigorous in nature. Overall, tense arousal and more specifically, the subscale tension may have been reduced following this protocol because the participants could have felt a sense of relief following the completion of this highly strenuous run to fatigue. To my knowledge this is the first study that describes the affective changes that accompanies prolonged exercise to fatigue and therefore the first that reports a reduction in tension and tense arousal following such a demanding exercise trial.

Interestingly, when one takes into account the exercise protocol, it is perhaps surprising that a decline in energetic arousal was not reported. Instead, it remained stable from pre to post exercise. The timing of administration of the AD ACL could explain this finding. In this study, the earliest administration was 15 min post exercise and due to the transient nature of affect, feelings of fatigue, which lead to the disposition of reduced energy may have been missed. In a study undertaken by Welsh et al. (2002), participants completed the POMS immediately following an intermittent shuttle run to fatigue and they reported significantly higher levels of fatigue at this time point. Furthermore, despite the nature of the exercise, EA following exercise remained at a similar level to that reported prior
to exercise. An increase in EA, which has previously been noted in studies examining exercise of short duration and moderate intensity, was not surprisingly absent in this study. However, despite the fatiguing nature, EA was still stable 15 min and 45 min post exercise. Scientists are still unclear what level of exercise results in fatigue instead of increased feelings of subjective energy. Results from this study suggest that even though the protocol was physically demanding energy levels were still maintained well into recovery. In a sense, this offers support for the efficacy of exercise in improving or maintaining subjective feelings of energy. Thayer (1989) suggests that the processes of subjective energy are likely to be cyclical and time related. For example, a given amount of exercise such as the prolonged run to exhaustion may have resulted in an initial period of fatigue, but then this was predisposed by increased feelings of energy a short time later. This certainly could be the case in the present study, however because the AD ACL was not administered at fatigue, firm conclusions cannot be stated.

Analysis on the FS and RPE revealed the relationship to be rather inconsistent. Due to the differences in run times to fatigue, four time points were analysed across both conditions. Five time points out of the eight available displayed significant correlations, ranging from -.55 to -.75. Previously Acevedo et al. (1996) and Hardy and Rejeski (1989) have also found correlations that are of a moderate magnitude. Such findings suggest that there is a difference between what one feels and how one feels at varying intensities of work. Further research should continue to utilise both measures, in order to fully understand the exercise effect.

In conclusion, the present study explored a relatively new approach to the investigation of the influence of CHO supplementation and exercise type on affect. The assessment of affective responses during exercise, which has largely been ignored in the literature on exercise and affect (Petruzzello & Tate, 1997) illustrated the dynamic nature of affect and the significant shift towards negative affect, reaching a nadir at fatigue. The pattern of affective change was consistent across both trials, and a pattern characteristic of a rebound model was observed. Reports of similar affective responses and effort sense ratings across the conditions are consistent with run times to fatigue. In agreement with Acevedo et
al. (1996), it is highly feasible that if participants don't feel better during exercise under one condition, they are unlikely to persist longer at the activity on that occasion. If participants perceive exertion and affect to be similar then it is perhaps not surprising that run times were similar. However, if the opposite had been found and effort sense had been reduced and affect improved, then an increase in run time may have been expected. The prolonged run to fatigue also led to a reduction in tension and the global state of tense arousal. Further research should continue to combine measures that assess not only 'what' a participant feels while they are exercising under certain nutritional or climatic conditions, but also 'how' they feel.
Chapter VII

Study Four

The influence of carbohydrate ingestion during prolonged cycling on affective states and effort sense

7.1 Introduction

The importance of carbohydrate ingestion (CHO) during prolonged exercise has over decades been stressed by many authors (Coyle et al., 1986; Hargreaves, 1996). In addition, numerous studies have been conducted on the influence of CHO on perceived exertion during such exercise, but results have proved equivocal, depending on exercise mode and duration. Generally, the consensus is that CHO ingestion during prolonged cycling reduces perceptions of exertion (Burgess et al., 1991; Kang et al., 1996). Although these studies have reported differences in ‘what’ the participants felt, as measured by the RPE, ‘how’ they feel has largely been ignored. Indeed, self reported affect during exercise may be important in terms of the individual’s persistence and effort at the activity (Acevedo et al., 1996). Previously (Study 3) it was observed that during a prolonged run to fatigue, CHO ingestion did not influence how and what the person felt during exercise. However, in light of the contradicting RPE findings reported in the literature between cycling and running, this study was designed to investigate the impact CHO ingestion has on these two feeling states during prolonged cycling. In addition, research has been conducted on the influence that glucose-containing drinks exert on affective states, however, such studies have been predominantly undertaken at rest and the effect has been relatively small and inconsistent (Benton & Owens, 1993). Given the brain’s high metabolic rate and the fact that it requires a continuous supply of glucose in order to function adequately, the increased peripheral glucose requirements during prolonged exercise may indeed have an effect on the influence that ingesting CHO during such a demanding task has on affect.
7.2 Materials and Methods

7.2.1 Participants
Nine endurance trained males (mean ± SEM; age $25 \pm 2$ yr; height $191 \pm 4$ cm; body mass $76.8 \pm 2.8$ kg; $\dot{V}O_2\text{max}$, $64.7 \pm 2.7$ ml.kg$^{-1}$.min$^{-1}$) volunteered to participate in this study. All participants were fully informed of the nature and purpose of the study before signing a statement of informed consent. The study had the approval of the Ethical Advisory Committee of Loughborough University.

7.2.2 Measures

7.2.3 Self-reported affect
The Feeling Scale (FS; Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: Svebak & Murgatroyd, 1985) and AD ACL (Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered before exercise, every 15 min throughout the prolonged cycle, upon cessation of exercise and 5 min, 15 min, 30 min and 60 min post exercise. The AD ACL was administered before exercise and at 5 min, 15 min, 30 min and 60 min post exercise.

7.2.4 Rating of perceived exertion
The rating of perceived exertion scale (RPE; (Borg, 1982) was used as a measure of perceived exertion during exercise, as previously described (Chapter 3).

7.2.5 Preliminary procedures
Maximal oxygen uptake was estimated by means of a continuous incremental exercise test on an electrically braked cycle ergometer (Load, Excalibur, Groningen, The Nederlands) to volitional fatigue. This procedure has previously been described in Chapter 3. From the $\dot{V}O_2$ work relationship, the work rate equivalent to 70% $\dot{V}O_2\text{max}$ was interpolated.
7.2.6 Familiarisation
Participants completed a one-hour familiarisation trial as previously described (Chapter 3).

7.2.7 Experimental procedures
In a randomised, counter balanced design participants completed two exercise trials; each separated by at least 7 d. On each occasion participants consumed either a carbohydrate (6.4%) solution (CHO) (See Chapter 3 for drink composition), flavoured with lemon, or a placebo solution (PLA) that was artificially sweetened and coloured with lemon. These solutions were ingested immediately before exercise (5ml.kg\(^{-1}\) body mass), every 15min during (2ml.kg\(^{-1}\) body mass) and 5 min post exercise (5ml.kg\(^{-1}\) body mass).

The schematic representation of the protocol is shown in Figure 7.1. Participants reported to the laboratory at 08:00 h on each occasion following an overnight fast. Participants were then required to empty the bladder before body mass (in shorts only) was measured. Participants were then seated quietly for 15 min after which a blood sample was taken from an antecubital vein by venopuncture. They then performed a 2 h cycle ergometer ride on an electronically braked ergometer (Lode Excalibur), at 70% VO\(_2\) max. The FS and FAS scales were administered at intervals of 15 min, the first set being administered during the 14\(^{th}\) min of the test. Expired air samples were obtained using the standard Douglas bag method as previously described (Chapter 3) at min 20, 50, 80 and 110 during the exercise bout. Heart rates were recorded every 15 min during exercise as previously described (Chapter 3). Participants’ ratings of perceived exertion (Borg, 1982) were also obtained at 15 min intervals throughout the cycling exercise (Chapter 3).

Upon cessation of the exercise task, participants immediately responded to the FS and FAS. Participants once again responded to these measures along with the AD ACL at Post 5’, Post 15’, Post 30’ and Post 60’. Further blood samples were taken immediately post exercise and at 1 h post exercise. No food was consumed during this period, and fluid ingestion was as prescribed.
Figure 7.1. Schematic representation of the 120 min cycling protocol.
7.2.8 Blood analyses
Blood was collected into vacutainer tubes (Becton Dickinson, Oxford, UK) containing lithium heparin. Refer to chapter 3 for the details on the storage and analysis of blood samples.

7.2.9 Statistical analysis
Results were analysed as described under statistical analysis (Chapter 3). Values are presented as mean (SEM).
Chapter VII
CHO Ingestion and Prolonged Cycling

7.3 Results

7.3.1 Affective responses to the exercise protocol

Analysis on the FS revealed that during exercise, an overall main effect for treatment was observed (F (1, 8) = 8.456; p<.05) but not time (Table 7.1). Affective valence, as measured by the FS, increased and was maintained throughout exercise in the CHO trial but not the PLA trial. Analysis on the pre to post exercise changes revealed an interaction effect (F (4, 32) = 2.77; p<.05) when analysed to 30 min post-exercise, with affective valence being higher overall in the CHO trial compared to the PLA trial. Figure 7.1 and 7.2 illustrates the shift to a reduction in valence in the PLA trial and to improvement and maintenance in the CHO trial, depicted in Circumplex space.

Table 7.1. Descriptive statistics (mean ± SEM) of FS and FAS before, during and following the 120 min cycle.

<table>
<thead>
<tr>
<th></th>
<th>FS (M ± SEM)</th>
<th>FAS (M ± SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHO</td>
<td>PLA</td>
</tr>
<tr>
<td>Pre</td>
<td>1.9 ± 0.5</td>
<td>2.3 ± 0.4</td>
</tr>
<tr>
<td>14 min</td>
<td>2.2 ± 0.5</td>
<td>2.1 ± 0.5</td>
</tr>
<tr>
<td>29 min</td>
<td>2.6 ± 0.3</td>
<td>1.7 ± 0.5</td>
</tr>
<tr>
<td>44 min</td>
<td>2.6 ± 0.3</td>
<td>1.4 ± 0.5</td>
</tr>
<tr>
<td>59 min</td>
<td>2.3 ± 0.4</td>
<td>1.9 ± 0.5</td>
</tr>
<tr>
<td>74 min</td>
<td>2.1 ± 0.5</td>
<td>1.1 ± 0.6</td>
</tr>
<tr>
<td>89 min</td>
<td>2.2 ± 0.6</td>
<td>1.1 ± 0.8</td>
</tr>
<tr>
<td>104 min</td>
<td>2.0 ± 0.6</td>
<td>1.1 ± 0.6</td>
</tr>
<tr>
<td>119 min</td>
<td>2.4 ± 0.5</td>
<td>1.3 ± 0.6</td>
</tr>
<tr>
<td>Post-0</td>
<td>2.6 ± 0.6</td>
<td>1.9 ± 0.8</td>
</tr>
<tr>
<td>Post-5</td>
<td>2.9 ± 0.5</td>
<td>2.2 ± 0.5</td>
</tr>
<tr>
<td>Post-15</td>
<td>3.4 ± 0.4</td>
<td>2.1 ± 0.5</td>
</tr>
<tr>
<td>Post-30</td>
<td>3.2 ± 0.5</td>
<td>2.9 ± 0.2</td>
</tr>
<tr>
<td>Post-60</td>
<td>3.2 ± 0.4</td>
<td>2.9 ± 0.4</td>
</tr>
</tbody>
</table>
Figure 7.2. Changes in affective valence (FS) and activation (FAS) before, during and following the 120 min cycle, plotted in circumplex space.

Figure 7.3. Affective valence (FS) before, during and following the 120 min cycle (Overall main effect of condition during exercise; p< .05).
There was no significant difference in the FAS both pre- to post-exercise and during. It increased at the onset of exercise and remained stable throughout the exercise period at a higher level compared to pre-exercise values (Table 7.1).

### 7.3.2 Changes in energetic and tense arousal

Table 7.2 illustrates the changes in EA, TA and the subscales before and following 2 h cycling. The alpha coefficient for the EA scale was 0.84 and for the TA scale 0.85 indicating high internal consistency. The alpha coefficients of the energy, tiredness, tension and calmness subscales were 0.76, 0.60, 0.92, 0.82 respectively. Analysis on the EA subscale revealed no change as a result of exercise (Figure 7.4), however a marked change was observed in self-reported energy, a subcomponent of EA. Energy declined (F(4,32) = 7.382; p<.001) across both trials from pre- to post-exercise.

Table 7.2. Descriptive statistics (mean ± SEM) of the AD ACL items and subscales before and following the 120 min cycle.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>28.2 ± 1.1</td>
<td>17.4 ± 2.0</td>
<td>14.1 ± 0.5</td>
<td>10.9 ± 0.8</td>
<td>7.2 ± 1.3</td>
<td>14.8 ± 1.5</td>
</tr>
<tr>
<td>Post 5</td>
<td>25.7 ± 2.6</td>
<td>16.6 ± 1.2</td>
<td>10.8 ± 1.4</td>
<td>10.1 ± 1.4</td>
<td>6.0 ± 0.3</td>
<td>14.4 ± 1.2</td>
</tr>
<tr>
<td>Post 15</td>
<td>26.9 ± 2.5</td>
<td>16.6 ± 1.4</td>
<td>11.2 ± 1.3</td>
<td>9.3 ± 1.5</td>
<td>6.0 ± 0.4</td>
<td>14.4 ± 1.3</td>
</tr>
<tr>
<td>Post 30</td>
<td>25.3 ± 2.4</td>
<td>16.1 ± 1.3</td>
<td>10.3 ± 1.3</td>
<td>10.1 ± 1.6</td>
<td>5.3 ± 0.3</td>
<td>14.2 ± 1.4</td>
</tr>
<tr>
<td>Post 60</td>
<td>24 ± 1.8</td>
<td>15.4 ± 1.3</td>
<td>9.1 ± 1.1</td>
<td>10.1 ± 1.3</td>
<td>5.6 ± 0.4</td>
<td>15.1 ± 1.1</td>
</tr>
<tr>
<td><strong>PLA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>26.8 ± 2.7</td>
<td>19 ± 1.6</td>
<td>13.3 ± 0.9</td>
<td>11.6 ± 1.0</td>
<td>6.4 ± 0.6</td>
<td>12.4 ± 1.4</td>
</tr>
<tr>
<td>Post 5</td>
<td>23.4 ± 2.5</td>
<td>17.9 ± 2.1</td>
<td>9.9 ± 1.3</td>
<td>11.4 ± 1.5</td>
<td>6.7 ± 0.5</td>
<td>13.8 ± 1.4</td>
</tr>
<tr>
<td>Post 15</td>
<td>23.3 ± 1.6</td>
<td>19.6 ± 1.8</td>
<td>9.7 ± 1.1</td>
<td>11.3 ± 1.5</td>
<td>6.2 ± 0.5</td>
<td>11.7 ± 1.8</td>
</tr>
<tr>
<td>Post 30</td>
<td>24 ± 1.5</td>
<td>18.3 ± 1.5</td>
<td>9.4 ± 0.9</td>
<td>10.4 ± 1.1</td>
<td>5.7 ± 0.3</td>
<td>12.3 ± 1.6</td>
</tr>
<tr>
<td>Post 60</td>
<td>24.2 ± 1.7</td>
<td>16.7 ± 1.5</td>
<td>10.3 ± 0.8</td>
<td>11.1 ± 1.0</td>
<td>5.4 ± 0.3</td>
<td>13.8 ± 1.4</td>
</tr>
</tbody>
</table>
Figure 7.4. Affect, as measured by the AD ACL before and following the 120 min cycle, plotted in circumplex space.

7.3.3 Individual responses

Change scores were compared for the FS and FAS from the 14th minute (i.e. the first during exercise assessment) to the 60th minute (the mid-point of the protocol) of exercise, from the 14th minute to the 119th minute (i.e. the last minute of exercise) of exercise and from pre exercise to post 0'. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response with each category are shown in Table 7.3.

The results indicate that the individual change trends did not exhibit a pattern of homogeneity at any of the time points with the FS and FAS. Specifically, from 14 min to 119 min during exercise 67% of individuals in the PLA trial reported a reduction in FS, this is in contrast to 33% in the CHO trial. Across both trials,
33% reported an increase in FS, and only in the CHO trial did participants report no change (33%).

A similar response pattern emerged from 14 min to 60 min of exercise, and from pre- to post-exercise, with more participants in the PLA trial reporting decreases during exercise, which supports the ANOVA findings. In FAS most participants (56%) reported increases pre- to post-exercise, but during exercise results were mixed between the subgroups. For example between the 14 min and 60 min, 23% of participants observed an increase in the CHO trial compared to only 11% in the PLA trial, 77% reported no change in the CHO trial, compared to 44% in the PLA trial and finally no participants reported a decrease in activation during the CHO trial, but 44% did in the PLA trial.

7.3.4 Rating of perceived exertion
RPE increased over time (F (7, 56) = 21.072; p<.001) across both conditions. There was an interaction of treatment x time (F (7, 56) = 2.589; p<.05), with RPE lower at 75 min in the CHO trial compared with the PLA trial (Figure 7.5).

![Figure 7.5. Rating of perceived exertion during the 120 min cycle; * p<.05, CHO vs PLA.](image-url)
Table 7.3 Frequency and magnitude of individual affective responses.

<table>
<thead>
<tr>
<th>Scale</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Feeling Scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(from 14th min of ex to 60th min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (33%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>4 (44%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (2%)</td>
<td>1-2</td>
</tr>
<tr>
<td>(from 14th min of ex to 119th min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (33%)</td>
<td>1-3</td>
</tr>
<tr>
<td>No change</td>
<td>3 (33%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>3 (33%)</td>
<td>1-2</td>
</tr>
<tr>
<td>(from pre to post 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>4 (44%)</td>
<td>2-3</td>
</tr>
<tr>
<td>No change</td>
<td>2 (23%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>3 (33%)</td>
<td>1</td>
</tr>
<tr>
<td>Felt Arousal Scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(from 14th min of ex to 60th min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>2 (23%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>7 (77%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(from 14th min of ex to 119th min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>4 (44%)</td>
<td>1-3</td>
</tr>
<tr>
<td>No change</td>
<td>4 (44%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (11%)</td>
<td>1</td>
</tr>
<tr>
<td>(from pre to post 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>5 (56%)</td>
<td>1-4</td>
</tr>
<tr>
<td>No change</td>
<td>3 (33%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (11%)</td>
<td>1</td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).
7.3.5 Physiological responses to the exercise protocol
Oxygen uptake, heart rate and % VO2 max did not differ between trials demonstrating that the participants were exercising at the same relative exercise intensity in both conditions. Heart rate during exercise ranged from approximately 158-170 beats min⁻¹.

7.3.6 Plasma glucose
Plasma glucose concentration was higher (6.1 ± 0.3 mmol l⁻¹ vs 5.4 ± 0.3 mmol l⁻¹; CHO vs PLA; interaction of treatment x time; F (2, 16) = 7.563; p<.05) in the CHO trial, compared to the PLA trial upon cessation of exercise. In the CHO trial, blood glucose concentration increased from pre exercise to immediately post-exercise. However in the PLA trial the concentration remained stable from pre exercise to post 0' and by 1 h post-exercise had fallen to a concentration lower than that observed pre-exercise (Figure 7.6).

Figure 7.6. Changes in plasma glucose concentration (mmol l⁻¹) upon cessation of exercise and 1 h post; * p<.05 CHO vs PLA.
7.3.7 Plasma cortisol

Plasma cortisol concentrations increased by 11% during the CHO trial (528 ± 23 nmol.l⁻¹ to 588 ± 74 nmol.l⁻¹) and by 24% (576 ± 46 nmol.l⁻¹ to 811 ± 153 nmol.l⁻¹) in the PLA trial but this increase was not statistically significant (F (1, 10) = 2.058; ns). Overall, post exercise cortisol concentration was higher in the PLA trial (main effect of treatment; F (1, 8) = 8.709; p<.05) (Figure 7.7) compared with the CHO trial.

![Figure 7.7. Changes in plasma cortisol concentration (nmol.l⁻¹) upon cessation of exercise and 1 h post; overall main effect of treatment, p< .05.](image)

7.3.8 Plasma lactate

Plasma lactate concentrations increased from pre exercise to post exercise (Main effect for time; F (1, 8) = 14.736; p< .05) (Figure 7.8). There were no interaction x time effects.

7.3.9 Diet

A nutrient analysis of the 2-day food records prior to each of the two exercise sessions revealed no differences in the energy intake and nutrient composition between conditions. The mean energy intake of the participants was 2322
kcal/day, with the proportion of energy being 61% from CHO, 24% from fat and 15% from protein.

Figure 7.8. Changes in plasma lactate concentration (mmol.l⁻¹) upon cessation of exercise.

7.3.10 Correlations between the FS and the RPE scale

Table 7.4 displays the correlations found between the FS and the RPE scale. All the correlations demonstrated a negative relationship, however, the only one significant correlation was reported at 90 min in the PLA trial.

Table 7.4 Correlations between the FS and RPE scale

<table>
<thead>
<tr>
<th>Time</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>-.61 (ns)</td>
<td>-.14 (ns)</td>
</tr>
<tr>
<td>30</td>
<td>-.22 (ns)</td>
<td>-.40 (ns)</td>
</tr>
<tr>
<td>45</td>
<td>-.02 (ns)</td>
<td>-.63 (ns)</td>
</tr>
<tr>
<td>60</td>
<td>-.07 (ns)</td>
<td>-.34 (ns)</td>
</tr>
<tr>
<td>75</td>
<td>-.36 (ns)</td>
<td>-.55 (ns)</td>
</tr>
<tr>
<td>90</td>
<td>-.02 (ns)</td>
<td>-.75*</td>
</tr>
<tr>
<td>105</td>
<td>-.02 (ns)</td>
<td>-.13 (ns)</td>
</tr>
<tr>
<td>120</td>
<td>-.26 (ns)</td>
<td>-.39 (ns)</td>
</tr>
</tbody>
</table>

* Correlation is significant at the p<.05 level
7.4 Discussion

The purpose of this study was to investigate the influence of ingesting a carbohydrate-electrolyte solution on psychological affect and perceived exertion during prolonged cycle exercise. Research has ignored the influence of CHO ingestion on affective responses during exercise, despite numerous studies in the literature examining its effects in resting individuals (Benton, 2002; Benton & Owens, 1993). This is perhaps surprising when one considers the increased peripheral glucose requirements during prolonged exercise and the demands the brain exerts for a continuous supply of blood glucose. It was hypothesised that in accordance with previous studies investigating CHO ingestion and RPE during cycling exercise (Burgess et al., 1991; Coggan & Coyle, 1987), a reduction in RPE will be observed following CHO ingestion. As in previous studies in this thesis and in accordance with the assertion of Hardy and Rejeski (1989), 'what' and 'how' a person felt was examined during the prolonged exercise session. This was facilitated by the administration of the Borg (1982) RPE scale, a measure of 'what' a person feels and the Feeling Scale (Hardy & Rejeski, 1989) as one of the measures of 'how' they feel. This is a new approach to CHO supplementation research, but it appears that how a person feels may be just as important in terms of cognition and behaviour (Ekman, 1994) and thus persistence at an activity and subsequently performance. Consistent with the preceding chapters repeated assessments of activation were obtained, before, during and following exercise, as measured by the Felt Arousal Scale (Svebak & Murgatroyd, 1985) and changes in energetic and tense arousal as measured by the AD ACL (Thayer, 1989) across exercise. For further details on these measures the reader is directed to Chapter 3.

Affect, assessed by the FS and FAS was plotted onto a two-dimensional Circumplex model, with the aim of recognising any salient changes occurring during the prolonged cycling session following CHO and PLA ingestion. Consistent with the work of Ekkekakis and Petruzzello (1999), a diversity of patterns and responses emerged as the exercise bout continued. This finding was facilitated through repeated in-task assessment of affect, which has not been common practice in the exercise psychology literature. Indeed, CHO ingestion
during prolonged cycling influenced 'what' the participant felt as measured by the RPE and 'how' they felt during exercise as measured by the FS. Affective valence was observed to shift in opposite directions when the CHO and PLA trials were compared, with participants in the PLA trial reporting a reduction in valence. However, in the CHO trial, improvement and maintenance of valence was reported and an impression of a more pleasurable exercise experience observed (Figure 7.3).

Despite the strenuous nature of this 120 min cycling protocol, the average values reported across both conditions for affective valence did not fall below a score of one. Indeed, when compared to the same time point in the prolonged run to fatigue protocol undertaken in our laboratory (Study 3) we can see that in this cycling study the average score on the FS is two values higher when the same time point is compared. This is an interesting finding when one considers that the relative intensity of exercise was the same for these studies. The aerobic fitness of the groups was also similar (Cycling: 64.7 ± 2.7 ml.kg\(^{-1}.\)min\(^{-1}\) v Running: 63.9 ± 2.3 ml.kg\(^{-1}.\)min\(^{-1}\)) and participants were well trained in the exercise mode performed in both studies. However, the contrast in self reported affective valence could be due in part to the differing demands that running and cycling place on the human body. Running involves a much larger muscle mass compared to cycling which places more demand on the legs rather than the arms and torso. Further, differences in the metabolic responses to running and cycling have been posited (Utter et al, 1999) as being responsible for the lack of improvement in endurance capacity and this explanation could apply to the inconsistent findings on the influence of CHO ingestion on effort sense. Moreover the nature of the protocol employed could explain these findings. It is plausible that in the present study, the fixed duration of the protocol could have enhanced the affective experience. In the cycling study at 90 min the participant would be aware that they only have 30min left but in the run to fatigue, the uncertainty of how much longer they were going to have to exercise at any of the time points (as a consequence of the run time being hidden from the participant) could have produced the lower reported affective valence.
The overall differences during exercise in affective valence between the CHO and PLA trials could be linked to the physiological changes observed following the 2 h exercise. Immediately post exercise, blood glucose concentrations were higher (p<.05) following the CHO trial. This finding may explain the increased self-reported affect following CHO ingestion because previous studies report that low blood glucose concentrations are associated with negative mood states (Gold et al., 1995; Gonder-Frederick, 1989; Krall, 1978); this is particularly the case with diabetic patients. Although participants in the PLA trial did not become hypoglycaemic, glucose concentrations were markedly lower. However, the advocacy of this mechanism in explaining the link between CHO ingestion and affect during exercise is still in question and no firm conclusions have been made. Nevertheless, in the present study, it cannot be ruled out as an influencing factor.

In addition, cortisol concentrations were higher in the PLA trial compared to the CHO trial upon cessation of exercise, which is consistent with the findings of Utter et al. (1999). They reported lower RPEs following CHO ingestion during the later stages of a 2.5 h cycle at ~75% \( \text{VO}_2 \text{ max} \) and lower cortisol concentrations. According to Morgan et al. (2001) such findings may indicate that the PLA trial was more stressful, both perceptually and physiologically. This hormone is often secreted in response to emotional stress and unpleasant sensations and this hormone itself could be involved in affecting the perception of exertion through a neurological mechanism (Utter et al., 1999), but this is yet to be determined. In the present study the perceived exertion findings would go some way to supporting such a hypothesis as there was an increased perception of exertion in the PLA trial after 75 min of exercise. This offers support to previous research that has reported a reduction in perceived exertion following CHO ingestion during prolonged cycling exercise (Burgess et al., 1991; Coggan & Coyle, 1987; Utter et al., 1999). Utilising Borg’s (1982) category ratio scales, Burgess et al. (1991) observed a reduction in perceived exertion at the site of the legs during the last hour of a 180 min cycle when CHO was ingested. In the present study blood glucose concentration was higher following exercise in the CHO trial upholding the assertion proposed by Coggan and Coyle (1989) that during cycling elevated circulating levels of blood glucose reduce the perceived exertion response.
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following CHO ingestion. Indeed, Burgess et al. (1991) also reported blood glucose concentration to be higher at all exercising time points apart from 60 and 90 min. However, Burgess et al. found that the impact on RPE was more sustained during the later stages of the 180 min cycle than in this present study that only reports a difference at 75 min but not thereafter. This could relate to the fact that Burgess et al. utilised category scales that focused on the legs, chest and torso region in addition to an overall rating scale. Only the legs scale produced any significant findings. Nevertheless, the present study offers support to the assertions (Burgess et al., 1991; Coggan & Coyle, 1987; Wilber & Moffatt, 1992) that elevated blood glucose concentration is a mediator in the intensity of perceived exertion. The finding of the present study and those just highlighted differ with the studies of Ivy et al. (1979) and Felig et al. (1982). Despite elevated circulating blood glucose concentrations during exercise following CHO supplementation, they observed no differences in RPE. It is still unclear why such discrepancy exists during cycling protocols, but differences in methodology have often been cited (Refer to Chapter 2 for a more detailed review on this topic).

Again, in support of Davidson and Irwin (1999), this study demonstrated the variability among individuals in the direction and intensity of the response to the exercise stimulus. For example, during the CHO trial, between minutes 14 and 119 there was an equal split in the directional change of FS, with 33% reporting an increase, a decrease and no change, whereas in the PLA trial, again 33% reported an increase, but 67% reported a decline. This offers confirmation of the ANOVA finding that participants in the CHO condition reported more positive affect. A similar trend was observed for the FAS with 44% reporting an increase in activation, 44% no change and 11% a fall in the CHO trial. In the PLA trial 23% increased, 33% remained constant and 44% declined in their reports of activation. Such variability in individual responses is important and should always be considered when undertaking research of this nature. This finding again highlights the issue that the traditional nomothetic assumptions of the exercise-affect relationship, i.e. most participants are expected to experience similar changes in affect in response to the same exercise stimulus. In support of these findings, Van Landuyt et al. (2000) also provided evidence that questions the assumption of a homogenous response because approximately half of the sample
in their study exhibited progressive improvements and half progressive deterioration during exercise.

This study again addressed the relationship between FS and RPE during the prolonged cycle and the correlation between RPE and FS. Studies 1, 2 and 3 have reported inconsistent findings, with a variety of significant and non-significant relationships emerging. The significant relationships have been negative and of a moderate to large nature. In the present study, only one significant relationship was noted at 90 min in the PLA trial. Such findings could be explained due to the fact that the sample size was relatively small.

Analysis on the AD ACL revealed that there was no significant change in EA as a result of exercise or treatment. However, the subscale energy was found to decline across both trials from pre exercise to post exercise. There were no differences observed between conditions, so the ingestion of CHO during exercise did not enhance the subjective energy reported by the participants following exercise. This perhaps could relate to the findings of previous studies undertaken with individuals at rest (Christensen, 1991; Thayer, 1987) which reported that the immediate reaction to CHO ingestion is enhanced energy or vigour, but this enhancement in affect is sometimes short lived and is followed by feelings of fatigue. Previous research has highlighted that CHO intake is associated with feeling less energetic about 2 h after ingestion (Benton & Owens, 1993) and that there may be a short term small increase in energy before this takes place in non exercising individuals. However, no studies to date have examined the relationship with exercising individuals. Furthermore, the ingestion of CHO during exercise had no impact on subjective fatigue. Interestingly, following high intensity intermittent exercise, Welsh et al. (2002) observed a greater decrease in fatigue following the PLA trial compared with the CHO trial. However, this was not replicated here. The items on the AD ACL that make up the fatigue subscale could answer this discrepancy if the participants did not relate to those words and identify with them and their mental state. In addition, the POMS does not measure energy per se, it uses the label ‘vigour’, making comparisons more difficult.
Consistent with the observations of previous studies (Study 1) it was once again clear that at the same sampling time, there are discrepancies between the FS/FAS scales and the AD ACL in their location of affect on the circumplex model. At the pre-time point there seems to be a commonality in the location in the pleasant unactivated quadrant, however, a discrepancy can be seen to exist at 15 min post exercise. The FS and FAS scales locate affect as being in the activated pleasant quadrant, yet according to the AD ACL, participants are reporting a state of unactivated pleasantness. It seems there is variation in the measuring tools, again along the activation dimension. The same is true for the 60 min post exercise time point. The FS/FAS combination reports higher activation than the AC ACL. As previously explained (Study 1) this could be due to the items on the AD ACL not being particularly relevant to the participant, or indeed, difficult to decipher and therefore the response does not reflect the true affective state. Anecdotally participants were unsure of the items `placid' and `calm'; for example a number of participants found it difficult to comprehend if they were placid, or indeed what it involved to have that feeling. Therefore participants may not have responded to these words accurately, which could impact on the scores on the activation dimension. There is also the issue of a dimensional finding originating from a categorical beginning, which is the case for the AD ACL. Participants have to respond to categorical words, which may or may not be relevant to them, and that is mapped in dimensional form at the end. However, with the single item scales, participants merely have to rate themselves on a dimension from high to low, or good to bad, which may be less open to poor interpretation and this type of measurement will always be relevant to all individuals.

In sum, by investigating both what and how a person feels during exercise following CHO ingestion, we observed that participants not only perceived the exertion of exercise to be lower following CHO ingestion but they also found it to be more pleasurable. Acevedo et al. (1994) state that an individual's cognition and affect during exercise can lead to a positive or negative evaluation of the task and the association between negative affect and impaired performance appears strong. This study suggests that the affective experience during prolonged cycling can be enhanced when CHO is ingested. This in turn may lead to an enhancement in both a cyclist's performance and persistence as a result. Therefore, athletes, coaches
and sport and exercise scientists can extrapolate from this study the observation that CHO ingestion during exercise also influences the athletes psychological state, as assessed by the FS, which adds to the already documented physiological, performance and exertion literature.
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Study Five

The influence of carbohydrate ingestion during high intensity intermittent shuttle running on affective states and effort sense

8.1 Introduction
The purpose of the present study was to examine the influence of ingesting a CHO-E solution on the core dimensions of affect, namely valence and activation, as well as effort sense during 90 min of high intensity, intermittent shuttle running (Nicholas et al., 2000). The Loughborough intermittent shuttle running test (LIST) was designed as a controlled field test to simulate the activity patterns observed during a game of soccer. It could prove to be a valuable measuring tool to assess changes in core affect during intermittent high intensity exercise, as it allows us to maintain sufficient control over the exercise regimen and environmental conditions.

Previous studies (Studies 1, 2, 3 and 4) have focused on the affective responses and ratings of perceived exertion elicited during prolonged submaximal exercise. Consequently this study aims to expand on those by investigating high-intensity intermittent shuttle running, characteristic of sports such as football. A number of studies have been undertaken that have investigated the influence of CHO ingestion on ratings of perceived exertion (Borg, 1982) during intermittent exercise (Nicholas et al., 1999). However, as emphasised previously, although this scale measures the participant’s perception of effort and exertion during exercise (Borg, 1982), it does not give any indication of whether the participant is finding the exercise pleasurable, nor does it examine the participant’s perceived activation, both of which may be important in determining motivation and persistence at an activity (Acevedo et al., 1994). Anecdotal reports in my
laboratory suggest that CHO ingestion exerts a 'feel good' effect, and this study was designed to examine such reports.

Therefore, the present study will incorporate a variety of self-report measures in order to assess the influence of CHO ingestion on affective responses and effort sense during prolonged high intensity intermittent exercise. It also serves to explore the influence of such an exercise protocol on these responses, because previous studies have focused on prolonged submaximal exercise.
8.2 Materials and Methods

8.2.1 Participants
Seventeen male soccer players (Mean ± SEM: age 21 ± 1 yrs, height 170 ± 10 cm, body mass 71.5 ± 1.4 kg, VO₂ max 59 ± 0.8 ml.kg.min⁻¹) volunteered to participate in this study, which had the approval of the Ethical Advisory Committee of Loughborough University. They were all semi-professional players, ex-professionals or at least university 1st/2nd team standard. They undertook regular training sessions and match play.

8.2.2 Measures of affect
The Feeling Scale (FS; Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: Svebak & Murgatroyd, 1985) and AD ACL (Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered pre-LIST, every 15 min throughout the LIST (during the last walk stage of each 15 min block) upon cessation of block 6, post-LIST skills test and 15 min post-exercise (Figure 8.1). The AD ACL was administered before the LIST, post-LIST skills tests and then 15 min afterwards (see Figure 8.1).

8.2.3 Rating of perceived exertion
The rating of perceived exertion scale (RPE; (Borg, 1982) was used as a measure of perceived exertion during exercise, as previously described (Chapter 3). It was administered every 15 min during the LIST (during the last walk stage of each 15 min block).

8.2.4 Preliminary procedures
Participants performed preliminary tests to: (i) predict VO₂ max in order to calculate the relative exercise intensities as previously described (Chapter 3) and (ii) to familiarise themselves with the experimental procedures and determine their height and body mass.
8.2.5 Experimental procedures

Two main trials, separated by at least 7 days were undertaken. The order of trials was randomised to counteract any possible order effects. As described in chapter 3, participants recorded their food intake for the 2 days prior to the first main trial and then repeated this intake prior to the second trial.

Participants arrived at the laboratory following a glycogen depleting protocol the previous evening and a low CHO meal. This was then followed by an overnight fast. The glycogen depletion protocol was designed to reduce the glycogen content in both Type I and Type II muscle fibres. The protocol was based on a model suggested by Vollestad and colleagues (1992). The protocol involved 1 h 15 min of submaximal cycling and 3, 50 s sprints, with rest intervals in between. The participants were provided with 2ml.kg⁻¹.BM of water before and after every 15 min of exercise to offset dehydration.

Upon arrival the following morning, participants completed the battery of affect questionnaires as described in chapter 3. The participant’s body mass was then determined and a resting blood and expired gas sample was taken. Participants then undertook a soccer specific skills test and following its cessation, were provided with the test drink. In the CHO trial participants ingested a commercially available sports drink containing 6.4% CHO (Lucozade Sport, GlaxoSmithkline, Brentford). In the PLA trial participants were provided with a non-electrolyte artificially sweetened placebo (See Chapter 3). Both solutions looked and tasted the same and were manufactured by the same company (GlaxoSmithkline, Brentford). Prior to the onset of the LIST (for further detail on the LIST refer to Chapter 3) participants ingested a bolus equivalent to 8ml.kg⁻¹.BM and then 3ml.kg⁻¹.BM after every 15 min of exercise.

Following consumption of the initial fluid bolus participants completed six 15 min blocks of the LIST. Each block was separated by 4 min rest periods. During these 4 min periods, participants undertook a skills test (passing), then ingested 3ml.kg⁻¹.BM of the test drink. The FS and FAS were administered during the last walk stage of each 15 min block of the LIST, along with the RPE (See fig 8.1). Expired air samples were collected using the modified Douglas bag method (Chapter 3).
again towards the end of each block of the LIST. A whirling hygrometer was used to measure the environmental temperature prior to exercise and during the last walk phase of each 15min block of exercise (Chapter 3). Heart rate was monitored constantly throughout exercise via short-range telemetry (Chapter 3). Participants were encouraged to maintain the pace set by the audio signals and to perform maximally during the sprints. Upon completion of the LIST participants were given a brief rest period (~5min) prior to the post-LIST skill tests. Following completion of the skills test participants were administered the FS, FAS and AD-ACL. They then towel dried to remove any excess sweat and nude body mass was determined. After 15 min of quiet rest, participants again completed the FS, FAS and AD-ACL.

8.2.6 Blood sampling
Blood samples were withdrawn from an indwelling venous cannula (Chapter 3) in volumes of 10ml at rest, and after 30, 60 and 90 min of the LIST. Blood was dispensed, treated and stored as previously described (Chapter 3).

8.2.7 Statistical analyses
The procedures used were the ones described under statistical analysis in Chapter 3. The results are presented as mean (SEM). Statistical significance was accepted at $p<.05$. 

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Figure 8.1. Schematic representation of the LIST and experimental design.
8.3 Results

8.3.1 Changes in affective valence and activation

Table 8.1 shows the changes in FS before, during and following the LIST. There was a main effect of time ($F_{3,43} = 4.295, p<.05$) for the valence responses, with significantly higher ratings post-skills tests ($1.9 \pm 0.4$) and 15 min after the skills test ($2.4 \pm 0.3$) than after block 6 ($0.6 \pm 0.5$). Such an effect reflects the rebound pattern (Figure 8.2b) observed following the last block of the LIST (block 6) to post skills and 15 min post (Figure 8.2a). Although FS ratings appeared to be higher towards the end of the LIST in the CHO trial, there was no effect of condition or interaction of treatment x time (Figure 8.2a).

Table 8.1. Descriptive statistics (Mean ± SEM) of the FS and FAS before, during and following the LIST.

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th>FAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHO (M ± SEM)</td>
<td>PLA (M ± SEM)</td>
</tr>
<tr>
<td>Pre</td>
<td>1.7 ± 0.5</td>
<td>1.4 ± 0.5</td>
</tr>
<tr>
<td>Block 1</td>
<td>1.2 ± 0.3</td>
<td>1.1 ± 0.4</td>
</tr>
<tr>
<td>Block 2</td>
<td>1.5 ± 0.4</td>
<td>1.3 ± 0.4</td>
</tr>
<tr>
<td>Block 3</td>
<td>0.8 ± 0.5</td>
<td>0.7 ± 0.3</td>
</tr>
<tr>
<td>Block 4</td>
<td>0.7 ± 0.5</td>
<td>0.7 ± 0.4</td>
</tr>
<tr>
<td>Block 5</td>
<td>0.7 ± 0.6</td>
<td>0.3 ± 0.6</td>
</tr>
<tr>
<td>Block 6</td>
<td>1.2 ± 0.7</td>
<td>0.1 ± 0.7</td>
</tr>
<tr>
<td>Post skills</td>
<td>1.7 ± 0.6</td>
<td>2.2 ± 0.6</td>
</tr>
<tr>
<td>15 min post</td>
<td>2.4 ± 0.5</td>
<td>2.5 ± 0.4</td>
</tr>
</tbody>
</table>

Table 8.1 shows the changes in FAS before, during and following the LIST. A main effect of time ($F_{3,52} = 7.001, p<.01$) and an interaction of condition x time ($F_{4,67} = 3.216, p<.05$) was found across the assessment period. Significantly higher responses were observed in the CHO trial following blocks 5 ($4.1 \pm 0.3 \text{ vs. } 3.0 \pm 0.3, \text{CHO vs PLA, } p<.05$) and 6 ($3.8 \pm 0.4 \text{ vs. } 2.7 \pm 0.4, \text{CHO vs PLA,}$
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CHO Ingestion and HIIT Exercise

$p<.05$; Figure 8.2) of the LIST. This corresponds to the final 30 minutes of exercise. Figure 8.4, illustrates this finding, because during the CHO trial, participants report a state of activated pleasantness at each block, however in the PLA trial, during blocks 3-6 a state of deactivated pleasantness was reported.

Figure 8.2 a). Changes in affective valence during and following the LIST, displaying a temporal pattern characteristic of a rebound model. b). Rebound model (Bixby, Spalding, & Hatfield, 2001).

8.3.2 Changes in energetic and tense arousal

Table 8.2 shows the changes in EA, TA and the subscales before and following the LIST and skills test. The alpha coefficient for the EA scale was 0.87 and for the TA scale 0.83 indicating high internal consistency. The alpha coefficients of the energy, tiredness, tension and calmness subscales were 0.84, 0.85, 0.83, 0.81 respectively. Analysis on the EA scores revealed no significant main effect for time or condition. For TA, there was a main effect of time ($F_{2,32} = 5.237, p<.05$), however post hoc analysis revealed no significant sampling point changes, only overall changes across both conditions. There was no interaction of treatment x time.
Figure 8.3. Changes in affective valence (FS) and activation (FAS) before, during and following the LIST plotted in circumplex space.

Figure 8.4 Activation (FAS) before, during and following the LIST and skills test. * post-hoc difference, p<0.05, CHO vs PLA).
Table 8.2. Descriptive statistics (Mean ± SEM) of the AD ACL items and subscales before and following the LIST.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>19.9 ± 1.4</td>
<td>20.1 ± 1.1</td>
<td>9.1 ± 0.8</td>
<td>14.2 ± 0.8</td>
<td>7.7 ± 0.9</td>
<td>12.6 ± 0.8</td>
</tr>
<tr>
<td>Post skills</td>
<td>18.8 ± 1.4</td>
<td>20.8 ± 1.1</td>
<td>8.3 ± 0.8</td>
<td>14.4 ± 0.8</td>
<td>7.2 ± 0.5</td>
<td>11.5 ± 0.7</td>
</tr>
<tr>
<td>Post 15</td>
<td>17.8 ± 1.2</td>
<td>16.6 ± 0.8</td>
<td>7.5 ± 0.7</td>
<td>14.7 ± 0.8</td>
<td>5.8 ± 0.4</td>
<td>14.2 ± 0.8</td>
</tr>
<tr>
<td>PLA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>20.1 ± 0.8</td>
<td>18.8 ± 1.0</td>
<td>9.6 ± 0.8</td>
<td>14.6 ± 0.8</td>
<td>7.3 ± 0.8</td>
<td>13.4 ± 0.9</td>
</tr>
<tr>
<td>Post skills</td>
<td>19.1 ± 1.6</td>
<td>21.8 ± 1.3</td>
<td>8.5 ± 0.9</td>
<td>14.4 ± 0.8</td>
<td>7.9 ± 0.5</td>
<td>11.4 ± 0.8</td>
</tr>
<tr>
<td>Post 15</td>
<td>18.2 ± 1.4</td>
<td>18.8 ± 0.9</td>
<td>8.5 ± 0.9</td>
<td>15.4 ± 0.7</td>
<td>7.0 ± 0.6</td>
<td>12.9 ± 0.6</td>
</tr>
</tbody>
</table>

8.3.3 Individual Responses

Change scores were compared for the FS and FAS from block 1 of the LIST (i.e. the first during exercise assessment) to block 3 (the mid-point of the protocol) of the LIST, from block 1 to block 6 (i.e. the last minute of exercise) of exercise and from pre exercise to post skills. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response with each category are shown in Table 8.3.

The results indicate that the individual change trends did not exhibit a pattern of homogeneity at any of the time points with the FS and FAS. Specifically, from block 1 to block 6 of the LIST in the CHO trial, 47% of participants reported an increase, 35% a decrease and 18% no change in valence. This compares to 24% reporting an increase, 53% a decrease and 24% remained unchanged in the PLA trial. A similar response pattern emerged from block 1 to block 3 of the LIST and from pre to post skills. Again with the FAS a uniform response to the exercise stimulus was not displayed.
However, the change between block 1 and block 3 was exactly the same in terms of the percentage of participants that perceived an increase, decrease or no change in activation. The change trends in FAS between block 1 and block 6 support the reported ANOVA findings. In the PLA trial, 70% of individuals reported a reduction in activation, compared to only 47% in the CHO trial, supporting the observation.

Figure 8.6 shows the affective response patterns for four of the participants in this study, plotted in circumplex space. The patterns of change can be contrasted between individuals and it is clear to see that the response trajectories are very different between these participants in the way that they respond to the valence and activation dimensions. Subject A appears to have the largest degree of arousal focus and subject B a larger degree of valence focus.
Table 8.3. Frequency and magnitude of individual affective responses to the LIST.

<table>
<thead>
<tr>
<th>Scale</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Feeling Scale (Block 1-block 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>6 (35%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>3 (18%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>8 (47%)</td>
<td>1-3</td>
</tr>
<tr>
<td>(Block 1-block 6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>8 (47%)</td>
<td>1-4</td>
</tr>
<tr>
<td>No change</td>
<td>3 (18%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>6 (35%)</td>
<td>1-7</td>
</tr>
<tr>
<td>(from pre to post skills)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>8 (47%)</td>
<td>1-5</td>
</tr>
<tr>
<td>No change</td>
<td>3 (18%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>6 (35%)</td>
<td>2-6</td>
</tr>
<tr>
<td>Felt Arousal Scale (Block 1-block 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (18%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>7 (41%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>6 (35%)</td>
<td>1-3</td>
</tr>
<tr>
<td>(Block 1-block 6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>6 (35%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>3 (18%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>8 (47%)</td>
<td>1-3</td>
</tr>
<tr>
<td>(from pre to post skills)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>7 (41%)</td>
<td>1-3</td>
</tr>
<tr>
<td>No change</td>
<td>1 (6%)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>9 (53%)</td>
<td>1-3</td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).
Figure 8.6. Affective response patterns for four participants, plotted in circumplex space.
8.3.4 Rating of perceived exertion

Rating of perceived exertion increased over time ($F_{2,27} = 38.637; p<.01$) with the mean value during each block of exercise being significantly higher than the previous one (Figure 8.7). An interaction of condition x time was found ($F_{4,56} = 3.091, p<.05$), but there were no differences at any sampling times between conditions.

![Figure 8.7. Rating of perceived exertion during each 15 min block of the LIST.](image)

8.3.5 Physiological responses to the exercise protocol

Oxygen uptake, heart rate and %\( \dot{V}O_2 \) max did not differ between trials demonstrating that the participants were exercising at the same relative exercise intensity in both conditions. Expressed in terms of %\( \dot{V}O_2 \) max, the relative exercise intensity averaged 77.6 ± 0.68 in the CHO trial and 77.3 ± 0.69 in the PLA trial. Heart rate during exercise ranged from approximately 158-170 beats.min\(^{-1}\).
8.3.6 Plasma glucose

Plasma glucose concentration was maintained above resting values during the CHO trial, but a marked fall in the PLA condition was observed after 30 min of exercise; significant differences were found at 60 and 90 min (5.4 ± 0.2 vs 4.6 ± 0.2 mmol.l⁻¹ [60 min]) (5.2 ± 0.1 vs 4.0 ± 0.3 mmol.l⁻¹ [90 min]) CHO v PLA (F₃, 27 = 9.612, p< .05 and p< .01) respectively (Figure 8.8).

![Figure 8.8. Changes in plasma glucose concentration (mmol.l⁻¹) during the LIST; (* p< .05 CHO vs PLA; ** p< .01 CHO vs PLA).](image)

To assess the influence of changing plasma glucose levels during the experiment on affective states the participants across both trials were classified according to the change in their plasma glucose concentrations. This was carried out using the pre exercise plasma glucose value and the final assessment figure (90 min of exercise). The groups were formulated on the following basis;

PG Rising: those participants whose plasma glucose had fallen by 1 mmol.l⁻¹ or more (in this case 5).

PG Maintenance; those participants who did not fit into the rising or falling categories (in this case 13).
PG Falling; those participants whose blood glucose had risen by 1 mmol/l⁻¹ or more (in this case 2).

In the case of the FAS, when represented graphically according to changes in plasma glucose (Figure 8.9), those participants where an increase in plasma glucose was observed were associated with a rise in FAS, whereas those that experienced a fall or maintenance profile were associated with a fall in activation.

With the FS, the association appears to be more striking (Figure 8.10), with FS remaining stable in the rising category, but decreasing to negative values on the FS scale when plasma glucose fell (>1.0 mmol/l⁻¹).

Figure 8.9. The effect of rising and falling plasma glucose on self reported activation before and at 90 min into exercise.

Figure 8.10. The effect of rising and falling plasma glucose on self reported affective responses before and at 90 min into exercise.
8.3.7 Plasma cortisol

Initially cortisol concentration decreased from rest until 60 min into exercise (main effect for time, $15.9 \pm 0.6$ vs $10.8 \pm 0.8 \, \mu g.dl^{-1}$ rest vs 60 min, $F_{3,30} = 14.607; p< .01$) but until 90 min it increased (main effect for time, $10.8 \pm 0.8$ vs $13.6 \pm 1.4 \, \mu g.dl^{-1}$ 60 vs 90 min, $F_{3,30} = 14.607; p< .05$). When examined separately there was a trend for maintenance in cortisol in the CHO trial, but a continued rise during exercise in the PLA condition (interaction of treatment x time, $F_{1,10} = 3.663; p=0.08$, n.s) (Figure 8.11).

8.3.8 Diet

A nutrient analysis of the 2-day food records prior to each of the two exercise sessions revealed there were no differences in the mean daily energy intake ($10.9 \pm 0.7 \, MJ$ and $11.2 \pm 1.0 \, MJ$, CHO v PLA trials respectively) or CHO content ($396 \pm 36 \, g$ and $386 \pm 44 \, g$, CHO v PLA trials respectively).
**8.3.9 Correlations between the FS and the RPE scale**

Table 8.4 displays the correlations between the FS and the RPE scale at the various time points sampled during the LIST protocol. Significant correlations were noted from block 3 onwards. A moderate to strong negative relationship was demonstrated with increases in RPE being associated with decreases in valence.

Table 8.4 Correlations between the FS and RPE scale

<table>
<thead>
<tr>
<th>Time</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>-.16</td>
<td>-.45</td>
</tr>
<tr>
<td>Block 2</td>
<td>-.17</td>
<td>-.37</td>
</tr>
<tr>
<td>Block 3</td>
<td>-.51*</td>
<td>-.61**</td>
</tr>
<tr>
<td>Block 4</td>
<td>-.50*</td>
<td>-.57*</td>
</tr>
<tr>
<td>Block 5</td>
<td>-.52*</td>
<td>-.68**</td>
</tr>
<tr>
<td>Block 6</td>
<td>-.27</td>
<td>-.58*</td>
</tr>
</tbody>
</table>

**Correlation is significant at the p<.01 level; * Correlation is significant at the p<.05 level.
8.4 Discussion

The present study was, to my knowledge, the first to examine the influence of CHO ingestion on the core dimensions of affect, namely valence and activation, during intermittent high-intensity shuttle running (IHI) exercise. Research has ignored the influence of CHO ingestion on affective responses during exercise, despite numerous studies in the literature examining its effects in resting individuals (Benton, 2002; Benton & Owens, 1993). The main finding was that the ingestion of a CHO-E solution before and during IHI exercise led to an enhanced perception of activation, as measured by the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985) when compared to the PLA trial. Specifically, activation was higher in the CHO trial throughout the final 30 min of exercise (Figure 8.4). Plotting the FS and FAS in circumplex space (Figure 8.3) further illustrates this finding. Towards the end of exercise (blocks 4-6 of the LIST) in the CHO trial, participants reported an activated pleasant state, which is associated with feelings of excitement and enthusiasm. In contrast, in the placebo trial during blocks 3-6 of the LIST, participants were located in the deactivated pleasant quadrant, and feelings of relaxation and calmness are characteristic of this state. Therefore based on the results of the present study, it appears that during high intensity shuttle running, the ingestion of CHO exerts a positive influence on perceived activation during the later stages of exercise. The LIST is a test that is designed to simulate the minimum physical demands faced by football players during a game and therefore such a finding is interesting. The sensation of activation is often recognised as a readiness to perform, and this could be a vital component of performance in a game like football, where complex perceptual information about decisions relating to player positions and timing of tackles and passes etc, have to be made. However, despite the ingestion of CHO leading to a higher sensation of activation, one must consider the fact that there is no information that allows the identification as to whether or not it was an appropriate activation state for that player. Future studies investigating IHI and CHO ingestion could address this further.
It is plausible that we noted a change in activation in this study and not the previous studies due to the fact that prior to completing this trial, participants undertook a glycogen depleting protocol the night before the trials (for details see section 8.2.6). Consequently, ingesting a CHO solution throughout the exercise bout, compared to a PLA solution, could have had a greater impact on self-reported activation because of the reduced glycogen levels of the individuals prior to exercise. The CHO solution would have supplied the participant with an exogenous source of CHO, which is reflected in the blood glucose profiles, described later. This rationale is based on speculation and no firm conclusions can be made. Future research studies should continue to consider the influence of prior nutritional status and its impact on affective states during exercise.

To my knowledge, a study undertaken by Welsh et al. (2002) is the only one in the literature that has examined the acute effects of CHO ingestion on affective states during high-intensity intermittent shuttle running exercise. However, they adopted a categorical approach in their measurement and utilised the POMS (McNair, Lorr, & Droppleman, 1981) which does not examine core affect, but rather mood states. Due to the lack of information relating to CHO ingestion on affective responses and effort sense during prolonged intermittent high intensity shuttle running, it is difficult to compare the findings of this study with others in the literature. However, it is hoped that this thesis will encourage exercise physiologists to consider this aspect when conducting their experiments because as scientists concerned with human behaviour and exercise performance, we must consider both the physiological and psychological aspects.

The observation of an enhanced sensation of activation during the later stages of exercise in the CHO trial corresponds to significant differences in blood glucose concentrations. Specifically, glucose concentrations were higher at 60 and 90 min during the CHO trial. As highlighted, Welsh et al. (2002) undertook a protocol involving IHI exercise, that attempted to simulate the demands of a basketball game. It was divided into four quarters of 15 min, separated by a 20 min half time rest period, and then participants completed a run to fatigue. They ingested an 18% CHO solution prior to exercise and a 6% CHO solution at regular intervals.
during the session. Welsh and colleagues also reported an increase in blood glucose concentrations in the CHO trial during the second half of the exercise protocol. However, the only significant difference in the psychological status of the participants was observed for the sensation of fatigue, a subcomponent of the POMS. It was reported to be lower (p=.048) in the CHO trial upon fatigue compared to the PLA trial. Despite regular sampling during the exercise bout, there were no differences in any of the remaining variables, including the one positive sensation of vigour. Still, results from the present study support the assertions of Davis and colleagues (2000) that the blood profile could be a possible mediator of enhanced CNS function during vigorous exercise with CHO ingestion. Glucose is clearly an important energy source for the brain, especially in those areas most active during strenuous exercise (Welsh et al., 2002). Lieberman (2002) further asserts the importance of glucose in that the brain requires a constant supply, and during prolonged exercise, such as that undertaken in this study, the peripheral glucose requirements increase. One could speculate that due to the fact that the participants began the protocol in a glycogen depleted state to begin with, ingesting CHO before and during exercise resulted in a more pronounced effect on activation than previously reported. Lieberman (2002) observed that during a more extreme protocol, which included a 19.3km march and two 4.8 km runs, interspersed with rest periods, participants that ingested a CHO solution during the study reported less confusion and greater vigor. Finally, Benton and Owens (1993) carried out one of the few studies at rest that measured affect acutely (after 14 min or 30 min) following CHO ingestion. In studies at rest it has been common to only assess affect after 2 h, and at this time point, participants have commonly reported feelings of lethargy and calmness (Smith et al., 1988; Spring et al., 1989). However, Benton and Owens, as a consequence of their acute measurement found that the sugar containing drink elicited an increase in self reported energy. This is consistent with the work of Thayer (1987a). Therefore, in the present exercising study, the ingestion of CHO appears to have exerted its influence on activation during the latter stages of the protocol, and this corresponds to a time of enhanced blood glucose concentration. When participants were divided into categories of rising and falling blood glucose, it was interesting to note through graphical representation (Figure 8.9) that only in the rising category was activation found to increase.
Affective valence did not significantly improve from pre to post exercise. However, due to the methodology adopted whereby core affect was repeatedly assessed during exercise, a rebound effect consistent with previous investigations (chapters 4, 5, 6 & 7) was again observed. Affective valence was higher following the skills test in the PLA trial, and 15 min following exercise in both trials compared to the final in-task assessment. This rebound effect again supports the work of Bixby et al. (2001), and the assertions by Ekkekakis (2003), and reinforces the importance of repeated sampling during exercise. If a pre-post design had been adopted, this phenomenon would have been missed and one would be misled into believing that the affective responses had remained fairly unchanged. Indeed, there was a shift towards negative affectivity during the latter stages of exercise and consequently upon cessation of exercise, affective valence was observed to improve back to pre-exercise levels. In the present study, such an improvement in valence could be the result of ensuing relief in completing such a demanding protocol, and the satisfaction of being able to do so. Further, although no significant improvements were made from pre to post exercise, it was interesting to note that the negative affects states elicited towards the end of exercise disappeared quickly, highlighting the transient nature of affective responses.

During this high intensity shuttle running protocol, ratings of perceived exertion were not influenced by the ingestion of CHO. A trend was evident for RPE values to be better maintained during the last 30 min of exercise in the CHO trial, whereas they continued to increase in the PLA trial. However, such a difference was not significant and is in agreement with the previous study on prolonged running. The results are also consistent with previous reports by McGregor et al. (PhD thesis) and Nicholas et al. (1999) who observed no differences in RPE when ingesting a 6.4% CHO electrolyte solution, compared to a flavoured placebo during studies utilising the LIST. There have been clear and strong relationships shown between ratings of perceived exertion and blood glucose during exercise (DeMarco et al., 1999). However, in the present study, it seems that despite an elevation in blood glucose concentration, which has been posited as a strong mediator of effort sense, particularly during cycling exercise, it did not significantly reduce the participants’ sensation of effort. Therefore, this study
serves to highlight once again the equivocal nature of the relationship between CHO ingestion and RPE. In the literature the most consistent findings do indeed emerge from studies that employ cycling as the mode of exercise and this thesis appears to support that.

As with the other studies in this thesis, the relationship between the FS and the RPE scale was examined. A more consistent pattern emerged in this study, with significant correlations occurring from block 3 of the LIST onwards. The only exception to this was during the final block of the LIST in the CHO trial. It is unclear why this time point was not significant. In support of all the significant correlations reported in the previous studies, a negative relationship was found. As perceptions of exertion increased, valence ratings decreased. From blocks 3 to 5 of the CHO trial, and block 3 to 6 of the PLA trial, the relationship was of a moderate magnitude (range -.50 to -.68). Again, the findings confirm the conclusions of Hardy and Rejeski (1989) that from a phenomenological perspective, there is a difference between what one feels and how one feels at varying intensities of work.

An analysis of individual changes during and following this protocol again revealed that the response patterns were not homogenous which is consistent with previous studies (Chapters 4, 5 & 7). If we compare the early stages of exercise, it is clear that there is a large variability in the individual responses to the same exercise stimuli. For example, during the CHO trial 36% reported an increase in valence, 47% a reduction and 18% remained stable. The same variability was evident in the PLA trial (Table 8.3), although the percentages that increased, decreased and remained the same were slightly different. This variability in responses to the same exercise stimuli is interesting to note because all participants were of comparable fitness and playing level as they all represented the university first or second team. This study again demonstrates that individual differences are found in the self-reported structure of affect and this is supported by the study of Feldman (1995). Individual differences in the structure of affect can be interpreted as variations in both valence and arousal focus, or in the degree to which individuals attend to and report the hedonic and arousal components of their affective experience (Feldman, 1995). In the present study, and the studies
already reported, the exercise setting may have exerted an influence on the affective component. As Frijda (1986) suggests, the valence of an affective state has been linked with the tendency to view a situation as personally relevant. It could be that, in this instance, some of the participants were able to view the laboratory based setting and exercise protocol as a relevant exercise setting, whereas others may perceive it to be a false environment and consequently would only experience valence in the field. In terms of the valence focus, personality trait differences could also offer some explanation as the trait “affect intensity” (Larsen et al., 1987) is associated with the tendency to be emotionally responsive to the environment. Personality traits were not determined in the present study, and future research during exercise should incorporate such an assessment.

According to Blascovich et al. (1992) some individuals are dispositionally hypersensitive to their arousal states, whereas others are hyposensitive. Internal cues are attended to when labelling their affective states in hypersensitive individuals, whereas hyposensitive people look to external (environmental) cues to label affect. This is perhaps a significant concept when one considers the exercise setting. Some of the participants taking part in this study and those previously described may be good at experiencing and recognising their physiological reactivity or actual physiological arousal to the exercise stimulus. As a consequence, during exercise, those good internal perceivers might display a large degree of arousal focus, in contrast to those that are not as good at perceiving their internal state. Thus “individuals may vary in their integration of information about their internal state with information about their immediate environment…valence focus and arousal focus may be related to allocating attention to environmental and internal stimuli respectively” (Feldman, 1995, p.163). This is an important consideration when examining the exercise-affect relationship and the influence of potentially mediating factors such as nutritional supplementation.

In summary, our results indicate that the ingestion of a CHO solution during 90 min of IHI exercise appears to elicit a favourable psychological profile, specifically, enhanced activation levels, during the latter stages of exercise. The mechanisms responsible for such findings are not entirely clear, however, a
favourable metabolic profile, including enhanced blood glucose concentration, is appealing.
Chapter IX

Study Six

The influence of carbohydrate ingestion during high intensity intermittent shuttle running to fatigue on affective states and effort sense

9.1 Introduction

The studies that have revealed a general improvement in participants' affective states following a single bout of exercise, have essentially been limited to moderate intensity exercise of short duration (Petruzzello & Tate, 1997; Yeung, 1996). As highlighted throughout this thesis there has been limited research undertaken on prolonged, moderate to high intensity exercise, in particular intermittent high intensity exercise. The exercise-affect literature is void of such study designs, which is surprising when one considers the fact that many individuals regularly take part in high intensity intermittent exercise, such as football, at an elite and recreational level. Furthermore, although more studies are beginning to investigate the influence of CHO-E solutions on prolonged, high intensity intermittent running (Nicholas et al., 1999; Nicholas et al., 1995), only the study by Welsh and colleagues (2002) to date has included some mood state measures during the experiment, as an adjunct to Borg's RPE scale. The previous study (Chapter 8), which examined the influence of a commercially available isotonic CHO-solution, observed a differential effect on perceived activation and self-reported energy, between the CHO and PLA solutions. No differences were observed in the valence responses or the perceived exertion rating.

Therefore, the purpose of the present study was to again repeatedly sample affect before, during and following a prolonged high intensity intermittent running protocol to fatigue. Study 3 also involved participants running to fatigue, however, this was undertaken on a motorised treadmill at a constant pace, so it will be interesting to examine whether a deactivated unpleasant state is also reported
following IHI exercise to fatigue. The influence of ingesting a CHO-E solution on such responses was once again examined, and the same hypotonic CHO solution (GlaxoSmithKline) administered in Study 3 was used in this investigation. In the prolonged run to fatigue study, no reported differences emerged in the affective and perceptual responses elicited between the CHO and PLA trials. In addition performance time was not affected.
9.2 Materials and Methods

9.2.1 Participants
Twelve recreationally active males (Mean ± SEM; age 20.8 ± 0.5 yrs; height 175 ± 2 cm; body mass 74.7 ± 2.5 kg; \( \dot{V}O_2 \) max 57.5 ± 1.3 ml.kg\(^{-1}\).min\(^{-1}\)) volunteered to participate in this study, which had the approval of the Ethical Advisory Committee of Loughborough University.

9.2.2 Measures of affect
The Feeling Scale (FS; Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: Svebak & Murgatroyd, 1985) and AD ACL (Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered before exercise, every 15 min throughout the LIST (during the last walk stage of each 15 min block) upon fatigue and 15 min post-exercise. The AD ACL was administered before exercise and then at fatigue and 15 min post exercise. The post-exercise assessment times were limited to 15 min post in this study because of constraints imposed by the experimental protocol.

9.2.3 Rating of perceived exertion
The rating of perceived exertion scale (RPE; (Borg, 1982) was used as a measure of perceived exertion during exercise, as previously described (Chapter 3). It was administered every 15 min during the LIST (during the last walk stage of each 15 min block).

9.2.4 Preliminary procedures
Participants performed preliminary tests to: (i) predict \( \dot{V}O_2 \) max in order to calculate the relative exercise intensities as previously described (Chapter 3) and (ii) to familiarise themselves with the experimental procedures and determine their height and body mass.
9.2.5 Experimental procedures

Two experimental trials were performed, separated by at least 7 days in a randomised double blind, crossover design. The order of trials was randomised to counteract any possible order effects. As described in chapter 3, participants recorded their food intake for the 2 days prior to the first main trial and then repeated this intake prior to the second trial.

On each occasion participants consumed either a 6.5% hypotonic carbohydrate-electrolyte solution (Glaxo-SmithKline) or a placebo solution, which was manufactured to replicate the test solution and contained electrolytes. Solutions were administered immediately prior to the trials (5 ml.kg\(^{-1}\) BM) and then at 15 min intervals (2ml.kg\(^{-1}\) BM) during exercise until cessation of Part A of the protocol.

Participants were asked to refrain from strenuous exercise, caffeine and alcohol during the 2 days prior to the first trial. Participants reported to the laboratory after an overnight fast (~10 h) and voided prior to the measurement of nude body mass. An indwelling cannula (Venflon, 16-18G, Ohmeda, Hatfield, Herts, UK) was inserted into an antecubital vein and kept patent with infusion of sterile saline. A standing position was assumed by the participants 15 min before the resting blood sample was taken. Further, resting heart rate was monitored and expired air collected over a 5 min period. All participants completed a standardised 15 min warm up which consisted of jogging, striding, soccer specific movements and stretching.

The protocol comprised 2 parts, Part A and Part B. Part A was of fixed duration and consisted of five blocks of the LIST (see Chapter 3), separated by 3 min recovery. During the recovery periods, participants responded to the FS, FAS and RPE scales and blood samples were taken. Participants also ingested the test drink during this time period. Expired air samples were collected for one complete cycle (~80s) of each 15 min LIST period as described in the general methods section. Heart rate was monitored every 15s during exercise using short-range telemetry.
(Polar Electro Sports Testers PE3000, Polar Electro, Kempele, Finland), and the mean was recorded for each 15 min exercise period.

Part B was designed to facilitate glycogen depletion and comprised alternate 20 m shuttles; 2 shuttles at 95% \( \dot{V}O_2 \text{max} \) followed by 2 at 55% \( \dot{V}O_2 \text{max} \). This continued until the participant was unable to maintain the desired running speed, at which stage the participant was withdrawn and testing ceased. Upon fatigue and 15 min post exercise participants responded to the FS and FAS scales.

9.2.6 Blood sampling and analysis
An 11ml blood sample was taken at rest, at 15min intervals during Part A of the protocol and at fatigue. See Chapter 3 for further details.

9.2.7 Statistical analysis
Results were analysed as described under statistical analysis (Chapter 3). Values are presented as mean (SEM).
Figure 9.1. Schematic representation of LIST to fatigue protocol.
9.3 Results

9.3.1 Changes in affective valence and activation
Table 9.1 shows the changes in FS before, during and following the LIST to fatigue. There was a main effect for time for affective valence, as measured by the FS from pre- to post-exercise ($F_{2, 22} = 10.860, p<.01$). Post hoc analysis revealed that across both trial, FS decreased from pre-exercise to fatigue ($1.17 \pm 0.6$ vs. $-1.83 \pm 0.6$) (Figure 9.2). A rebound effect was observed, FS ratings were significantly higher 15 min post-exercise (CHO $0.58 \pm 0.6$; PLA $0.83 \pm 0.4$) compared to fatigue (CHO $-2.08 \pm 0.6$; PLA $-1.58 \pm 0.8$) across both trials ($F_{3, 53} = 4.567, p< .01$) (Figure 9.2). Analysis of affective changes during exercise, revealed that affect decreased ($F_{2, 21} = 7.561, p<.05$) as the duration of exercise increased.

Table 9.1 shows the changes in FAS before, during and following the LIST to fatigue. A main effect for time ($F_{2, 22} = 10.860, p<.01$) was found from pre- to post-exercise with both trials reporting a decrease in activation from fatigue to 15 min post-exercise ($p<.05$). Activation remained fairly constant throughout the exercise period (CHO; $4.3 \pm 0.3$; PLA; $4.0 \pm 0.3$).

Table 9.1. Descriptive statistics (Means ± SEM) of the FS and FAS before, during and following the LIST to fatigue.

<table>
<thead>
<tr>
<th></th>
<th>FS</th>
<th>FAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHO (M ± SEM)</td>
<td>PLA (M ± SEM)</td>
</tr>
<tr>
<td>Pre</td>
<td>1.2 ± 0.5</td>
<td>1.2 ± 0.4</td>
</tr>
<tr>
<td>Block 1</td>
<td>0.8 ± 0.7</td>
<td>1.2 ± 0.4</td>
</tr>
<tr>
<td>Block 2</td>
<td>0.7 ± 0.8</td>
<td>0.3 ± 0.4</td>
</tr>
<tr>
<td>Block 3</td>
<td>0.0 ± 0.8</td>
<td>-0.3 ± 0.5</td>
</tr>
<tr>
<td>Block 4</td>
<td>-0.2 ± 0.7</td>
<td>-0.8 ± 0.6</td>
</tr>
<tr>
<td>Block 5</td>
<td>-0.9 ± 0.6</td>
<td>-1.3 ± 0.8</td>
</tr>
<tr>
<td>Fatigue</td>
<td>-2.1 ± 0.6</td>
<td>-1.6 ± 0.4</td>
</tr>
<tr>
<td>15 min post</td>
<td>0.6 ± 0.6</td>
<td>0.8 ± 0.0</td>
</tr>
</tbody>
</table>
Figure 9.2. Changes in affective valence (FS) and activation (FAS) before, during and following the LIST to fatigue plotted in circumplex space.

### 9.3.2 Changes in energetic and tense arousal

Table 9.2 shows the changes in EA, TA and the subscales before and following the LIST to fatigue protocol. The alpha coefficient for the EA scale was 0.86 and for the TA scale 0.82 indicating high internal consistency. The alpha coefficients of the energy, tiredness, tension and calmness subscales were 0.74, 0.81, 0.80, 0.76 respectively.

Analysis on the EA scores revealed no significant main effect for time or condition. For TA, the analysis revealed a significant effect of time ($F_{2, 22} = 6.062$, $p<.05$), and a time x condition interaction effect ($F_{2, 22} = 3.325$, $p<.05$), with the
post hoc analysis showing that the only decrease in TA occurred 15 min post exercise in the CHO trial only (23.5 ± 1.1 vs. 18.4 ± 1.3; ).

Table 9.2. Descriptive statistics (Means ± SEM) of the AD ACL items and subscales before and following the LIST to fatigue.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>21.4 ± 2.2</td>
<td>23.5 ± 1.1</td>
<td>10.3 ± 1.0</td>
<td>13.8 ± 1.3</td>
<td>9.6 ± 0.8</td>
<td>11.1 ± 0.7</td>
</tr>
<tr>
<td>Fatigue</td>
<td>19.7 ± 2.4</td>
<td>24.1 ± 1.1</td>
<td>8.1 ± 1.2</td>
<td>13.4 ± 1.4</td>
<td>8.3 ± 0.7</td>
<td>9.3 ± 0.6</td>
</tr>
<tr>
<td>Post 15</td>
<td>17.8 ± 1.3</td>
<td>18.4 ± 1.3</td>
<td>7.3 ± 0.6</td>
<td>14.5 ± 1.0</td>
<td>7.1 ± 0.7</td>
<td>13.7 ± 0.9</td>
</tr>
<tr>
<td>PLA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>19.1 ± 1.6</td>
<td>18.9 ± 1.5</td>
<td>8.8 ± 0.9</td>
<td>14.7 ± 0.9</td>
<td>8.4 ± 0.9</td>
<td>14.5 ± 0.8</td>
</tr>
<tr>
<td>Fatigue</td>
<td>19.7 ± 1.8</td>
<td>22.6 ± 1.3</td>
<td>7.8 ± 0.9</td>
<td>13.1 ± 1.2</td>
<td>8.8 ± 1.1</td>
<td>11.2 ± 0.9</td>
</tr>
<tr>
<td>Post 15</td>
<td>17.7 ± 2.0</td>
<td>18.3 ± 1.3</td>
<td>6.9 ± 0.9</td>
<td>14.3 ± 1.3</td>
<td>7.0 ± 0.6</td>
<td>13.8 ± 0.9</td>
</tr>
</tbody>
</table>

The tension subscale revealed a main effect for time and further analysis indicated that tension was reduced 15 min post-exercise across both trials (9.0 ± 0.8 vs. 7.0 ± 0.7; $F_{1,16} = 4.352, p<.05$). There were two main effects as well as an interaction effect for the subscale calmness. Calmness decreased from pre-exercise to fatigue in the PLA trial only (14.5 ± 0.0 vs. 11.2 ± 0.9; $F_{2,22} = 7.121, p<.05$). Significant differences were observed between trials, with calmness reportedly higher pre-exercise and upon fatigue in the PLA trial ($F_{2, 22} = 4.139, p<.05$). Figure 9.3 illustrates the changes reported on the AD ACL pre- and post-exercise.
Chapter IX

CHO Ingestion and IHH Exercise to fatigue

Figure 9.3. Affect, as assessed by the AD ACL before, during and following the LIST to fatigue, plotted in circumplex space.

9.3.3 Individual responses

Change scores were compared for the FS and FAS from block 1 of the LIST (i.e. the first during exercise assessment) to block 3 (the mid-point of the protocol) of the LIST, from block 1 to block 5 (i.e. the last minute of exercise) of exercise and from pre exercise to fatigue. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response with each category are shown in Table 9.3.

The results indicate that the individual change trends for the FS ratings exhibited somewhat uniform responses during the LIST to fatigue (Table 9.3). Specifically, from block 1 to block 5 of the LIST across both trials 75% of participants reported...
a decrease in valence. This pattern also emerged at the other time points assessed.
The response to the FAS was more homogenous during the PLA trial than the
CHO trial. In the PLA trial the majority of participants reported an increase in
activation, however, there was a much wider spread of reports in the CHO trial.

Table 9.3. Frequency and magnitude of individual affective responses to the LIST
to fatigue protocol.

<table>
<thead>
<tr>
<th>Scale</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Range</td>
</tr>
<tr>
<td>Feeling Scale (Block 1-block 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>2 (17%)</td>
<td>1-2</td>
</tr>
<tr>
<td>No change</td>
<td>2 (17%)</td>
<td>0</td>
</tr>
<tr>
<td>Decrease</td>
<td>8 (67%)</td>
<td>1-3</td>
</tr>
<tr>
<td>(Block 1-block 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (25%)</td>
<td>1-4</td>
</tr>
<tr>
<td>No change</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>9 (75%)</td>
<td>1-7</td>
</tr>
<tr>
<td>(from pre to fatigue)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>1 (8%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>2 (17%)</td>
<td>0</td>
</tr>
<tr>
<td>Decrease</td>
<td>9 (75%)</td>
<td>2-7</td>
</tr>
<tr>
<td>Felt Arousal Scale (Block 1-block 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (25%)</td>
<td>1</td>
</tr>
<tr>
<td>No change</td>
<td>8 (67%)</td>
<td>0</td>
</tr>
<tr>
<td>Decrease</td>
<td>1 (8%)</td>
<td>1</td>
</tr>
<tr>
<td>(Block 1-block 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>5 (42%)</td>
<td>1-4</td>
</tr>
<tr>
<td>No change</td>
<td>3 (25%)</td>
<td>2 (17%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>4 (33%)</td>
<td>1-2</td>
</tr>
<tr>
<td>(from pre to fatigue)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>5 (42%)</td>
<td>1-3</td>
</tr>
<tr>
<td>No change</td>
<td>5 (42%)</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (16%)</td>
<td>1-2</td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).
9.3.4 Rating of perceived exertion

Rating of perceived exertion increased over time ($F_{2,17} = 40.464, p<.01$) with the mean value during each block of exercise being significantly higher than the previous one. Analysis on the FS and RPE scale revealed a correlation of -.69 ($p<.01$) (Figure 9.4).

![Figure 9.4. Rating of perceived exertion during the LIST to fatigue.](image)

9.3.5 Physiological responses to the exercise protocol

Oxygen uptake, heart rate and $\%\hat{V}O_2\text{max}$ did not differ between trials demonstrating that the participants were exercising at the same relative exercise intensity in both conditions. Expressed in terms of $\%\hat{V}O_2\text{max}$, the relative exercise intensity averaged $81.35 \pm 1.5$ in the CHO trial and $80.96 \pm 1.9$ in the PLA trial. Heart rate during exercise ranged from approximately 160-170 beats.min$^{-1}$ during blocks 1 to 5 of the LIST.
9.3.6 *Plasma glucose*

Plasma glucose concentration was maintained above resting values during both trials. Concentrations were higher ($F_{6, 50} = 2.332, p<.05$) 15 min into exercise (6.9 ± 0.3 mmol.l\(^{-1}\) vs 6.1 ± 0.2 mmol.l\(^{-1}\)) during the CHO trial compared to the PLA trial (Figure 9.5).

![Figure 9.5. Changes in plasma glucose concentration (mmol.l\(^{-1}\)) during the LIST to fatigue; (* p<0.05 CHO vs PLA).](image)

9.3.7 *Serum cortisol*

There was a trend for serum cortisol concentration to change with time ($p=0.056$) and also a trend for cortisol to be higher in the PLA trial compared to the CHO trial ($p=0.09$). However, no significant main or interaction effects were observed (Figure 9.6).
9.3.8 Plasma lactate

Lactate concentrations were higher during exercise across both conditions than at rest (main effect for time, $0.83 \pm 0.05$ vs $4.77 \pm 0.0.5 \text{mmol.l}^{-1}$ rest vs exercise, $F_{2, 10} = 31.171$, $p<.01$). The peak lactate concentration was reached upon fatigue and was higher than the 75 min time point across both trials (CHO: $4.37 \pm 0.6$ vs $5.88 \pm 0.5$; PLA: $4.38 \pm 0.6$ 6.03 ± 0.4, 75 min vs fatigue, $p<.05$) (Figure 9.7). Over 6 time points (Block 1 – fatigue) lactate concentration and valence ratings had an inverse correlation of -.35 ($p<.01$).

Figure 9.6. Changes in Serum Cortisol Concentration (nmol.l$^{-1}$) during the LIST.

Figure 9.7. Changes in Plasma Lactate Concentration (mmol.l$^{-1}$) during the LIST.
9.3.9 Running capacity
There were no differences in endurance capacity between trials. In the CHO trial, participants ran for 554.17 ± 112 min and in the PLA trial, 554.33 ± 125 min.

9.3.10 Diet
A nutrient analysis of the 2-day food records prior to each of the two exercise sessions revealed there were no differences in the mean daily energy intake (8.6 ± 1.9 MJ and 8.8 ± 1.9 MJ, CHO v PLA trials respectively) or CHO content (316 ± 69 g and 309 ± 64 g, CHO v PLA trials respectively).

9.3.11 Correlations between the FS and the RPE scale
Table 9.4 displays the correlations between the FS and the RPE scale at the various time points sampled during the LIST protocol. Significant correlations were found throughout the CHO trial. Specifically, a moderate to strong negative relationship was demonstrated with increases in RPE being associated with decreases in valence. This significant relationship was only observed during the final two blocks of the LIST in the PLA trial.

Table 9.4 Correlations between the FS and RPE scale

<table>
<thead>
<tr>
<th>Time</th>
<th>CHO</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 1</td>
<td>-.59*</td>
<td>-.09</td>
</tr>
<tr>
<td>Block 2</td>
<td>-.63**</td>
<td>-.04</td>
</tr>
<tr>
<td>Block 3</td>
<td>-.65*</td>
<td>-.37</td>
</tr>
<tr>
<td>Block 4</td>
<td>-.67**</td>
<td>-.61*</td>
</tr>
<tr>
<td>Block 5</td>
<td>-.64*</td>
<td>-.58*</td>
</tr>
</tbody>
</table>

** Correlation is significant at the p<.01 level; * Correlation is significant at the p<.05 level.
9.4 Discussion

The aim of the present study was to examine the effects of ingesting a carbohydrate-electrolyte solution on affective responses and effort sense during a prolonged high intensity intermittent shuttle run to fatigue. The activity pattern of the present study consisted of a fixed bout of variable intensity running, followed by a combination of high and low speed intermittent running until volitional fatigue. The pattern of part A of the test is similar to that which occurs in team sports such as football (Reilly & Thomas, 1976). Further, the mean oxygen consumption throughout part A of the test accounted for 81.35 ± 1.5% \( \dot{V}O_2\) max in the CHO trial and 80.96 ± 1.9% \( \dot{V}O_2\) max in the PLA trial. The average aerobic energy yield during a national level game is around 80% of the individual maximum (Ekblom, 1986).

In agreement with previous research on the hypotonic CHO-E solution (Chapter 6) affect, as measured by the FS, was not enhanced and RPE not reduced following the ingestion of the CHO solution. Under both conditions the completion of a prolonged high intensity shuttle running protocol to fatigue elicited negative affective changes, characterised by a deactivated unpleasant state upon fatigue. As observed in Study 3, participants first went through the activated unpleasant quadrant (upper left-hand corner of the circumplex), in this case from block 3 to block 5 of the LIST, but reached fatigue in the deactivated unpleasant quadrant (lower left-hand corner of the circumplex). Thus confirming the fatiguing nature of this protocol (Figure 9.2). Several studies have shown that when the intensity of exercise was gradually increased to levels that approached the participant’s functional limits, valence ratings showed a progressive decline with each increase in intensity (Acevedo et al., 1994; Parfitt et al., 1996). The present study again serves to highlight that such responses could in part be due to the claim by Nesse (1998) that affective responses represent adaptive reactions that have evolved to promote survival in a specific context. The increased physical stress that the body is placed under during a high intensity shuttle running protocol to fatigue will alter the body’s homeostasis. As this disruption enters consciousness (Cabanac, 1995; Damasio, 1995) the adaptive responses elicited are
those of negative affect which serves as an alarm to stop the individual and withdraw them from the activity that is affecting their homeostasis (Hall et al, 2002). Previous research on fatiguing exercise has been limited and the present study and study 3 adds a unique contribution to the literature. It appears that regardless of how the end point of fatigue is reached, whether it is following a short bout of exhaustive exercise or a prolonged submaximal bout, the valence responses elicited are consistent. In keeping with the previous research on affective responses during prolonged exercise, was the finding once again that negative valence responses were dominant across both trials during the latter stages of the bout. Further this study located participants in a state of activated unpleasantness, in block 4 and block 5 in the CHO trial, and from block 3 to block 5 in the PLA trial, and this has not been observed in the previous studies. The high intensity component of this protocol could explain the differences in activation to that observed during the prolonged constant paced run to fatigue reported in Study 3.

In the present study the ingestion of a CHO-E solution did not reduce the perceived exertion of the activity and in turn did not delay endurance capacity. This offers support to the previous study (Study 3) where the same findings emerged when participants ran to fatigue at a constant pace on a motorised treadmill ingesting the same hypotonic CHO-E solution. Consistent with the run to fatigue protocol (Study 3), the individual responses on the FS were more homogenous in this study than has previously been found, and this could offer support to Ekkekakis’ (2003) Dual Mode Model. Such protocols may push the participants closer to their functional limits and as such, reduce the variability of affective responses. Indeed, in the present study across both trials, 75% of participants reported a decrease in affective valence from block 1 to block 5. This pattern was also reflected in the remaining time point comparisons (Table 9.3). This is consistent with a homogenous set of 92% of participants across both trials reporting a decrease in affective valence in the run to fatigue study. There were no significant correlations noted when pre to post exercise changes in physiological variables were compared to pre to post exercise changes in the FS and FAS, and therefore no associations are apparent between the physiological and the psychological changes, however, it is important that a multi dimensional approach
to research whereby physiological and psychological measures are combined is pursued further if we are to fully understand the exercise experience.

The findings of the correlational analysis between the FS and the RPE scale revealed an inconsistent response pattern across the two conditions, which has been characteristic of the previous studies undertaken in this thesis. Throughout the CHO trial, the relationship between the scales was significant and it was moderate to strong. However, the only significant correlations in the PLA trial occurred in block 4 and 5. In support of the CHO trial and studies 1-5, these were negative relationships, so as the perception of exertion increased, valence decreased. It is unclear why a significant relationship was not observed in the PLA trial during the first three blocks of the LIST and a lack of studies within this area of research make comparisons difficult. However, once again the results support the conclusions of Hardy and Rejeski (1989) that although the RPE and the FS do share some commonality, they are not isomorphic constructs.

Once again a rebound effect, similar to that described by Bixby et al. (2001), was demonstrated. From the final during exercise assessment to 15 min post exercise an increase in valence was observed. Certainly such an effect has been evident across all the modes of exercise undertaken in this thesis and serves to highlight the importance of assessing affective states during exercise. A researcher who fails to assess such states during the exercise bout limits their knowledge of the exercise experience and fails to capture an important aspect of the exercise-affect relationship, which can serve to develop our understanding of the adherence issue in the public health domain. In the studies reported in this thesis, the population undertaking the moderate to vigorous exercise modes comprised healthy and physically active males. If such a population reports a shift to more negative affective states, it is not surprising that sedentary individuals who are prescribed a fitness programme, which contains vigorous intensity exercise, do not consistently adhere to such a programme.

The ingestion of a hypotonic CHO-E solution once again elicited a metabolic profile that was no more favourable when compared to the PLA trial, thus supporting the findings of the prolonged run to fatigue study (Study 3). Indeed,
plasma glucose concentrations were only higher 15 min into exercise when compared to the PLA trial. For the remainder of the trial and upon fatigue there was no difference in the concentration. This is in contrast to the previous study reported in chapter 8 also involving intermittent high intensity exercise. A more favourable metabolic profile was established and associated with this finding was a difference in affective responses between conditions, in the way of the activation component of core affect. One could speculate that the glycogen depletion trial undertaken the evening before the main trial in the IHI study of Study 5 may have had an influence on the findings reported. Due to the nature of such a protocol, participants will have started the trial in a more depleted energy state, thus ingesting CHO before and during exercise may have resulted in a more pronounced effect on self reported activation. In contrast, the ingestion of a hypotonic CHO solution during 75 min of simulated football, followed by a run to fatigue, provided a similar performance benefit to the ingestion of a sweetened water placebo. This again points towards a clear lack of benefit of consuming the hypotonic CHO solution over consuming a sweetened placebo in terms of performance, affective beneficence and perceptions of exertion. Investigations undertaken by Foskett (Unpublished doctoral dissertation) offer further support for this assertion.

In the present study tense arousal was only observed to decrease 15 min post exercise in the CHO trial. Thayer (2001) asserts that tense or anxious moods are signals of the need for more energy, and the ingestion of CHO will have provided the participants with more energy compared to the placebo trial. However, the metabolic profile was only enhanced during the early stages of exercise in the present study. It is possible that a significantly different metabolic profile may have been elicited following exercise, which would correspond to the time point when a difference was observed in TA. However, blood samples were not obtained at this time point and therefore no data exists to support or refute such a proposition. Furthermore, this is the only study in which a significant reduction in TA has been confined to one condition only. Indeed, such a reduction in TA has only been reported in study 3, which involved a prolonged run to exhaustion. In that study, in support of the present study, there was little difference in the metabolic profile and the reduction in TA occurred across conditions. Benton
(2002) concludes that the relationship between CHO ingestion and mood is inconsistent when examined in resting individuals; the studies undertaken in this thesis could offer some support for this statement. Few studies of this nature have been undertaken in an exercise setting, which makes the comparison of results difficult. However, it is hoped that this research will encourage the development of this line of investigation further.

In summary, the ingestion of a hypotonic CHO solution during 75 min of simulated football, followed by a run to volitional fatigue provided similar performance benefits and affective responses to the ingestion of a sweetened placebo. Reduced tense arousal was observed 15 min following exercise in the CHO trial; however, the potential mechanisms for this remain unclear. The fatiguing nature of this protocol once again elicited a negative affective profile, reported by 75% of participants across both conditions. Indeed, in support of previous studies (Study 3, Hall et al., 2002) when plotted in circumplex space, a state of deactivated unpleasantness emerged.
Chapter X

Study Seven

The influence of fluid ingestion on affective states and effort sense during 60 min of continuous or intermittent running in the heat

10.1 Introduction

Previous studies in this thesis have investigated both continuous and intermittent exercise. This final study aims to compare a continuous exercise with an intermittent exercise in one within-participant design, thus allowing changes in core affect to be contrasted. In addition, this study was undertaken in the heat (30°C), which adds another element to the exercise-affect relationship and the influence of fluid ingestion on affective responses. The additional stressors of increased environmental temperature and dehydration, known to accentuate physiological responses to exercise, may also impact upon the psychological domain (Ekkekakis, 1997). In addition, exercise in the heat has been shown to be associated with reduced positivity of affect (Maw et al., 1993). A further aim of this study is to explore the efficacy of the thermogenic hypothesis (deVries et al., 1981; Raglin, 1985) by following changes in core body temperature throughout the periods of exercise.

When the ambient temperature and humidity are high, the capacity to perform exercise is further reduced (Costill & Fink, 1974; Morris et al., 1998). Small losses of body water can decrease the capacity for exercise. Dehydration resulting from profuse sweating may be the primary cause of fatigue even in moderate environmental conditions (Maughan, 1992). Based on a physiological perspective, it is clear that participants should ingest fluid to match the rate of sweat loss. In such conditions, the type of fluid ingested is important because increasing the carbohydrate content of drinks will increase the amount of fuel that can be
supplied, however solutions containing 4% of more CHO will delay gastric emptying, which in turn might limit the rate of fluid delivery (Vist & Maughan, 1994). In the present study, sweat losses may mean that the provision of fluid rather than fuel is far more important, and in turn affective responses and effort sense may be influenced by the strategies adopted in such an environment. As highlighted, the rate of gastric emptying, an important factor in determining the fate of ingested fluid, is impaired when the exercise intensity is high, such as during intermittent exercise (Maughan, 1992).

Therefore, the purpose of the present study is to compare the effects of two fluids on affective responses and perceived exertion during 60 min of both continuous and intermittent high intensity treadmill running in the heat.
10.2 Materials and Methods

10.2.1 Participants
Fifteen male endurance trained runners (mean ± SEM: age 24 ± 1 yrs; body mass 68.2 ± 1.5 kg; \( \dot{VO}_2 \) max 70.0 ± 2.2 ml.kg\(^{-1}\).min\(^{-1}\)) took part in this study. The participants were informed of the demands of the study and the possible risks and discomforts prior to receiving their written consent. The study had the approval of the Ethical Advisory Committee of Loughborough University. Prior to testing, participants were informed that the purpose of the study was to examine the influence of fluid ingestion on the sweating responses during a continuous and intermittent 60 min run. No mention was made of the potential for positive/negative psychological outcomes following the exercise task.

10.2.2 Measures of affect
The Feeling Scale (FS: (Hardy & Rejeski, 1989), Felt Arousal Scale (FAS: (Svebak & Murgatroyd, 1985) and the Activation-Deactivation Adjective Check List (AD ACL; Thayer, 1989) were used as measures of affect during this study as previously described (Chapter 3). The FS and FAS scales were administered before exercise, every 15 min during the 60 min run, upon cessation of exercise and 5 min, 15 min and 30 min post exercise. The AD ACL was administered before exercise and then upon cessation of exercise and 5 min, 15 min and 30 min post exercise.

10.2.3 Rating of perceived exertion
The Rating of Perceived Exertion scale (RPE; (Borg, 1982) was used as a measure of perceived effort during exercise, as previously described (Chapter 3).

10.2.4 Preliminary procedures
The participants undertook two preliminary tests to determine:
1) the relationship between running speed and oxygen uptake using a 16 min incremental submaximal running test, 2) their maximal oxygen uptake (\( \dot{VO}_2 \) max) using an uphill treadmill running test to fatigue (Taylor, 1955). These procedures have previously been described (Chapter 3).
Before the first experimental trial the participants undertook a 15 min treadmill run at 60% \( \dot{V}O_2 \) \( \text{max} \). Expired air was then collected every 5 min, to confirm the speed was eliciting the required percentage of maximal oxygen uptake and that the participants were familiar with the experimental procedures.

**10.2.5 Experimental procedures**

In a randomised cross-over design, participants performed four runs on a motorised treadmill for 1 h, with at least 7 days in between each trial. On each occasion participants consumed either a 6.4% carbohydrate-electrolyte solution (CHO) (Lucozade Sport, Glaxo-SmithKline) or a flavoured water solution (Osmolality 45 mOsmol.kg\(^{-1}\); \( Na^+ \) 7 mmol.l\(^{-1}\); \( K^+ \) 0.56 mmol.l\(^{-1}\)), before the run (6.5ml.kg\(^{-1}\) BM) and every 15 min during exercise (3.5ml.kg\(^{-1}\) BM). The water was flavoured with orange cordial (Robinsons no added sugar; Concentration: \( \frac{1}{4} \) squash and \( \frac{3}{4} \) water).

Before the study began, four individuals (none of whom subsequently participated in the study) were given the two solutions in random order. They were told that one of the solutions was a carbohydrate-electrolyte and one flavoured water and were asked to taste the drinks and say which drink was which. In reality, the drinks did not taste identical, although they all had a very similar flavour. During this ‘tasting’ individuals consumed the drinks in a short space of time during which any differences in the taste of the solutions would have been most obvious. None of the four participants in the tasting successfully identified the solutions correctly or had any idea which solution was which. In the study, main trials were separated by 7 – 10 days, making it even more unlikely that the participants could have identified any differences in the solutions.

Participants were asked to refrain from heavy exercise for 2 days prior to each trial and their dietary intake was monitored during the 48h preceding each trial using a food diary. The participants followed the same diet during the 48h prior to the second trial. In addition caffeine and alcohol were also prohibited during the 48h prior to the trial because both have been found to have transient effects on mood (Rogers et al., 1992).
Ambient temperature was maintained at 30°C by means of an electric fan heater (Xpelair) together with three electric fans, placed at the corners of the room, however, they were not placed facing the participant on the treadmill. Relative humidity was regulated by a dehumidifier (DE 320, Delonghi, UK).

Figure 10.1 shows a schematic representation of the intermittent protocol. On the morning of each trial participants arrived at the laboratory between 08:00h and 09:00h following an overnight fast of ~10 h. On arrival participants were asked to rate their responses on the FS, FAS and AD ACL. Participants then went to a private room to insert the rectal probe (Edale Instruments Ltd, Cambridge, UK) to a depth of 10 cm beyond the anal sphincter. The participant whilst lying on a couch then had four skin thermistors (Edale Instruments Ltd, Cambridge, UK) secured to the chest, arm, thigh and calf in order for skin temperatures to be monitored. During this time, the participant ingested the prescribed solution. Nude body mass was then measured on a beam balance (Avery, Birmingham, UK).

Participants stood on the treadmill and the rectal probe and thermistors were attached to a data logger (800 Series Squirrel, Grant Instruments, UK). The heart rate monitor was also placed around the chest. Finger prick samples were then taken and then the participant was ready to begin the trial. The continuous trial consisted of a 60 min run on a level treadmill at a speed that elicited 60% of the individual’s \( \dot{V}O_2 \) max. This run was interspersed with three 2-min walks at 4km.hr\(^{-1}\). In the intermittent trial, the treadmill speed varied every 2 min in order to elicit speeds equivalent to 40, 60 and 80% of the participants \( \dot{V}O_2 \) max (Figure 10.1). The changes in treadmill speeds, which required a maximum of 10 seconds each time, was initiated by a computerised timer and controlled manually.

Upon cessation of the test, participants immediately responded to the FS, FAS and AD ACL. Nude body mass was then recorded and the thermistors removed. Participants were taken to a quite area in the laboratory to sit comfortably and the affect measures were assessed as described earlier.
Figure 10.1. Graphical representations of the intermittent protocol design (3 min stages at speeds equivalent to 40%, 60% and 80% VO$_2$$_{max}$, 3 x 2 min walks interspersed).

10.2.6 Blood analyses

Duplicate 20 µl samples of arterialised capillary blood were taken from the thumb of a pre-warmed hand before exercise, every 15min during and immediately after completion of the run. During the trial, the sampling was conducted during the walk phase of each protocol. Blood samples were immediately deproteinised in a solution containing 200 µl of 2.5% perchloric acid. Samples were then centrifuged and then frozen at -20°C and later analysed for blood glucose and lactate (Maughan, 1982).

10.2.7 Statistical analysis

Results were analysed as described under statistical analysis (Chapter 3). Values are presented as mean (SEM).
Figure 10.2. Schematic representation of the experimental protocol.
10.3 Results

10.3.1 Affective responses to the exercise protocols
Table 10.1 & 10.2 report the descriptive statistics of the FS and the FAS, before, during and following the continuous and intermittent 60 min runs in 30°C. Table 10.3 illustrates the changes in EA, TA and the subscales before and following the continuous and intermittent exercise trials. The alpha coefficient for the EA scale was 0.90 and for the TA scale 0.78, and for energy, tiredness, tension and calmness subscales 0.92, 0.84, 0.79, 0.75 respectively. All are considered satisfactory.

10.3.2 Continuous exercise protocol
Analysis on the FS pre and post exercise revealed no difference in the FS scores from pre to post continuous exercise. During exercise, valence as measured by the FS declined (F (1, 19) = 6.270, p<.05) across both conditions from the first within exercise assessment (14 min) to all time points (2.9 ± 0.2 vs 2.48 ± 0.3 vs 2.23 ± 0.3 vs 1.77 ± 0.3, p <.05; 14 min vs 29min, 44min, 59 min respectively).

A main effect for time for activation was observed across all time points (F (3, 43) = 6.849, p<.05). No condition or interaction effect was observed. Activation increased at the onset of exercise (2.63 ± 0.2 vs 3.57 ± 0.2, p <.05; pre vs 14 min) and remained elevated during the exercise bout and immediately post exercise 2.63 ± 0.2 vs 3.38 ± 0.2, p <.05; pre vs immediately post exercise). Activation increased from pre exercise to immediately post exercise across both conditions (p<.05).

10.3.3 Changes in energetic and tense arousal
Analysis on the EA subscale revealed an interaction effect (F (4, 56) = 2.663, p<.05) with reported EA being higher immediately post exercise in the CHO trial compared to the FW trial (32.2 ± 1.1 vs 29.2 ± 1.0, CHO vs FW, p <.05). Tiredness, a subcomponent of EA, was reduced (F (2, 34) = 4.636, p<.05) from pre exercise levels 5 min and 15 min post exercise. No condition or interaction effect was noted.
Table 10.1 Descriptive statistics (Means ± SEM) of the FS before, during and following the 60 min runs.

<table>
<thead>
<tr>
<th>FS</th>
<th>CNT-CHO</th>
<th>CNT-FW</th>
<th>INT-CHO</th>
<th>INT-FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>2.5 ± 0.4</td>
<td>2.4 ± 0.2</td>
<td>2.4 ± 0.4</td>
<td>2.8 ± 0.4</td>
</tr>
<tr>
<td>14 min</td>
<td>2.8 ± 0.3</td>
<td>3.0 ± 0.2</td>
<td>2.7 ± 0.3</td>
<td>3.1 ± 0.2</td>
</tr>
<tr>
<td>29 min</td>
<td>2.3 ± 0.4</td>
<td>2.7 ± 0.4</td>
<td>2.5 ± 0.4</td>
<td>2.5 ± 0.4</td>
</tr>
<tr>
<td>44 min</td>
<td>2.3 ± 0.4</td>
<td>2.2 ± 0.4</td>
<td>2.0 ± 0.5</td>
<td>2.2 ± 0.4</td>
</tr>
<tr>
<td>59 min</td>
<td>1.5 ± 0.5</td>
<td>2.1 ± 0.5</td>
<td>1.9 ± 0.5</td>
<td>1.8 ± 0.5</td>
</tr>
<tr>
<td>Post 0</td>
<td>2.6 ± 0.5</td>
<td>2.3 ± 0.4</td>
<td>2.6 ± 0.4</td>
<td>2.7 ± 0.5</td>
</tr>
<tr>
<td>Post 5</td>
<td>3.0 ± 0.4</td>
<td>3.0 ± 0.3</td>
<td>3.2 ± 0.3</td>
<td>3.1 ± 0.3</td>
</tr>
<tr>
<td>Post 15</td>
<td>3.3 ± 0.3</td>
<td>3.1 ± 0.2</td>
<td>3.5 ± 0.3</td>
<td>3.6 ± 0.3</td>
</tr>
<tr>
<td>Post 30</td>
<td>3.2 ± 0.3</td>
<td>3.2 ± 0.2</td>
<td>3.5 ± 0.3</td>
<td>3.8 ± 0.3</td>
</tr>
</tbody>
</table>

For TA, there was a main effect for time ($F_{(2,34)} = 7.013; p<.05$) however, post hoc analysis revealed there were no significant changes from pre exercise, the differences occurred from immediately post exercise. No condition or interaction effect was observed. Across both trials TA decreased from the rise immediately post exercise to 5 min, 15 min and 30 min post exercise (21.7 ± 1.0 vs 19.17 ± 0.9, 17.2 ± 0.7 vs 16.9 ± 0.7; immediately post vs 5 min, 15 min and 30 min post, $p<.05$). Tension, a subcomponent of TA, was observed to display a main effect for time ($F_{(3,35)} = 3.93; p<.05$) from pre to post exercise. No condition or interaction effect was observed. Post hoc analyses revealed that tension was reduced from pre exercise (6.67 ± 0.4) to 5 min (5.9 ± 0.3) 15 min (5.5 ± 0.2) and 30 min post exercise (5.5 ± 0.2) across both trials. A main effect for time ($F_{(2,32)} = 7.139; p<.05$) was also seen for calmness from pre to post exercise. Across both trials, calmness decreased from pre to immediately post exercise (12.3 ± 0.7 vs 9.4 ± 0.9, pre vs immediately post, $p<.05$). Thereafter, calmness returned to baseline levels.
Table 10.2. Descriptive statistics (Means ± SEM) of the FAS before, during and following the 60 min runs.

<table>
<thead>
<tr>
<th></th>
<th>CNT-CHO</th>
<th>CNT-FW</th>
<th>INT-CHO</th>
<th>INT-FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>2.5 ± 0.4</td>
<td>2.7 ± 0.4</td>
<td>2.7 ± 0.3</td>
<td>2.8 ± 0.4</td>
</tr>
<tr>
<td>14 min</td>
<td>3.4 ± 0.2</td>
<td>3.7 ± 0.3</td>
<td>3.4 ± 0.3</td>
<td>3.6 ± 0.3</td>
</tr>
<tr>
<td>29 min</td>
<td>3.5 ± 0.3</td>
<td>3.5 ± 0.3</td>
<td>3.6 ± 0.3</td>
<td>3.7 ± 0.2</td>
</tr>
<tr>
<td>44 min</td>
<td>3.9 ± 0.3</td>
<td>3.6 ± 0.2</td>
<td>3.6 ± 0.3</td>
<td>3.8 ± 0.3</td>
</tr>
<tr>
<td>59 min</td>
<td>3.8 ± 0.3</td>
<td>3.6 ± 0.3</td>
<td>3.7 ± 0.3</td>
<td>3.7 ± 0.3</td>
</tr>
<tr>
<td>Post 0</td>
<td>3.5 ± 0.4</td>
<td>3.2 ± 0.3</td>
<td>3.2 ± 0.3</td>
<td>3.4 ± 0.4</td>
</tr>
<tr>
<td>Post 5</td>
<td>3.1 ± 0.4</td>
<td>2.9 ± 0.3</td>
<td>2.7 ± 0.3</td>
<td>3.1 ± 0.4</td>
</tr>
<tr>
<td>Post 15</td>
<td>2.5 ± 0.4</td>
<td>2.7 ± 0.4</td>
<td>2.7 ± 0.4</td>
<td>2.7 ± 0.4</td>
</tr>
<tr>
<td>Post 30</td>
<td>2.3 ± 0.3</td>
<td>2.6 ± 0.4</td>
<td>2.6 ± 0.4</td>
<td>2.6 ± 0.4</td>
</tr>
</tbody>
</table>

10.3.4 Intermittent exercise protocols

Analysis on the FS pre and post exercise revealed a main effect for time (F (2,14) = 4.469, p<.05). There was no condition or interaction effect. Across both conditions, FS increased from pre exercise (2.58 ± 0.3) to 15 min (3.57 ± 0.2) and 30 min (3.67 ± 0.2) post exercise (p<.05) During exercise, a main effect for time (F (1,14) = 5.865, p<.05) was found with valence declining in both trials.

A main effect for time for activation was observed across all time points (F (3,36) = 7.941, p<.01). No condition or interaction effect was observed. Activation increased at the onset of exercise and remained elevated during the exercise bout. Activation increased from pre exercise to immediately post exercise across both conditions (p<.05).

10.3.5 Changes in energetic and tense arousal

Analysis on the subscale EA revealed a main effect for time (F (2,22) = 4.546, p<.05) and an interaction effect (F (3,36) = 3.643, p<.05). EA increased from pre exercise to 5 min post in the CHO trial, and to immediately post exercise in the FW trial. EA was higher in the FW trial immediately post exercise compared to the CHO trial (28.7 ± 1.3 vs 33.3 ± 1.0, CHO vs FW, p <.05). Energy, displayed
an interaction effect \((F_{(4, 56)} = 2.765, p<.05)\), and post hoc analysis revealed this to be limited to immediately post exercise, with reported energy being higher following the FW trial compared to the CHO trial.

For TA, there was a main effect for time \((F_{(4, 56)} = 11.509; p<.01)\) and an interaction effect of condition x time \((F_{(3, 39)} = 17.554; p<.01)\). TA increased immediately following exercise in the FW trial and 5 min post exercise in the CHO trial compared to pre exercise time points. Also, TA was found to be higher in the FW trial compared to the CHO trial immediately following exercise \((16.8 ± 1.0 vs 23.6 ± 1.2, \text{CHO vs PLA } p <.05)\), but this was reversed 5 min post exercise when TA was higher in the CHO trial \((22.7 ± 1.3 vs 18.9 ± 1.3, \text{CHO vs PLA}, p <.05)\).

Figures 10.3 & 10.4 show the changes in affect as measured by the FS and FAS, plotted in circumplex space. It can be seen that both the continuous and intermittent exercise modes initiate a similar temporal pattern of change. Participants prior to each mode of exercise reported a state of deactivated pleasantness prior to exercise and towards the end of the 60 min bout, responses are located in the activated pleasant quadrant. Following exercise, a state of deactivated pleasantness was once again achieved.

Figures 10.5 & 10.6 illustrate the changes in affect as assessed by the multi-item measure the AD ACL. A similar response pattern emerged to that of the FS and FAS scales. Participants reported a state of deactivated unpleasantness prior to the onset of exercise. Immediately following exercise their responses fell into the activated pleasant quadrant, before returning back to a state of deactivated pleasantness. A more pronounced response is observed for the increase in activation following the intermittent trials compared to the continuous trials (Figure 10.6).
Table 10.3 Descriptive statistics (Means ± SEM) of the AD ACL items and subscales before and following the 60 min runs.

<table>
<thead>
<tr>
<th></th>
<th>EA</th>
<th>TA</th>
<th>Energy</th>
<th>Tiredness</th>
<th>Tension</th>
<th>Calmness</th>
</tr>
</thead>
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<td><strong>CNT-CHO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>27.3 ± 1.9</td>
<td>18.5 ± 1.0</td>
<td>12.1 ± 1.2</td>
<td>9.7 ± 1.0</td>
<td>6.5 ± 0.6</td>
<td>13.0 ± 1.0</td>
</tr>
<tr>
<td>Post 0</td>
<td>32.2 ± 1.1</td>
<td>21.3 ± 1.3</td>
<td>14.1 ± 0.9</td>
<td>10.3 ± 0.4</td>
<td>5.9 ± 0.4</td>
<td>9.6 ± 1.2</td>
</tr>
<tr>
<td>Post 5</td>
<td>29.9 ± 1.5</td>
<td>18.7 ± 1.0</td>
<td>13.5 ± 0.9</td>
<td>8.6 ± 0.8</td>
<td>5.7 ± 0.3</td>
<td>12.0 ± 1.1</td>
</tr>
<tr>
<td>Post 15</td>
<td>28.6 ± 1.1</td>
<td>17.1 ± 0.6</td>
<td>12.5 ± 0.8</td>
<td>8.9 ± 0.9</td>
<td>5.5 ± 0.3</td>
<td>13.4 ± 1.1</td>
</tr>
<tr>
<td>Post 30</td>
<td>27.7 ± 1.1</td>
<td>16.3 ± 0.7</td>
<td>11.4 ± 1.0</td>
<td>8.7 ± 0.8</td>
<td>5.4 ± 0.2</td>
<td>14.1 ± 0.8</td>
</tr>
<tr>
<td><strong>CNT-FW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>26.7 ± 1.1</td>
<td>20.3 ± 1.2</td>
<td>12.5 ± 0.8</td>
<td>10.7 ± 1.0</td>
<td>6.9 ± 0.5</td>
<td>11.6 ± 1.1</td>
</tr>
<tr>
<td>Post 0</td>
<td>29.2 ± 1.0</td>
<td>22.1 ± 1.1</td>
<td>12.9 ± 0.9</td>
<td>10.7 ± 0.7</td>
<td>6.3 ± 0.4</td>
<td>9.1 ± 1.4</td>
</tr>
<tr>
<td>Post 5</td>
<td>30.2 ± 0.8</td>
<td>19.6 ± 0.9</td>
<td>13.1 ± 0.8</td>
<td>7.9 ± 0.7</td>
<td>6.1 ± 0.4</td>
<td>11.5 ± 1.2</td>
</tr>
<tr>
<td>Post 15</td>
<td>29.1 ± 1.2</td>
<td>17.3 ± 1.1</td>
<td>12.1 ± 0.8</td>
<td>8.0 ± 0.5</td>
<td>5.5 ± 0.3</td>
<td>13.2 ± 0.9</td>
</tr>
<tr>
<td>Post 30</td>
<td>29.1 ± 1.0</td>
<td>17.6 ± 1.1</td>
<td>12.4 ± 1.0</td>
<td>8.3 ± 0.7</td>
<td>5.7 ± 0.3</td>
<td>13.1 ± 1.0</td>
</tr>
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<td><strong>INT-CHO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>25.9 ± 1.9</td>
<td>18.4 ± 1.2</td>
<td>11.9 ± 1.0</td>
<td>11.1 ± 1.1</td>
<td>6.4 ± 0.7</td>
<td>13.0 ± 1.1</td>
</tr>
<tr>
<td>Post 0</td>
<td>28.7 ± 1.3</td>
<td>16.8 ± 1.0</td>
<td>12.5 ± 1.0</td>
<td>9.5 ± 0.6</td>
<td>5.7 ± 0.4</td>
<td>13.9 ± 1.0</td>
</tr>
<tr>
<td>Post 5</td>
<td>32.3 ± 1.2</td>
<td>22.7 ± 1.3</td>
<td>14.2 ± 0.9</td>
<td>6.9 ± 0.4</td>
<td>6.7 ± 0.6</td>
<td>8.9 ± 1.0</td>
</tr>
<tr>
<td>Post 15</td>
<td>30.4 ± 0.7</td>
<td>18.1 ± 1.0</td>
<td>13.1 ± 0.8</td>
<td>7.7 ± 0.5</td>
<td>5.7 ± 0.5</td>
<td>12.6 ± 1.1</td>
</tr>
<tr>
<td>Post 30</td>
<td>28.7 ± 1.0</td>
<td>17.1 ± 1.0</td>
<td>11.8 ± 1.0</td>
<td>8.1 ± 0.7</td>
<td>5.7 ± 0.4</td>
<td>13.7 ± 0.9</td>
</tr>
<tr>
<td><strong>INT-FW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>28.1 ± 0.8</td>
<td>19.6 ± 1.0</td>
<td>11.5 ± 0.7</td>
<td>9.5 ± 0.9</td>
<td>6.5 ± 0.5</td>
<td>11.9 ± 1.2</td>
</tr>
<tr>
<td>Post 0</td>
<td>33.3 ± 1.0</td>
<td>23.6 ± 1.2</td>
<td>11.5 ± 0.7</td>
<td>9.6 ± 0.4</td>
<td>6.4 ± 0.5</td>
<td>7.8 ± 0.9</td>
</tr>
<tr>
<td>Post 5</td>
<td>30.7 ± 1.1</td>
<td>18.9 ± 1.3</td>
<td>10.5 ± 1.2</td>
<td>7.8 ± 0.8</td>
<td>6.0 ± 0.4</td>
<td>12.1 ± 1.1</td>
</tr>
<tr>
<td>Post 15</td>
<td>29.5 ± 1.0</td>
<td>17.5 ± 1.3</td>
<td>9.9 ± 1.0</td>
<td>7.7 ± 0.6</td>
<td>5.9 ± 0.5</td>
<td>13.3 ± 1.1</td>
</tr>
<tr>
<td>Post 30</td>
<td>28.7 ± 1.2</td>
<td>17.0 ± 1.3</td>
<td>9.9 ± 1.0</td>
<td>8.3 ± 0.6</td>
<td>5.8 ± 0.4</td>
<td>13.8 ± 1.1</td>
</tr>
</tbody>
</table>
Figure 10.3. Changes in affective valence (FS) and activation (FAS) before, during and after the continuous 60 min run plotted in circumplex space.

Figure 10.4. Changes in affective valence (FS) and activation (FAS) before, during and after the intermittent 60 min run plotted in circumplex space.
Figure 10.5. Affect, as assessed by the AD ACL before and following the continuous 60 min run, plotted in circumplex space.

Figure 10.6. Affect, as assessed by the AD ACL before and following the intermittent 60 min run, plotted in circumplex space.
10.3.6 Individual responses

Change scores were compared for the FS and FAS from the 17th minute (i.e. the first during exercise assessment) to the 77th minute of exercise (when all participants are still exercising), from the 17th minute to the 37th minute of exercise (the mid-point of exercise) and from pre exercise to post 0'. Participants were then divided into subgroups for each scale; participants who showed increases, no change or decreases. The frequency counts and the magnitude of each affective response with each category are shown in Table 10.4.

In keeping with previous studies that did not push participants to such an extent that they reach their functional limits (such as the run and IHI exercise to fatigue studies, chapter 6 & 8 respectively), a varied response pattern was reported across both modes of exercise. For example, in the intermittent trial, pre to post changes in valence ratings resulted in 40% of participants reporting an increase, 40% no change and 20% a decrease following the CHO trial. In the FW trial, the same variety of responses was observed, with 47% reporting an increase, 13% no change and 40% a decrease in valence. The same mixed pattern emerged in the continuous trials, across the various time points sampled (Table 10.4).
Table 10.4. Frequency and magnitude of individual affective responses to the 60 min runs.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Continuous</th>
<th>Intermittent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHO</td>
<td>FW</td>
</tr>
<tr>
<td><strong>Feeling Scale (14th minute-29th minute)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>2 (13%)</td>
<td>1 (7%)</td>
</tr>
<tr>
<td>No change</td>
<td>9 (60%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>6 (40%)</td>
<td>5 (33%)</td>
</tr>
<tr>
<td><strong>(14th minute-59th minute)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>3 (20%)</td>
<td>1 (7%)</td>
</tr>
<tr>
<td>No change</td>
<td>2 (13%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>10 (67%)</td>
<td>6 (40%)</td>
</tr>
<tr>
<td><strong>(Pre to post 0)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>8 (53%)</td>
<td>5 (33%)</td>
</tr>
<tr>
<td>No change</td>
<td>3 (20%)</td>
<td>6 (40%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>4 (27%)</td>
<td>4 (27%)</td>
</tr>
<tr>
<td><strong>Felt Arousal Scale (14th minute-29th minute)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>4 (27%)</td>
<td>2 (13%)</td>
</tr>
<tr>
<td>No change</td>
<td>9 (60%)</td>
<td>8 (53%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (13%)</td>
<td>5 (33%)</td>
</tr>
<tr>
<td><strong>(14th minute-59th minute)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>8 (53%)</td>
<td>5 (33%)</td>
</tr>
<tr>
<td>No change</td>
<td>5 (33%)</td>
<td>4 (27%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (13%)</td>
<td>6 (40%)</td>
</tr>
<tr>
<td><strong>(Pre to post 0)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>11 (73%)</td>
<td>8 (53%)</td>
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<tr>
<td>No change</td>
<td>2 (13%)</td>
<td>4 (27%)</td>
</tr>
<tr>
<td>Decrease</td>
<td>2 (13%)</td>
<td>3 (20%)</td>
</tr>
</tbody>
</table>

(N.B. Percentages have been rounded to the nearest whole number).
10.3.7 Rating of perceived exertion

Ratings of perceived exertion increased over time ($F(2, 26) = 10.515; p< .001$) across both conditions in the continuous trial (Figure 10.7, a.), and post hoc analysis showed that RPE was higher after 44 min and 59 min compared to the 14 min time point ($p<0.05$) in the CHO and FW trials.

![Figure 10.7. Ratings of perceived exertion during a) the continuous 60 min protocol and b) the intermittent 60 min protocol.](image)

A time effect was also found for the intermittent trial ($F(3, 42) = 32.736; p<.001$) with RPE being lower at 14 min compared to the remaining time points across both conditions (Figure 10.7b).

10.3.8 Physiological responses to the exercise protocols

Oxygen uptake, heart rate and % $\dot{V}O_2$ max did not differ between treatments in the intermittent and continuous trials. Mean HR for the CNT-CHO, CNT-FW, INT-CHO and INT-FW trials was 1.53 ± 3 vs 150 ± 3 vs 152 ± 3 vs 151 ± 4 beats.min$^{-1}$ (n.s) respectively.

The mean relative oxygen uptake corresponded to 63 % $\dot{V}O_2$ max in the CNT trial and 55% $\dot{V}O_2$ max in the INT trials. The lower % $\dot{V}O_2$ max in the INT trial was a consequence of a 2 min run at 40% preceding the 1 min expired air collection (60% was meant to be elicited).
10.3.9 Blood lactate

There were no differences between trials during the exercise bout. Exercise values were higher than those found at rest in both the continuous (F (4, 20) = 3.614; p < .05) and intermittent exercise protocols (F (2, 10) = 9.679; p < .05).

10.3.10 Blood glucose

During the continuous exercise protocol, blood glucose concentration remained stable during the FW trial, but increased during the CHO trial and was higher at 45 min (Interaction of condition x time, F (3, 27) = 5.105; p < .05) in the CHO trial compared to the FW trial (Figure 10.8a.).

In the intermittent trial, blood glucose concentration again remained stable in the FW trial, and increased in the CHO trial (F (3, 27) = 3.128; p < .05). A main effect of condition was observed with blood glucose concentration being higher in the CHO trial compared to the FW trial 44 and 59 min into exercise (44 min, 5.31 ± 0.23 vs 4.27 ± 0.25; 59 min, 5.54 ± 0.27 vs 4.40 ± 0.27 mmol·L⁻¹; CHO vs FW; F (1, 9) = 10.895; p < .05) (Figure 10.8b.).
10.3.11 Environmental conditions
There were no differences in the mean dry bulb, wet bulb and black globe (30.3 ± 0.1, 21.6 ± 0.4, 29.9 ± 0.1°C respectively) temperatures between the four trials. At the start of the runs, relative humidity was approximately 31.1 ± 0.5%, and rose to approximately 44.6 ± 0.5% by the end of the runs. In terms of the heat stress index (Verdaguer-Codina et al, 1993), the heat stress imposed on the athletes during the trials would be designated as ‘high’.

10.3.12 Thermoregulatory responses; Rectal temperature ($T_{rec}$)
$T_{rec}$ increased throughout exercise in all four trials (Continuous; Time effect, $F(2, 29) = 99.265; p < .01$; Intermittent; Time effect, $F(2, 30) = 90.134; p < .01$) and at the end of the run the highest recorded value was in the INT-CHO trial ($p < .05$) and the lowest in the CNT-FW trial. During the intermittent exercise trials a condition effect was observed ($F(1, 14) = 9.231; p < .05$). Overall $T_{rec}$ was higher in the CHO trial ($p < .05$) compared to the FW trial (Figure 10.9).

![Figure 10.9. Changes in rectal temperature during a) the continuous 60 min protocol and b) the intermittent 60 min protocol.](image)

10.3.13 Body mass loss and estimated whole body sweat rate
Pre and post-trial measurements indicated that body mass losses were similar across the four trials. Estimated body mass loss on the CNT-CHO, CNT-FW, INT-CHO, INT-FW was 0.59 ± 0.07, 0.67 ± 0.61, 0.61 ± 0.07, 0.73 ± 0.1°C (n.s) respectively. Therefore, body mass was well maintained throughout the trials, as
the loss was less than 1% of their pre trial body mass. The estimated mean whole body sweat rate, assessed from body mass change and corrected for the volume of fluid consumed, was not significantly different between trials. Average whole body sweat rate during the CNT-CHO, CNT-FW, INT-CHO and INT-FW trials were $1.75 \pm 0.08$, $1.83 \pm 0.08$, $1.77 \pm 0.07$, $1.89 \pm 0.17 \text{ l.h}^{-1}$ (n.s) respectively.

10.3.14 Correlations between the FS and RPE scale

Table 10.5 displays the correlations between the FS and the RPE scale at the various time points sampled during the four trials. Apart from the final exercise assessment, where all the relationships were significant and of a moderate to large magnitude, an inconsistent pattern once again emerged.

Table 10.5 Correlations between the FS and RPE scale

<table>
<thead>
<tr>
<th>Time</th>
<th>CNT-CHO</th>
<th>CNT-FW</th>
<th>INT-CHO</th>
<th>INT-FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 min</td>
<td>-.09</td>
<td>-.44</td>
<td>-.16</td>
<td>-.56*</td>
</tr>
<tr>
<td>29 min</td>
<td>-.23</td>
<td>-.64**</td>
<td>-.36</td>
<td>-.47</td>
</tr>
<tr>
<td>44 min</td>
<td>-.38</td>
<td>-.65**</td>
<td>-.54*</td>
<td>-.49</td>
</tr>
<tr>
<td>59 min</td>
<td>-.72**</td>
<td>-.74**</td>
<td>-.57*</td>
<td>-.61*</td>
</tr>
</tbody>
</table>

** Correlation is significant at the p<.01 level; * Correlation is significant at the p<.05 level.
10.4 Discussion

The purpose of this study was to examine the changes in the core dimensions of affect (namely valence and activation) and ratings of perceived exertion during and following continuous and intermittent exercise on a motorised treadmill in a hot (30°C dry bulb temperature) environment. Further, the influence of two fluid regimes on such responses was investigated.

When exercising in a hot environment, the delivery of fluid rather than fuel is the athlete's main concern. The prevention of an increase in body temperature and the maintenance of a hydrated state are paramount. Ekkekakis et al. (1997) assert that such stressors may impact on the psychological domain. To date, however, the effects of fluid ingestion regimes on affective responses to exercise have been under researched and the RPE scale remains the only subjective measure used in such studies. However, as Hardy and Rejeski (1989) assert and the studies in this thesis highlight, 'what' an individual feels may differ from 'how' they feel.

Repeated in-task assessments, achieved through the use of the FS and FAS, were once again plotted in circumplex space with the aim of recognising any salient changes in affect during the exercise protocols. Consistent with all the studies reported in this thesis and the work of Ekkekakis & Petruzzello (1999) a diversity of responses were recorded during and following exercise. As observed in previous studies that did not have a fatigue component (Studies 1, 2, 4, 5 & 7), participants across both modes (continuous and intermittent) and conditions (CHO and FW) of exercise, reported a state of deactivated pleasantness prior to exercise, which shifted towards an activated pleasant state as the exercise progressed. During recovery, participants were once again located in the deactivated pleasant quadrant. However, despite this commonality in movement across the circumplex space, significant differences did emerge between conditions and indeed modes of exercise with regards to the magnitude of the changes within the scales.

An improvement in affective valence was noted in the present study in the intermittent trials from pre to post exercise, which has not been a common finding
in the investigations reported within this thesis. This is probably due to the prolonged nature of the protocols employed. Participants in these trials reported an increase in valence from pre exercise to 15 min and 30 min post exercise. In the remaining experimental trials, valence ratings did not increase following exercise, but instead returned to baseline levels. It is interesting to note that this positive shift in valence corresponds to the observations that the highest recorded body temperatures (as assessed by rectal temperature) were in the intermittent exercise trials. Such an increase in rectal temperature is consistent with observations in previous studies (Galloway & Maughan, 2000; Morris et al., 2003). Core temperature may have been higher in these trials due to a delay in gastric emptying which might limit fluid delivery and hence elevate the rate of rise in rectal temperature. Such an observation could offer tentative support for the thermogenic hypothesis (deVries et al, 1981; Raglin, 1985). This hypothesis proposes that the elevation in deep body temperature during exercise contributes to affective changes following exercise. It is interesting to note that the enhancement in affective valence arose following the trial in which core body temperature was at its highest. However, firm conclusions cannot be made due to the fact that the enhancement in valence was not observed until post exercise. This makes attempts to associate the changes with body temperature (which were only assessed during exercise) difficult. Efforts to perform direct tests of the thermogenic hypothesis have not yielded compelling evidence in support of it and studies exist to refute it (Koltyn, 1997). Even so, a possible link between valence and core body temperature cannot be ruled out.

Changes in tense arousal following the intermittent trials conflicts with the enhanced affective valence profiles observed and questions the efficacy of this mechanism in explaining the enhanced valence shift. Within five minutes of completing the exercise trial, tense arousal was found to increase compared to the pre exercising state. However, it could be argued that the negative shifts in tense arousal were only upto 5 min post exercise, before returning to baseline levels thereafter. Such an observation leads one to question the suggestion that an elevation in deep body temperature can have so called anxiety reducing effects (deVries et al., 1981; Raglin, 1985), because the findings of this study would not uphold such an association. It is plausible that during the intermittent trials,
particularly the intermittent CHO trial, where the thermal strain is recorded as being the greatest, a subjective sensation of heat discomfort could result, so the participant could experience a sense of relief upon completion of the task which is manifested in positive changes in valence. Indeed, an ‘it hurts so good’ explanation could be offered for such changes in this trained group of individuals. However, there were no significant differences between trials during exercise to offer support for this, both in terms of valence and rating of perceived exertion.

Affective states were not observed to fall to negative values during exercise, which suggests that the thermal strain, imposed by the hot environment and the exercise protocol was tolerable. Certainly, the ingestion of fluid throughout exercise may account for this observation because if a trial had been included whereby no fluid was ingested, a more negative shift may have been apparent. Also, the participants in this study were well trained and this would also serve to attenuate the thermal load (Morris et al., 2003).

Participants in both the continuous and intermittent trials reported an increase in activation from pre to immediately post exercise, as well as the consistent increase in activation at the onset of exercise. However, there was no interaction of condition x time throughout the time points assessed. In contrast, during the intermittent exercise protocol of study 5, the supply of CHO throughout the exercise protocol led to an enhanced activation profile during the last 30 min of exercise. Significant differences in blood glucose concentration at corresponding time points was offered as an explanation for such an enhanced profile. However, during the intermittent trials in the present study, blood glucose concentrations were higher in the CHO trial at 44 min and 59 min, but there was no enhancement in the activation ratings. It is feasible that in the present study the heat strain may have overridden such improved metabolic profiles and fluid availability may have become more important in reducing the heat stress of the body. In the CHO trials, a delay in gastric emptying will have occurred, which in turn may have limited the rate of fluid delivery (Vist & Maughan, 1994), thus eliminating the potential benefits of an increased glucose concentration on activation. In addition, the exercise trials in the present study were only 60 min in duration and in study 5, significant differences in activation did not occur until the last 30 min of a 90 min
IHI trial. The literature emphasises that the main benefits of CHO ingestion during exercise would seem to be the prevention of hypoglycemia, the provision of a CHO substrate for use late in exercise and sparing the limited glycogen stores in skeletal muscle (Coyle et al., 1986; Coggan and Coyle, 1991; Tsintzas et al., 1995, 1996; Nicholas et al., 1999). and these benefits appear to be most pronounced when the exercise duration is long (~2 h). In terms of subjective ratings of energetic arousal, despite increases across both fluid regimes in the intermittent trials, it was observed to be higher immediately post exercise in the FW trial, and self-reported energy was also higher in this trial at the same time point. In sum, the provision of CHO as an energy source during the present trial appears to have not been beneficial to the participant.

Energetic arousal displayed changes across exercise in the present study, which is in contrast to previous studies reported in this thesis, which were of a longer duration. Participants reported higher subjective sensations of energetic arousal following both the INT-CHO and INT-FW trials within the first 5 min of completing the exercise task. The shorter duration of these protocols compared to the previous studies described could in part explain this finding. When combined with the observation of an increase in tense arousal following both trials at the same time point, participants according to Thayer (2001) can be described as being in a state of tense energy. One might think of this state as being 'revved up and clicking on all cylinders' (Thayer, 2001), and it is a state seen by many as a positive feeling. Therefore, regardless of the fluid regime, this positive state was found to be elicited in trained males following a 60 min intermittent treadmill protocol undertaken in the heat.

A consistent finding across all the studies contained within this thesis is that of individual variability in affective responses at moderate exercise intensity. As noted previously, this study once again reports that individuals vary in the direction and intensity of their responses to the same exercise stimulus (Davidson & Irwin, 1999). For example, in the INT-CHO trial, pre to post exercise changes in valence ratings resulted in 40% of participants reporting an increase, 40% no change and 20% a decrease. In the FW trial, the same variety of responses was observed, with 47% reporting an increase, 13% no change and 40% a decrease in
valence. This finding again contradicts the traditional nomothetic assumption of the exercise-affect relationship, i.e., most participants are expected to experience similar changes in affect in response to the same exercise stimulus. As highlighted throughout this thesis, investigators interested in the exercise-affect relationship must pursue the issue of individual variability further if we are to fully understand this complex relationship.

Plotted in circumplex space, the EA and TA subscales illustrate that a more pronounced increase in activation occurs as a result of the intermittent exercise trial, and a comparison of the intermittent and continuous trial in which CHO was consumed, supports this graphical representation as significant increases in EA were limited to the intermittent trial. It was interesting to note that in the trials where flavoured water was consumed, no effect was seen on EA. The mechanisms for this finding are unclear.

Consistent with all the studies reported in the preceding chapters, ratings of perceived exertion increased across all four trials. Further, there were no differences reported between conditions. Similarly, heart rate and blood lactate responses were not different between the fluid trials. The relative exercise intensity was similar between trials, with the overall mean heart rate being ~151 beats.min⁻¹ during the four conditions. However, during the intermittent trials heart rate was elevated during the sprints to a value in excess of 80% HR max and consequently one could speculate that the physiological stress may have been greater during the intermittent trials. Blood glucose concentration was higher in the CNT-CHO trial at 44 min and in the INT-CHO trial at 44 min and 59 min compared to the respective FW trials. This finding again questions the efficacy of blood glucose concentration in explaining changes in perceptions of exertion.

The findings of the correlational analysis between the FS and the RPE scale offers support to the previous studies reported in this thesis because an inconsistent response pattern across the four trials emerged once again. The only consistent significant relationship occurred during the final exercise assessment. In this instance a moderate to large correlation was observed in the four trials. Again, in support of the previous studies, all the significant relationships were negative and
therefore as the perception of exertion increased, valence decreased. However,
once again the inconsistent pattern of results supports the conclusions of Hardy
and Rejeski (1989) that the FS and the RPE scale are not isomorphic constructs.

In conclusion, the addition of CHO to a solution ingested in the heat (30°C)
appears to provide no benefits in terms of the key thermoregulatory variables such
as rectal temperature and heart rate, or the psychological variables assessed. In
terms of the sensation of pleasantness, an increase was observed within 5 min of
completing the intermittent exercise trials. However, the mechanism responsible
for this change is unclear. It is feasible that a 'it hurts so good' phenomenon may
have elicited the changes in valence reported, or that participants felt a sense of
relief in completing the trials in which thermal strain was the greatest. The
increase in TA within 5 min of completing these trials could offer support for this
suggestion. During a 60 min trial, it is likely that any potential benefits of
ingesting a CHO-E solution may not have been realised, and that fluid delivery is
the most important factor.
11.1 Overview of experimental studies

Hardy and Rejeski (1989) asserted that the rating of perceived exertion scale on its own provides limited information about the subjective experiences of individuals during exercise. The statement that 'what' one feels and 'how' one feels may differ (Hardy & Rejeski, 1989) laid the foundations for the series of studies that comprise this thesis. In the laboratory, physiologists have inconsistently utilised the RPE scale as the only subjective measure of 'what' the participant is feeling during various exercise conditions. Such experimental trials are ultimately attempting to explain human sporting and exercise behaviour and aim to postulate how human performance can be improved through the manipulation of various conditions. However, by adopting such an approach they may be missing a crucial
element of human responses, namely affective states. RPE represents a ‘gestalt’ of various sensations related to the stress and strain of physical work (Borg, 1962), however, it may not accurately reflect the affect a person feels during exercise (Hardy & Rejeski, 1989). Acevedo et al. (1996) assert that “affective states and the cognitive appraisal of exertion during exercise may determine whether or not an individual will persist at an activity” (p.286). Furthermore, physiologists are not the only scientists that can be criticised for ignoring a potential mediator of human behaviour. Following a review of the exercise-affect literature (Chapter 2), it became clear that the potential impact of nutritional status and interventions had not been a consideration for investigators interested in the exercise-affect relationship. More specifically, fluid ingestion and its influence on exercise performance has been well researched and there has been a somewhat tentative approach to consider the subjective state of effort sense (Utter et al., 1997; 1999; Burgess et al., 1991), although psychological factors have largely been ignored. This is surprising when one considers the potential impact of such states on motivation and persistence at the activity, as already highlighted. The aim of the studies presented in this thesis was to examine the impact of various fluid ingestion regimes on affective responses and perceptions of exertion during prolonged running, cycling and high intensity intermittent shuttle running exercise. This was undertaken through a series of seven well-controlled studies.

It has previously been assumed that moderate intensity exercise will produce positive affective changes in all or most individuals (Biddle, Fox & Boutcher., 2000; Ekkekakis & Petruzzello, 1999a). However, the studies within this thesis (excluding the intermittent, high intensity exercise studies) question this assertion. All would be within the category of moderate exercise intensity according to ACSM (1995) guidelines that moderate intensity exercise comprises 50-74% VO₂ max. Clearly, the results of these investigations present a strong case for the importance of duration. Indeed, participants in only one study reported significant increase in the sensations of pleasantness following exercise, as measured by the FS. Specifically, following the 60 min intermittent run across both conditions (Study 7). In the remaining studies, the exercise per se did not make the participants feel any better than prior to undertaking the activity. Infact, during
exercise, valence was consistently observed to decline as the exercise progressed. Table 11.1 illustrates the results of all the studies and the changes observed.

Acute exhaustive exercise has traditionally been assumed to be emotionally aversive, but this assumption has not been extensively verified in empirical studies, particularly during studies that involve prolonged exercise to fatigue, such as Studies 3 and 6. The results of the two studies of this nature resulted in firm conclusions being drawn. When participants were approaching fatigue, their valence ratings exhibited a relatively homogenous pattern of decline, reaching a nadir upon fatigue. Therefore, regardless of the method used to induce volitional fatigue, for example following a prolonged, intermittent high intensity exercise protocol (IHI: Study 6) or a prolonged constant paced run (Study 3), the responses elicited displayed limited inter-individual variability. Specifically, across both these studies, we observed that participants scores were located in the lower left-hand quadrant of the circumplex model (deactivated unpleasant). These conclusions are unique and the studies are the first to describe the dynamic changes in affect as participants' exercise at a constant paced intensity until fatigue. Hall et al., (2002) also reported a negative affective state following fatiguing exercise, however, in contrast to Studies 3 and 6, upon fatigue, participants scores were located in the upper left-hand quadrant of the circumplex model (activated pleasant). This might indicate the different workings of a different fatiguing process, because the exercise protocol of Hall et al., (2002) was incremental and participants reached fatigue within about eleven minutes. However, in studies 3 and 6 participants exercised for significantly longer. Indeed, in study 6, the mean time to fatigue in the CHO trial was 147 minutes. It appears that regardless of how the end point of fatigue is reached, whether it is following a short bout of fatiguing exercise or a prolonged constant paced bout, the valence responses elicited are consistent. Such homogenous, negative affective states could be due to the claim by Nesse (1998) that affective responses represent adaptive reactions that have evolved to promote survival in a specific context. During the fatiguing protocols, the increased physical stress that the body is placed under during exercise alters the body's homeostasis. As this disruption enters consciousness (Cabanac, 1995; Damasio, 1995) the adaptive responses
elicited are those of negative affect, which serves as an alarm function to stop the individual and withdraw them from the fatiguing activity (Hall et al., 2002). The biological function of affect and emotions is the regulation of the internal state of the organism (Damasio, 1995). Consequently, this thesis has demonstrated that we can predict with some certainty that following certain stimuli (in this case a prolonged constant paced fatiguing exercise), particular affective states will be elicited (deactivated, unpleasant). Indeed, the finding that most individuals, (92% in the prolonged run to fatigue study and 75% in the IHI to fatigue study) respond negatively when the exercise becomes challenging, i.e. shortly prior to volitional fatigue, is in agreement with the Dual Mode hypothesis (Ekkekakis, 2003).

Ekkekakis (2003) postulates that affective responses during strenuous exercise unify into a negative trend as the intensity of exercise approaches each individual’s functional limits. Therefore, it seems that exercise undertaken to volitional fatigue leads to a decline in affective valence that exhibits limited inter-individual variability, supporting Ekkekakis (2003). The two studies that required participants to exercise to volitional fatigue also offered support to the statement by Acevedo et al. (1996) that it is highly feasible that if participants don’t feel better under one condition, they are unlikely to persist longer at that activity. Indeed, our studies uphold this because there was no significant difference in affect or perceived exertion and, in turn, no differences in the run to fatigue times between the CHO and PLA trials.

In contrast to the volitional fatigue studies, the remaining protocols did not produce such a homogenous response pattern. Instead, inter-individual differences were noted. This offers further support for the Dual Mode hypothesis (Ekkekakis, 2003). Ekkekakis asserts that affective responses during moderately vigorous exercise are characterised by marked inter-individual variability, with some individuals reporting positive and some negative affective changes. Indeed, there has been a tendency to assume that the relationship between exercise intensity and affective responses is unitary, leading to the assumption that ‘moderate’ exercise will produce positive affective responses in all or most individuals (Ekkekakis, 2003). In support of the inter-individual variability reported throughout the non-
fatiguing studies undertaken in this thesis is a study carried out by Van Landuyt and colleagues (2000). They noted that 44% of participants reported a progressive improvement in valence, whereas 41% reported a progressive decline. Moreover, the findings of this thesis fully support the assertion of Ekkekakis (2003) that, contrary to the assumption of variability, valence responses during exercise can vary considerably between individuals. In general it has been argued that in order for a situation to elicit an affective state, it must have significance or meaning to the individual. This significance or meaning is largely determined by a person’s motivation or personal goals (e.g., Lazarus, 1991). An implication of this position is that participants undertaking a laboratory-based study investigating the impact of exercise on affective states arrive at the laboratory with particular motives or goals in mind (Tuson & Sinyor, 1993). For example, one participant’s motive might be to physically challenge themselves, while another might seek diversion from exam stress. Tuson and Sinyor (1993) rationalise that the affective states they experience following the experimental session may depend largely on whether they perceive these goals to have been met. For example, the participant that comes into the laboratory looking for a physical challenge may feel proud and successful if she had finished the exercise test, and thus experience an improved affective state. On the other hand, if the participant had felt unchallenged and bored, or over-challenged and hence inadequate, then no change or a declining affective state may be experienced (Tuson & Sinyor, 1993). Future studies therefore should consider the motives and goals of the individual undertaking the experimental protocol and in turn the significance or meaning of the situation within which they are undertaking exercise.

Relevant literature remains limited in identifying the source of such variability, although, social cognitive theories have been shown to be related to affective responses to moderate exercise. Self-efficacy has been most extensively studied and associated with affective responses (McAuley & Courneya, 1992; Treasure, 1998). In the studies contained in this thesis, social cognitive theories were not directly tested, however, future research should strive to incorporate relevant measures to assess whether social-cognitive variables and indeed individual
differences (e.g., personality) account for a substantial portion of inter-individual variability.

Acevedo at al. (1996) and Hardy and Rejeski (1989) have assessed the relationship between the FS and the RPE scale during exercise and have reported that a moderate relationship exists. Indeed Hardy and Rejeski (1989) conclude that their data indicates “although the RPE and the FS do share some commonality, they are not isomorphic constructs. That is, from a phenomenological perspective, there is a difference between what one feels and how one feels at varying intensities of work” (p.310). The analyses conducted in this thesis revealed a variety of significant and non-significant relationships. Consequently, a relationship pattern was not apparent. For example, in study 2 the only significant correlations between the two scales were reported during the latter stages of the no fluid trial. Specifically a strong correlation was observed at 105 min (-.70, p<.05) and 120 min (-.67, p<.05). In study 4 only one significant relationship was noted at 90 min in the PLA trial. However in study 5 a more consistent pattern emerged, with significant correlations occurring from block 3 of the LIST onwards. The only exception to this was during the final block of the LIST in the CHO trial. It is unclear why this time point was not significant. Such inconsistencies could be explained by sample size. For example study 5 had seventeen participants, whereas study 4 had nine. However, the relationships reported by Acevedo et al. (1996) were consistent over time and their study only had 12 participants. Further research is warranted in order to examine more systematically the relationship between the FS and RPE in a variety of exercise settings. One can conclude however that the results do support the conclusions of Hardy and Rejeski (1989). Overall, the inconsistencies noted, along with the magnitude of the significant relationships suggests that although the FS and the RPE scale do share some commonality, they are not isomorphic constructs. Finally, a consistent finding across all the studies was the negative relationship observed between the FS and RPE scale. It was noted that as the perception of exertion increased, valence ratings decreased. Future research should continue to utilise both measures if we are to fully understand the exercise effect.
The relationship between fluid ingestion during exercise and affective states during and following exercise proved to be a complex one. In Studies 1 and 2, which compared a water ingestion trial to a no water trial during prolonged running and cycling, differences emerged, however they proved to be inconsistent. In Study 1, overall during the recovery period, valence was higher in the trial in which fluid was consumed. In study 2 however, there were no differences in valence between the water and no water trials. Water ingestion also resulted in increases in activation from pre- to post-exercise in study 1 but there were no differences between trials from pre- to post-exercise in Study 2. Water ingestion appeared to impact on the energy subscale of the AD ACL in Study 1, with reports of energy being higher in the fluid trial 5 and 15 min post-exercise compared to the pre-exercise time points. Indeed it was higher in the water trials compared to the no water trials at these times. Such a change was not observed in the trial whereby water was not consumed. Similarly in Study 2, EA was lower 5 min post exercise following water ingestion compared to no water ingestion and feelings of tiredness were higher 5 min post exercise in the no water trial. These findings stress the importance of assessing ‘how’ as well as ‘what’ the individual feels during such exercise bouts because a favourable affective profile was highlighted in the trials in which water was ingested but there were no differences in the perceptions of exertion. Therefore, although the participants did not perceive the exercise to be less demanding in the fluid trial, enhanced feelings of pleasantness and energy were reported during the running trial. Not surprisingly, subjective thirst ratings were significantly higher during the no fluid trials compared to the fluid trials across both exercise modes. It is feasible that the water deficit signalled by an increase in thirst could act as a potential cue in eliciting a more negative affective profile. However, if thirst were the key factor, one would expect valence to be enhanced in the cycling study also. There may be other factors beyond the control of the experimenter to explain such findings, and these will be discussed later. However, fluid ingestion should be considered as an important factor in the exercise-affect relationship as these studies have shown that there are some psychological benefits to ingesting fluid during exercise alongside the many well researched physiological benefits. This finding supports the proposition of Noakes (1993) that most researchers observed that fluid ingestion had more obvious
effects on the ‘psyche’ than on the ‘soma’. This finding is of practical importance, and fluid ingestion during exercise should be encouraged.

Previous research on the influence of CHO ingestion on affective responses during exercise has been severely limited, despite the well-documented influence on metabolism and performance. Indeed, to my knowledge, the only study to date that has examined changes in affect during exercise when ingesting a CHO drink versus a placebo drink was undertaken by Welsh and colleagues (2002). At rest in a study undertaken by Benton and Owens (1993) they concluded that higher blood glucose concentrations, that were within the normal range, were associated with lower self-reported tension and were correlated with greater self-reported energy. However, following a series of such investigations and a review of the literature they concluded that in studies undertaken at rest comparing sugar containing drinks with placebo drinks, the influence on mood is inconsistent. Reid and Hammersley (1995) using the POMS, reported no sizeable effect on mood of a sucrose drink immediately after consumption or at 30 and 60 min post-drink. Gonder-Frederick et al. (1989) in a study of insulin dependent diabetics, concluded that moods were related to blood glucose concentrations, but the relationships were highly idiosyncratic.

Affective responses were not influenced by the ingestion of a hypotonic CHO-electrolyte solution (GlaxoSmithKline) in the studies that involved exercise to fatigue (Studies 3 and 6). In addition ratings of perceived exertion were similar between trials. In support of such observations was the finding that the metabolic profile was not improved following CHO ingestion. In Study 3 no differences in blood glucose were found and in Study 6, the only significant difference was displayed 15 min into the exercise bout. In turn, across both modes of exercise, the ingestion of a CHO solution did not increase the run time to fatigue. Acevedo et al. (1996) asserted that an individual’s cognition and affect during physical work can lead to a positive or negative evaluation of the task, and in turn may lead to either the continuance or cessation of a task. Studies 3 and 6 offer support for such a relationship.
During the prolonged exercise trials of a fixed duration, the findings support the current literature stressing the inconsistency in responses to CHO feedings. In the prolonged cycling study (Chapter 7) and the IHI study (Chapter 8), differences were noted between trials. Specifically in the cycling study, ratings of perceived exertion were higher, significantly so at 75 min in the PLA trial. In addition, the sensation of pleasantness, as assessed by the FS, was enhanced in the CHO trial compared to the PLA trial. The ingestion of CHO was found to maintain and improve valence and a more pleasurable exercise experience was reported. In support of such reports was the observation that plasma glucose concentrations were higher following the CHO trial. Previous studies, using participants at rest, have noted an association between low blood glucose concentration and negative mood states (Gold et al., 1995). Furthermore, in the prolonged cycling study (Chapter 7), cortisol concentration was higher following exercise in the PLA trial. Cortisol is secreted in response to emotional stress and unpleasant sensations and this could be affecting the perception of exertion through neurological mechanisms (Utter et al., 1999) and therefore the same could be true for affective valence. An enhanced affective profile was also found following CHO ingestion during the prolonged IHI exercise protocol (Study 5). In this instance, it was restricted to the activation dimension. During the final 30 min of exercise, self-reported activation was higher in the CHO trial. In terms of the circumplex model of affect, this meant that towards the end of exercise, following CHO ingestion, participants responses were located in the activated pleasant quadrant. In contrast, in the PLA trial they were in the unactivated pleasant quadrant. Plasma glucose concentration was noted to be higher 60 min and 90 min into exercise in the CHO trial, compared to the PLA trial, and this could in part explain the increased activation state. However, this observation could have been facilitated by the glycogen depletion protocol that preceded the main trial. Only one previous study (Welsh et al., 2002) has examined the acute effects of CHO ingestion on affective states during IHI running exercise, and therefore it is difficult to compare our findings. In Study 7, undertaken in the heat, there were no differences in activation in the intermittent exercise trial when comparing the CHO and flavoured water trials despite a higher blood glucose concentration at 44 min and 59 min in the CHO trial. Participants in this study did not enter the laboratory in a
Chapter XI

General Discussion

depleted energy state, which could explain such a discrepancy in findings. Also the environmental conditions could indeed have exerted a strong influence on the findings, because fluid ingestion per se, rather than the energy content of the solution may have been the most important factor in determining the affective states elicited during such an exercise bout. Indeed, although energetic arousal (EA) increased from pre- to post-exercise across both intermittent exercise trials, it was found to be higher in the flavoured water trial. In contrast, in the continuous trial, EA was higher immediately post-exercise in the CHO trial, but tiredness, a subcomponent of EA was only observed to fall 5 min and 15 min post-exercise in the flavoured water trial immediately post exercise. Such discrepancies in findings are difficult to explain and supports the conclusion made by Benton and Owens (1993) that when sugar-containing drinks are compared with PLA drinks, the findings are inconsistent.

The reported changes in the EA dimension in Study 7 are of interest. At the present state of our scientific knowledge, the increased energy feelings appear to be part of a complex pattern of general bodily arousal (Thayer, 2001). Thayer (2001) suggests that intense and extended exercise does not increase energy, at least not immediately afterwards. It uses up 'your energy' and leaves 'you feeling exhausted'. However the increase in EA observed in Study 7, following the intermittent trial would question this assertion and its generalisability. It is also proposed (Thayer, 2001) that the primary mood effect of moderate exercise is increased energy, however the experimental protocols used in this thesis could be described as moderate when one considers the intensity at which participants exercised, however, duration also seems to be an important factor. In the studies reported in this thesis, only the 60 min intermittent exercise trial in the heat elicited such an increase in EA in its participants. Therefore, the relationship between subjective energy and exercise is more complex than one is led to believe.

Thayer (1989) reported that a reduction in tense arousal often follows exercise that is vigorous in nature and the findings of study 3 and to some degree study 6 supports this. An exercise trial cannot be more vigorous than one that leads to
fatigue and in the prolonged run to fatigue study (study 3) self-reported feelings of tense arousal were lower 15 min and 45 min following exercise, across both conditions. In the IHI exercise to fatigue study (study 6), such a reduction was limited to the CHO trial, 15 min post exercise. Tense arousal may have been reduced following these protocol because the participants may have felt a sense of relief upon completion of such a highly strenuous exercise trial which culminated in fatigue. To my knowledge these are the first studies that describe the affective changes that accompanies prolonged exercise to fatigue and therefore the first that reports a reduction in tense arousal following such demanding exercise trials. It is unclear why tense arousal was only reduced 15 min post exercise in the CHO trial only. Thayer (2001) asserts that tense or anxious moods are signals of the need for more energy, and it is assumed that the ingestion of CHO will have provided the participants with more energy compared to the placebo trial. However, the ingestion of CHO during studies 3 and 6 did not significantly enhance the metabolic profile. If such differences were evident in study 6, this could help to explain the differential changes in tense arousal between the CHO and PLA trials. Benton (2002) concludes that the relationship between CHO ingestion and mood is inconsistent when examined in resting individuals; the studies undertaken in this thesis could offer some support for this statement. Few studies of this nature have been undertaken in an exercise setting, which makes the comparison of results difficult. However, it is hoped that this research will encourage the development of this line of investigation further.

A consistent pattern of change in tense arousal did not emerge in the other trials reported in this thesis, in fact in the intermittent exercise trial in the heat (study 7) tense arousal was actually found to increase within five minutes of completing the exercise trial, compared to the pre exercising state. It could be argued that the negative shifts in tense arousal only occurred within the first 5 min of completing the exercise in both trials, before returning to baseline levels thereafter. Such an increase in tense arousal could be explained by the thermal strain imposed during exercise, which may have led to the sensation of heat discomfort and consequently affected the subjective ratings of tense arousal. Indeed, Baron (1977) notes that participants in high ambient temperatures show aggression and negative affect
compared to those in thermoneutral environments. However, there were no significant increases in tense arousal in the continuous exercise trials undertaken in the same environmental conditions. However, the greatest increases in core temperature were noted in the incremental trials.

In summary, a relationship between CHO ingestion and affective states during exercise remains tenable and cannot be discounted in future studies undertaken on the exercise-affect relationship and studies investigating nutritional intervention and exercise performance. However the findings of the present studies during exercise, as well as the literature on participants at rest (Benton, 2002) appears inconsistent and further research is now warranted to develop a sound knowledge base of this complex relationship.

A robust finding of all the studies undertaken in this thesis related to the changes in affective responses from the final within-exercise assessment, to the post exercise time points. Specifically, the affective valence responses were almost always uniformly positive. This finding transcended modes of exercise and also nutritional interventions. It appeared to be more dramatic among those participants reporting deterioration in affect during exercise, however it was still evident in those that reported maintenance or improvement during exercise. This finding is supported in the literature (Ekkekakis, 2003; Ekkekakis & Petruzzello, 1999a). In agreement with Ekkekakis and Petruzzello (1999a) such a response eliminated any divergent trends that might have occurred during exercise. In support of Bixby and colleagues (2001), the pattern of change in affective valence from the final within exercise assessment to the post exercise time points was similar to that of a rebound model (Bixby et al., 2001). Such a consistent finding emphasises the importance of assessing affective changes during exercise, as well as pre and post exercise, because a researcher who fails do this restricts themselves and the literature on the exercise-affect relationship from gaining a full understanding of the dynamic nature of affect.
Table 11.1 Overview of the study findings.

<table>
<thead>
<tr>
<th>Study Number</th>
<th>n &amp; sample</th>
<th>Exercise Type</th>
<th>FS During Ex</th>
<th>FS Pre–Post Ex</th>
<th>FAS</th>
<th>EA / TA</th>
<th>Energy/ Tiredness</th>
<th>Tension/ Calmness</th>
<th>RPE</th>
<th>Metabolic Indices</th>
<th>Additional Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 males</td>
<td>90 min running at 70% VO₂ max</td>
<td>Overall, during the recovery, valence ratings were higher in the fluid trial</td>
<td>No change</td>
<td>-Increased pre to post ex &amp; remained elevated in water trial only</td>
<td>Energy-higher in water trial of 5 &amp; 15 min post exercise compared to no water</td>
<td>No change</td>
<td>-Increase over time</td>
<td>-No condition effect</td>
<td>Not measured</td>
<td>Thirst rating higher in the NF trial</td>
</tr>
<tr>
<td>2</td>
<td>9 males</td>
<td>120 min cycling at 65% VO₂ max</td>
<td>Decrease with the duration of exercise</td>
<td>Reduced effect across both conditions</td>
<td>-Increase across both trials from pre to P0-During exercise, FS increased</td>
<td>Energy-decrease pre to post exercise Tiredness-higher in no water trial 5 min post exercise compared to water trial</td>
<td>Tension—higher in water trial only decreases in this trial to P30 &amp; P60</td>
<td>-Increase over time</td>
<td>-No condition effect</td>
<td>Plasma cortisol not different between conditions</td>
<td>Thirst rating lower in water trial</td>
</tr>
<tr>
<td>3</td>
<td>13 males</td>
<td>Run to fatigue at 70% VO₂ max</td>
<td>Decrease across both conditions</td>
<td>Decreased to P0 across both conditions - 92% decrease upon fatigue</td>
<td>No changes</td>
<td>TA—decrease from pre to P15 and P45 across both conditions</td>
<td>No changes</td>
<td>Tension—decrease from pre to P15 and P45 across both conditions</td>
<td>-Increase over time</td>
<td>-No condition effect</td>
<td>Glucose lower @ 20 min in CHO, no other differences</td>
</tr>
</tbody>
</table>

CNT — continuous exercise; INT — intermittent exercise; EA — Energetic Arousal; TA — Tense Arousal; FS — Feeling Scale; FAS — Felt Arousal Scale; CHO — Carbohydrate Solution; PLA — Placebo Solution; FW — Flavoured Water Solution; P15 — 15 min post exercise; Trec — Rectal Temperature.
Table 11.1 cont.d. Overview of the study findings.

<table>
<thead>
<tr>
<th>Study Number</th>
<th>n &amp; sample</th>
<th>Exercise Type</th>
<th>FS During Ex</th>
<th>FS Pre–Post Ex</th>
<th>FAS</th>
<th>EA / TA</th>
<th>Energy/ Tiredness</th>
<th>Tension/ Calmness</th>
<th>RPE</th>
<th>Metabolic Indices</th>
<th>Additional Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>9 males</td>
<td>Higher &amp; better maintained in CHO trial compared to PLA</td>
<td>Interaction-higher in CHO overall in recovery to P30</td>
<td>Increase at onset of ex &amp; remained stable throughout</td>
<td>No change</td>
<td>Energy-decrease from pre to post exercise across both conditions</td>
<td>No change</td>
<td>-Increase over time - Lower RPE in CHO trial @ 75 min</td>
<td>Glucose higher P0 in CHO trial, lactate &amp; cortisol lower at P0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>17 males</td>
<td>No change</td>
<td>Re-bound effect across both conditions</td>
<td>Higher in CHO trial during the last 30 min of ex</td>
<td>No change</td>
<td>Time effect for energy, but no sampling point changes</td>
<td>No change</td>
<td>-Increase over time</td>
<td>Glucose higher @ 60 &amp; 90 min in CHO trial - FFA - lower in CHO @ 60 &amp; 90 min in CHO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>12 males</td>
<td>Decrease during exercise across both conditions</td>
<td>-Decrease to fatigue across both trials -Re-bound effect, from fatigue to P15 across both trials - Fatigue (75% decrease in CHO, 67% in PLA)</td>
<td>Increase at onset of ex, constant throughout, no pre to post changes</td>
<td>TA – Decrease 15 min post ex in CHO trial</td>
<td>Tension – decrease from pre to P15 across both trials Calmness – decrease pre to fatigue in PLA trial only</td>
<td>No change</td>
<td>-Increase over time - No condition effect</td>
<td>Glucose lower at 15 min compared to PLA, no other differences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CNT – continuous exercise; INT – intermittent exercise; EA – Energetic Arousal; TA – Tense Arousal; FS – Feeling Scale; FAS – Felt Arousal Scale; CHO – Carbohydrate Solution; PLA – Placebo Solution; FW – Flavoured Water Solution; P15 – 15 min post exercise; Trec – Rectal Temperature.
Table 11.1 cont.d Overview of the study findings.

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<tr>
<th>Study Number</th>
<th>n &amp; sample</th>
<th>Exercise Type</th>
<th>FS During Ex</th>
<th>FS Pre - Post Ex</th>
<th>FAS</th>
<th>EA / TA</th>
<th>Energy/ Tiredness</th>
<th>Tension/ Calmness</th>
<th>RPE</th>
<th>Metabolic Indices</th>
<th>Additional Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>15 males</td>
<td>CNT or INT exercise on a motorised treadmill in 30°C</td>
<td>CNT: Decrease in FS across both conditions</td>
<td>CNT: No changes</td>
<td>CNT: Increase pre to P0 across both conditions</td>
<td>EA: CNT: EA higher P0 in CHO trial compared to FW INT: EA Higher P0 in FW trial compared to CHO TA: INT: Increase P0 in FW trial &amp; P5 in CHO trial</td>
<td>Energy INT: Higher in FW trial P0</td>
<td>Tiredness CNT: decrease to P5 and P15 across both trials</td>
<td>Calm CNT: Increase from PO across both trials back to baseline</td>
<td>Tension CNT: Decrease from pre ex to P5, P15 7 P30 across both trials</td>
<td>CNT: Increase across both ex modes in CHO trials</td>
</tr>
</tbody>
</table>

CNT – continuous exercise; INT – intermittent exercise; EA – Energetic Arousal; TA – Tense Arousal; FS – Feeling Scale; FAS – Felt Arousal Scale; CHO – Carbohydrate Solution; PLA – Placebo Solution; FW – Flavoured Water Solution; P15 – 15 min post exercise; Trec – Rectal Temperature.
11.2 Potential confounding factors
As a researcher interested in the exercise-affect relationship, one must be aware of the confounding factors that exist in this type of investigation. Factors that may influence this relationship include gender, age, fitness status, affect level prior to participation, attitude, expectancy, time of year, time of day, day of the week, temperature, humidity, duration of each session, inventory used for measurement. The research studies reported in this thesis have controlled as many of these variables as possible. One had to rely on the use of volunteers in the studies and the generalisability of the results of this thesis lies at the level of trained individuals who regularly participate in exercise and sport. The findings, which deal with the psychological outcomes of exercise and nutritional intervention, therefore, are restricted to the population from which the sample was drawn, which is in essence a student population of trained sports men. Consequently a limitation to the general applicability of the results is whether or not the findings are also applicable for those taking part in physical activity of a shorter duration and from different age groups, and therefore if the results are relevant within the public health domain. Clearly, the findings are of significant interest to this population, given the affective beneficence outlined, however, further research is required utilising such a population in order to allow firm conclusions to be made. In addition there is also the issue of 'ecological validity', which has been problematic for many years. Orne (1962) has defined ecological validity as “appropriate generalisation from the laboratory to non-experimental situations” (p.776). This is an important consideration because many behavioural scientists believe that variables, in this case affective states and effort sense, change when they are studied in the laboratory. Consequently, it could be argued that the present studies possess good ‘internal validity’ but lack generalisability from the laboratory to the field setting where the application of the results is often desired. Future research should investigate the influence of various nutritional regimes on affective states and effort sense in athletes in the training field and also during competition to examine whether the results are transferable to such a setting.

The studies outlined in the previous chapters may be subject to what Rosenthal (1966) describes as the experimenter expectancy effect, whereby outcome expectancies are communicated to the participants by the experimenter in an intended or unintended manner. This ultimately results in the participant being influenced and consequently
altering their ratings accordingly. However, the results and methodologies employed would direct us to the conclusion that such effects would be minimal and at best have been prevented. With the exception of the water ingestion studies (Studies 1 & 2), the experiments were double blind, thus reducing the potential for such an effect. In the case of the water ingestion studies, where such a practice was not possible, the unique nature of the studies employed meant that the experimenter had no previous results upon which to base a bias on. However, as previously outlined in these studies, a Hawthorne effect cannot be ruled out. It is possible that the participants in these studies tried to determine the true purpose of the study and in turn responded in accordance with the perceived hypothesis. In order to minimise such effects, the psychological aspects of the studies were always masked by the physiological variables being collected. However, participants had to complete psychological inventories and therefore, one could not completely hide such an element of the investigation. Further, in an experimental protocol whereby fluid ingestion is compared to no fluid ingestion, a double blind protocol is impossible, which means attempting to completely eliminate the potential confounding impact of the Hawthorne effect is simply not possible. In summary, an expectancy effect, on the beneficial merits of ingesting fluid during prolonged exercise, based on their own cognitions and perceptions, cannot be eliminated. However, we made every attempt to minimise such influences outlined by the methodologies employed in the studies outlined, particularly through collaboration with exercise physiology experiments, whereby no mention of psychology was made.

This research programme has attempted to elucidate some of the factors, both physiological and nutritional involved in the formation of affective states, and clearly the most heuristic view is that complex psychophysiological processes are involved. Affective responses are in a similar vein to ratings of perceived exertion, best viewed as a Gestalt, based upon various psychophysiological processes, which according to Morgan (Morgan, 1981) and his views on RPE, are technologically inaccessible, but readily available in terms of one’s self-awareness (p.424). The study of this evolving body of knowledge will pose a challenge to the researcher, but should be seen as an ongoing process, with the interplay of sound theoretical underpinning and research findings.
11.3 Recommendations for further research

Further research is warranted to explore the interaction between nutritional status and affective responses. The series of studies contained in this thesis has initiated a unique line of investigation and in order to take this approach forwards, further studies are warranted.

The fluids ingested in the studies reported in this thesis were that of water and CHO-solutions. It would be worth investigating the influence of other commonly consumed sporting beverages, such as caffeine, in order to examine the potential impact they may have on the subjective responses elicited. Furthermore, the studies reported in this thesis could be extended by the consideration of the amount and type of CHO ingested during such exercise protocols. Will such changes in methodology have an impact on the affective responses that ensue.

The nutritional influence on affective states could be extended to an examination of CHO ingestion in food form prior to exercise on subsequent affective states and ratings of perceived exertion during and following exercise. Such research has been reported in the exercise physiology and biochemistry literature in examining its effects on exercise performance per se. However, as was the case with fluid ingestion, the influence of such practices on the participants subjective experience has largely been ignored. It would be particularly interesting to examine the influence of different CHOs in relation to their glycemic index, as we may observe an association with the hypoglycemic effect elicited in some individuals following the ingestion of high glycemic index foods on affective states. Indeed, the influence of hypoglycemia on affect has been considered at rest (Gold et al., 1995; Gonder-Frederick, 1989), however, this has not been considered during exercise.

An understanding of how different methodologies may impact on affective states is worth pursuing. For example, what is the influence of conducting the experimental trials at different times of day, on the affective responses to exercise? Is there a greater tension reducing effect following exercise undertaken at 6pm, compared to 9am, when the participants may not have experienced the potential daily stresses. Are the responses different on a weekend, to those elicited during the week? There is
certainly great scope to extend this line of enquiry. In addition, this thesis was conducted using male participants, and consequently this work could be extended to include female participants. Further, the majority of participants involved in this research were of university age, so it would be interesting to examine the responses elicited by more mature adults.

The exercise modes used in this thesis were of a prolonged nature and consequently undertaken by well-trained individuals. It would be worthwhile exploring the effects of nutritional intervention on the active as opposed to the trained population. For example, will the ingestion of fluid during an exercise class, undertaken by women in their forties, have the same psychological benefit that ingesting water during a 90 min treadmill run proved to have?

It is clear in the exercise-affect literature that there are still many questions to be answered, particularly with regards to the issue of measurement of affect, in order to extend our understanding of the relationship (Ekkekakis & Petruzzello, 2000a). Future research should continue to examine changes in affect from a dimensional approach, such as the circumplex model of affect, in order to allow researchers to fully tap into the broad spectrum of affective states that may accompany exercise. In addition, more systematic examinations of the mechanisms involved in affective changes are certainly warranted.
References


References


FEELING SCALE

+5  ______  Very good

+4  ______

+3  ______  Good

+2  ______

+1  ______  Fairly

0  ______  Neutral

-1  ______  Fairly bad

-2  ______

-3  ______  Bad

-4  ______

-5  ______  Very bad
Appendix B

FEELT AROUSAL SCALE

1 — Low arousal
2
3
4
5
6 — High arousal
Self-Assessment Inventory

INSTRUCTIONS: Following are some adjectives that describe people’s feelings. Please, read each of the adjectives and then indicate how you are feeling *at this particular moment*, by circling the appropriate response. There are no right or wrong answers, so do not spend too much time on any one item. Check to make sure you have responded to all the items.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Active</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>2. Placid</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>3. Sleepy</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>4. Jittery</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>5. Energetic</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>6. Intense</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>7. Calm</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>8. Tired</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>9. Vigorous</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>10. At rest</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>11. Drowsy</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>12. Fearful</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>13. Lively</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>14. Still</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>15. Wide-awake</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>16. Nervous</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>17. Quiet</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>18. Full-of-energy</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>19. Tense</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
<tr>
<td>20. Wakeful</td>
<td>✓✓</td>
<td>✓</td>
<td>?</td>
</tr>
</tbody>
</table>

Thayer (1989)
Rate Of Perceived Exertion

6

7  Very Very Light

8

9  Very Light

10

11  Fairly Light

12

13  Fairly Hard

14

15  Hard

16

17  Very Hard

18

19  Very Very Hard

20
STATEMENT OF INFORMED CONSENT

I have read the subject information sheet, detailing the procedures and requirements which are involved with this study and I fully understand what is required of me. I have had an opportunity to ask for further information and clarification of the demands of each of the procedures. I am aware that I have the right to withdraw at any time with no obligation to give reasons for my decision.

I agree to take part in the study.

Name ___________________________ Phone No. ___________________________

Age __________ Date of Birth ___________________________

Contact Address __________________________________________________________________________
                                                                                              
                                                                                              
Signed ___________________________ Witnessed by ___________________________

Date ___________________________
Appendix F

HEALTH SCREEN FOR STUDY VOLUNTEERS

Name or Number  .................

It is important that volunteers participating in research studies are currently in good health and have had no significant medical problems in the past. This is to ensure (i) their own continuing well-being and (ii) to avoid the possibility of individual health issues confounding study outcomes.

Please complete this brief questionnaire to confirm fitness to participate:

1. At present, do you have any health problem for which you are:
   (a) on medication, prescribed or otherwise...........................................Yes ☐ No ☐
   (b) attending your general practitioner.................................................Yes ☐ No ☐
   (c) on a hospital waiting list...............................................................Yes ☐ No ☐

2. In the past two years, have you had any illness which require you to:
   (a) consult your GP ........................................................................Yes ☐ No ☐
   (b) attend a hospital outpatient department......................................Yes ☐ No ☐
   (c) be admitted to hospital ...............................................................Yes ☐ No ☐

3. Have you ever had any of the following:
   (a) Convulsions/epilepsy .................................................................Yes ☐ No ☐
   (b) Asthma ....................................................................................Yes ☐ No ☐
   (c) Eczema ....................................................................................Yes ☐ No ☐
   (d) Diabetes ..................................................................................Yes ☐ No ☐
   (e) A blood disorder ........................................................................Yes ☐ No ☐
   (f) Head injury ...............................................................................Yes ☐ No ☐
   (g) Digestive problems .................................................................Yes ☐ No ☐
   (h) Heart problems .........................................................................Yes ☐ No ☐
   (i) Problems with bones or joints .................................................Yes ☐ No ☐
   (j) Disturbance of balance/coordination ........................................Yes ☐ No ☐
   (k) Numbness in hands or feet ......................................................Yes ☐ No ☐
   (l) Disturbance of vision ................................................................Yes ☐ No ☐
   (m) Ear / hearing problems ...........................................................Yes ☐ No ☐
   (n) Thyroid problems ....................................................................Yes ☐ No ☐
   (o) Kidney or liver problems ........................................................Yes ☐ No ☐
   (p) Allergy to nuts .........................................................................Yes ☐ No ☐

4. Has any, otherwise healthy, member of your family under the age of 35 died suddenly during or soon after exercise? .............Yes ☐ No ☐

If YES to any question, please describe briefly if you wish (eg to confirm problem was/is short-lived, insignificant or well controlled.) ...........................................................

........................................................................................................
.........................................................................................................

Thank you for your cooperation!