Exercise and Affect
– the Study of Affective Responses to Acute Exercise: The Dual-mode Model

Panteleimon Ekkekakis

Approximately 40% of the adults in the United States report no regular physical activity (United States Department of Health and Human Services, 2000), 65% do not meet the current physical activity recommendations of 30 minutes of daily moderate activity (Jones et al., 1998), only 15% participate in activities of sufficient intensity, duration, and frequency to improve or maintain cardiorespiratory fitness (United States Department of Health and Human Services, 1996), and 50% of those who start an exercise program drop out during the first 6 to 12 months (Dishman & Buckworth, 1996, 1997). According to the 1998-99 Progress Review of the Healthy People 2000 program, over the past 15 years, "the proportion of the population reporting physical activity has remained essentially unchanged, and progress is very limited" (United States National Center for Health Statistics, 1999, p. 29). Moreover, data from the National Health and Nutrition Examination Survey show that overweight, defined as a BMI ≥25, increased from 55.9% in 1988-1994 to 64.5% in 1999-2000 and obesity, defined as a BMI ≥30, increased from 22.9% to 30.5% during the same period (Flegal et al., 2002). For these reasons, the promotion of physical activity has been characterized a national public health priority (United States Department of Health and Human Services, 1996, 2000) and "the new imperative for public health"(Sparling, Owen, Lambert, & Haskell, 2000). In Europe, among 15 country-members of the European Union, 11% of the residents report no participation in any physical activity or exercise, 31% are overweight, and 10% are obese (Institute of European Food Studies, 1999).

The problem of low participation in physical activity is clearly a function of both a low rate of initial engagement and a high rate of subsequent dropout. However, much less research attention has been directed over the years to the psychological processes underlying dropout than those underlying initial engagement. According to Dishman (2001):

> It is clear that most research efforts during the past 10 years have been guided by models best suited to increasing the initial adoption of physical activity rather than understanding maintenance and periodicity of participation... It is my contention that the currently low prevalence of physical activity in the US and other developed nations can partly be explained by the nearly exclusive focus of research during the past decade or so on interventions designed mainly to increase adoption and theories that do a poor job of explaining adherence. (p. 281)

More specifically, a mechanism that is often assumed, but has yet to be studied in a systematic manner consists of a causal chain linking (a) the intensity of physical activity, (b) affective responses of pleasure or displeasure, and (c) adherence or dropout. According to Dishman (2003), "though physical activity arguably offers more opportunities for pleasure than do most other health-related behaviors (compared to brushing, flossing, buckling up, and seeing the doctor, for example), we, ironically, have learned very little about intrinsic reinforcements (e.g., enjoyment of physical activity) for continued participation" (p. 46). Nevertheless, this idea has been around for a long time. A connection between pleasure and adherence was proposed by Morgan as early as 1977:

> It seems reasonable to assume that [individuals] must experience some form of positive reinforcement from the outset. In other words, if the experience is not ... pleasurable, one should expect the volunteer to drop out. The exercise must not be perceived as primarily noxious, and it also must be sufficiently pleasurable to compete successfully with other pleasurable options available to the exerciser. (p. 244)

Reiterating essentially the same idea, more than 20 years later, the text of the Healthy People 2010 program in the United States emphasized that "each person should recognize that starting out slowly with an activity that is enjoyable ... is central to the adoption and maintenance of physical activity behavior" (United States Department of Health and Human Services, 2000, p. 22-4).

An essential first step in the process of examining the causal pathway linking intensity, affect, and adherence or dropout is gaining a better understanding of the crucial first link, namely the relationship between exercise intensity and affect. The current "orthodox" view on this subject in exercise psychology is that (a) exercise makes people feel better, (b) moderate-intensity exercise (not too low, not too high) optimizes the conditions for positive affective change, and (c) affective responses to exercise depend mainly on cognitive processing and appraisal. Propositions (a) and (b), in particular, are generally assumed to have a nearly nomothetic scope, being applicable to 80% or 90% of exercisers. Some examples of these propositions, as they have appeared in exercise psychology writings, are shown on Table 1.

Table 1. Examples of statements representing the orthodox view in exercise psychology regarding affective responses to exercise.

(a) Exercise makes people feel better	
1.	"The 'feeling better' sensation that accompanies regular physical activity is so obvious that it is one of the few universally accepted benefits of exercise" (Morgan, 1981, p. 306).
2.	"Both survey and experimental research provide support for the well publicized statement that 'exercise makes you feel good'" (Fox, 1999, p. 413).
(b) Moderate-intensity exercise is best	
1.	"Moderate-intensity exercise ... consistently has been associated with mood benefits" (Berger & Motl, 2000, p. 81).
	"While individual differences often prevail, it is believed that best psychological benefits are derived using a moderate intensity of exercise as opposed to a very low or very high intensity" (Cox, 2002, p. 367).
(c) How you think determines how you feel ("mind over muscle")	
1.	"The arousal created by physical activity can lead to a variety of feelings, good or bad, depending upon the cognitive label assigned to events" (Gauvin & Rejeski, 1993, p. 405).
2.	"As the history of cognitive psychology has shown, reality is in the eye of the beholder. Although we certainly do not want to dismiss the objective demands inherent in exercise programs, ultimately it is an individual's construction of reality that determines any sense of threat, challenge, or loss/harm experienced" (Rejeski & Hobson, 1994, p. 108).

On the basis of these assumptions, some authors have questioned whether there is really a connection between affective responses and adherence. Simply put, many in exercise psychology believe that exercise makes nearly everyone feel better and, therefore, affective responses to exercise cannot account for the fact that half of those who start to exercise soon drop out. According to Morgan and O'Connor (1988), “to argue that people who feel good following exercise would be more likely to adhere than those who do not may be intuitively defensible, but such a view is simplistic..., [because] roughly 80% to 90% of individuals in exercise programs report that exercise makes them feel better, but 50% drop out within a few months” (p. 116). This view, however, seems to be dramatically different from the portrayal of exercise in the popular media, where businesses make billions of dollars marketing products that promise weight loss and various health benefits without having to “suffer through exercise.” This is a paradox that needs to be resolved if exercise psychology is to offer meaningful assistance to those individuals who experience difficulties coping with the unpleasant affective responses that accompany the early stages of their physical activity participation.

The purpose of this paper is to (a) present a number of methodological issues that might have contributed to the “orthodox” view described above (i.e., “exercise makes people feel better”, etc.,) by blurring the true relationship between exercise and affect, (b) outline a theoretical formulation that accounts for dose-response effects, including negative affective responses to exercise and inter-individual variability, and (c) present some preliminary supporting data.

Methodological issues

Four methodological issues will be discussed: (a) the measurement of affect, (b) the timing of affect assessments, (c) the examination of patterns of inter-individual variability, and (d) the standardization of exercise intensity.

Measurement of affect

In most published studies, affect was assessed in terms of distinct states, such as state anxiety, mood states, or specific states thought to be influenced by exercise (e.g., revitalization, fatigue). The primary problem with concentrating on a small number of distinct states is that it is possible that other changes, possibly the most experientially salient ones, might go undetected. This is important, given that, at the current stage of knowledge development, it is not possible to predict what responses may occur in different participants under different conditions. As a solution, it has been suggested that a dimensional model of affect may offer an advantage over previous approaches (Ekkekakis & Petruzzello, 1999, 2000, 2002a). The main assumption underlying dimensional models is that affective states are systematically interrelated, such that their relationships can be modeled parsimoniously in terms of as few as two basic dimensions. The dimensional model used in the studies to be described here is the circumplex model of affect (Russell, 1978, 1980), according to which the affective space is defined by the orthogonal and bipolar dimensions of affective valence and perceived activation. Different affective states can, therefore, be viewed as combinations of varying degrees of these two dimensions, such that they can be conceptualized as located around the perimeter of a circle defined by the two dimensions. Experientially similar affective states (e.g., “happy” and “delighted”) are closer together on the circle, whereas affective states perceived as antithetical (e.g., “happy” and “sad”) are opposite on the circle. A division of the circle into quadrants produces (a) unactivated pleasant affect, characterized by relaxation and calmness, (b) unactivated unpleasant affect, characterized by boredom, fatigue, or depression, (c) activated unpleasant affect, characterized by tension and distress, and (d) activated pleasant affect, a state characterized by energy, excitement, and enthusiasm. At the unavoidable expense of some specificity, the circumplex model can provide the most encompassing and parsimonious representation of the affective space and, thus, a useful platform for investigating the effects of various physical activity stimuli on affect.

Timing of affect assessments

In most previous studies on the influence of acute exercise on affect, including most dose-response studies, affective changes were examined from pre- to various time points post-exercise. It is not clear how this practice was initiated. One possibility is that researchers assumed that the trajectory of change from pre- to post-exercise would be linear. Another possibility is that the practice was simply dictated by convenience, since the questionnaires used consisted of multiple items, which would have required the activity to be interrupted in order to obtain assessments during exercise. Interestingly, most of the studies examining the effects of different exercise intensities on affective changes from pre- to various time points post-exercise have failed to show evidence of reliable dose-response effects (Ekkekakis & Petruzzello, 1999). However, given the timing of assessments, it is possible that dose-response effects might have occurred (i.e., during exercise) but had dissipated by the time the post-exercise assessments took place. In fact, studies in which affective valence was assessed repeatedly during exercise by single-item rating scales (such as the Feeling Scale; Hardy & Rejeski, 1989) have revealed a consistent pattern of dose-response effects. Specifically, with increasing exercise intensity, there is a progressive decline in affective positivity or increased negativity during exercise, but this trend is reversed as soon as the exercise bout is terminated (e.g., Acevedo, Rinehardt, & Kraemer, 1994; Hall, Ekkekakis, & Petruzzello, 2002; Hardy & Rejeski, 1989; Parfitt & Eston, 1995; Parfitt, Eston, & Connolly, 1996; Parfitt, Markland, & Holmes, 1994). This "rebound" (Bixby, Spalding, & Hatfield, 2001) is reminiscent of the affective contrast phenomenon described by Solomon (1991). Given this pattern of affective change during and following a bout of activity, it is possible that findings of positive changes from before to after an activity bout, regardless of intensity, might actually reflect the positive effect of the preceding seconds or minutes of recovery from the activity and not the effects of the activity itself. To obtain a more accurate depiction of the affective changes associated with a bout of activity, it is necessary to sample affect repeatedly during the exercise bout, with adequate frequency to ensure that no major changes will escape detection.

Examination of inter-individual differences

The differences between individuals in affective responses to the same exercise stimulus have not been examined systematically. A common assumption in previous research has been that inter-individual variability in affective responses is primarily a matter of the degree to which individuals experience positive changes. However, exercise can have bidirectional effects on affect. Therefore, it is possible that some individuals will experience affective improvement while others experience decline. In fact, in a study in which individual changes during a bout of moderate exercise (30 min of stationary cycling at 60% of estimated maximal aerobic capacity) were examined, it was found that 44.4% of the participants reported improvements in affective valence, whereas 41.3% reported declines (Van Landuyt, Ekkekakis, Hall, & Petruzzello, 2000). As a result of these divergent trends during exercise, the average response appeared unaltered, which is clearly a misrepresentation of the actual changes that took place.

Standardization of exercise intensity. One of the important methodological challenges in dose-response studies stems from the need to equate the level of exercise intensity provided to different participants. In previous research, the levels of exercise intensity that were compared were either different levels of absolute workload (e.g., a certain number of Watts or a work rate that elicited a certain heart rate) or different percentages of maximal exercise capacity (e.g., percentages of age-predicted maximal heart rate or maximal aerobic capacity). Relative methods (i.e., those based on percentages of maximal capacity) are generally deemed preferable because they take individual differences in maximal exercise capacity into account. However, what this approach fails to take into account is the issue of the metabolic processes involved, a problem identified since the 1950s (Wells, Balke, & Van Fossan, 1957). For example, at 70% of maximal aerobic capacity, some individuals may use exclusively aerobic metabolism, whereas others may need to supplement aerobic with anaerobic metabolism. In a study involving 31 participants, when exercise was performed at 80% of maximal heart rate (62.5% of maximal aerobic capacity), 17 participants were working at a level above, whereas 14 were working at a level below metabolic acidosis, a sign of anaerobic metabolism (Katch, Weltman, Sady, & Freedson, 1978). This is a critical issue, because whether aerobic or anaerobic metabolism is involved has significant implications for adaptation. Although the resources available to aerobic metabolism are vast and aerobic effort can be maintained for a prolonged period of time while at a physiological steady state, the resources available to anaerobic metabolism are very limited. If anaerobic effort is continued, the maintenance of a physiological steady state becomes impossible and exercise leads to exhaustion. Therefore, examining levels of exercise intensity defined on the basis of the point of transition from aerobic to anaerobic metabolism should help clarify the dose-response relationship between exercise and affect by effectively equating the workload across individuals.

The dual-mode theory: Basic assumptions

At the present stage, the main obstacle for progress in research examining the exercise-affect relationship is the absence of a comprehensive theoretical framework. Such a framework should satisfy the following five desiderata.

- First, it should reintegrate the “mind” and the “body,” thus overcoming the dualistic separation that has occurred with the development of insular “cognitive” and “biological” sets of hypotheses proposed to explain the exercise-induced “feel-better” phenomenon.
- Second, the new framework should take into account the information that is emerging from related scientific fields such as affective neuroscience and genetics.
- Third, the framework should account for dose-response patterns in affective responses.
- Fourth, there should be an acknowledgment and accounting for the patterns of inter-individual variability in affective responses.
- Finally, the new framework should go beyond the simplistic notion that the only affective change elicited by exercise is to “make people feel good” and, instead, acknowledge and account for the fact that the affective responses to exercise are multifaceted.

The dual-mode theory was developed to address these needs (Ekkekakis, 2003). A central thesis underpinning this conceptual model is that physical activity must be considered from an adaptational perspective. Physical activity has been an integral part of life for the human species throughout its evolutionary history (Åstrand, 1986, 1994; Cordain, Gotshall, & Eaton, 1997; Cordain, Gotshall, Eaton, & Eaton, 1998; Eaton, Shostak, & Konner, 1988). Although it is clear that certain aspects of the adaptational significance of physical activity behavior for humans have changed over evolutionary time (e.g., in most cases, it is no longer necessary to exert oneself to obtain food or to fight off predators) and there is inherent risk in drawing analogies between Pleistocene and modern humans, who live much longer and generally succumb to different causes of death, many of the adaptational implications of activity appear to have remained invariant. In particular, both then and now, humans had to be active to stay alive and had to stay alive while being active.

Within this adaptational framework, the dual-mode theory is based on the following core assumptions. First, physical activity is considered an essential component of the human Environment of Evolutionary Adaptedness (EEA; Tooby & Cosmides, 1990a), the set of conditions that shaped human evolution. Unlike previous views of what the EEA encompasses, emphasis is placed on the internal environment of the body and the constraints that it presents (to be described in the following section).

Second, affective responses are viewed as manifestations of evolved psychological mechanisms, selected for their ability to promote health and well-being or to solve recurrent adaptational problems (Nesse, 1990) within the particular EEA of physical activity. Pleasure is believed to signify utility and displeasure to signify danger (Cabanac, 1971, 1979, 1995; Panksepp, 1998a, 1998b). As noted earlier, different levels of physical activity intensity may entail either utility or danger. Affective responses of pleasure and displeasure during physical activity of different intensities are believed to be reliably and meaningfully linked to those levels of intensity that entail utility and danger, respectively.

Third, consistent with emerging evidence from affective psychology and neuroscience, it is assumed that affective responses, including those that originate in the body (Craig, 1996, 2002; Damasio, 1995), depend on a hierarchically organized system involving multiple layers of control. This system ranges from oligosynaptic, subcortical, and evolutionarily primitive pathways that underlie survival-critical, automatic or obligatory responses at the bottom, and polysynaptic, evolutionarily recent, cortical pathways producing complex, flexible, and highly individualized responses at the top (Berntson, Boysen, & Cacioppo, 1993; Berntson & Cacioppo, 2000; Damasio, 1995; LeDoux, 1986; Toates, 2002). Within this hierarchical system, control can shift from more complex to simpler mechanisms and vice versa, depending on which can provide the appropriate response to a given situation (Berntson & Cacioppo, 2000; Toates, 1996, 1998, 2002). The occasional relegation of control to less flexible mechanisms can confer an adaptive advantage because the multivariate inferential (i.e., cognitive) processes of the higher levels are slower and, by intervening between direct perception and response, may introduce options that are maladaptive. According to Griffiths (1990), "it is vital for an organism to be able to accept data which contradict even its most firmly held beliefs" (p. 186). This is because "a condition for the reliability of perception ... is that it generally sees what's there, not what it wants or expects to be there. Organisms that don't do so become deceased" (Fodor, 1983, p. 68). Although reliance on low-level pathways may lead to some false positives, "false positive responses ... probably have more survival value than false negative responses" (LeDoux, 1986, p. 241).

Fourth, it is assumed that "more primitive phylogenetic structures and functions, being the successful outcome of eons of adaptation, display less variation from individual to individual" (Reber, 1993, p. 7), whereas structures and functions that are evolutionarily recent show higher plasticity and are mostly shaped by individual developmental histories (Geary & Huffman, 2002). In general, "natural selection is a process that eliminates variation" (Tooby & Cosmides, 1990b, p. 37), whereas the presence of variation "generally signals a lack of adaptive significance" (Tooby & Cosmides, 1990b, p. 38). If a trait conferred a consistent adaptive advantage, it would have spread through the population and, thus, it would exhibit limited heritable variation. Conversely, if it proved consistently maladaptive, it would have been eliminated and, thus, it would also show limited heritable variation. According to Tooby and Cosmides (1990b), "people display more diversity in their preferences for hat color or in their beliefs about gods and spirits than in their desire to continue breathing, their attraction to sex, or their desire to avoid pain" (p. 58). Nevertheless, although there is a general "desire to avoid pain," there is also considerable heritable variation in pain sensitivity and tolerance (Mogil, 1999), as well as in the preferred level of sensory stimulation (Eysenck, 1983; Fulker, Eysenck, & Zuckerman, 1980). Presumably, this variability exists because these traits are, ultimately, adaptively neutral, involving a trade-off between advantages and risks. For example, individuals, who seek or can tolerate higher levels of somatosensory stimulation related to physical activity, may gain greater access to food and mates, but also take greater risks by "pushing the envelope" and approaching their biological limits. Conversely, those who prefer or have low tolerance for somatosensory stimulation play it safe but may miss out on some additional opportunities for foraging and mating.

Returning to the idea of pleasure as indicative of utility and displeasure as indicative of danger, the presence of variability in affective responses (i.e., pleasure responses in some individuals, displeasure in others) could be interpreted as an indication that the situation entails neither a substantial benefit nor an imminent danger. On the other hand, whenever all or most individuals respond in a similar manner, either with pleasure or with displeasure (within reasonable quantitative variation), it can be assumed that the situation is one that has significant and consistent, positive or negative, implications for adaptation.

Exercise intensity from an adaptational standpoint

With these assumptions in mind, it is instructive to consider the adaptational implications of different levels of exercise intensity. Gaesser and Poole (1996) proposed that the functional range of exercise intensity can be divided into three domains that are distinct in terms of their metabolic requirements.

First, the domain of moderate exercise encompasses the intensities below the lactate threshold. In this domain, aerobic metabolism is the predominant source of energy. Activities that typically fall in this range include walking, gardening, moderate swimming, as well as most of hunting, scavenging, and gathering activities preponderant during human evolution (Cordain et al., 1998). Because of the abundance of energy stores available for aerobic metabolism in the human body, activities in the moderate range can be maintained for a long period of time, while the organism can remain in a physiological steady state. It has been suggested that humans and other animals may have an innate propensity for moderate physical activity, evolved to maintain a healthy balance between energy intake and expenditure and to sustain overall health, strength, and mobility (Rowland, 1998). Given the substantial health benefits to be had, it would make good adaptational sense if natural selection would favor a psychological mechanism, such as pleasure, that would reward and, thus, promote physical activity in this range (Eikelboom, 1999; Sher, 1998).

The second range of intensity, termed the range of heavy activity, extends from the lactate threshold to the highest work rate at which blood lactate can be stabilized (also referred to as the maximal lactate steady state). In this domain, lactate appearance and removal rates can regain balance over time, but at elevated lactate concentration levels. As a result of a continuous drift in oxygen uptake that appears in this domain, the oxygen cost per unit of work is increased compared to the moderate range. The activity cannot be continued indefinitely, but it can be continued for a considerable period. From an adaptational standpoint, the events in this range present a challenge, as considerable physiological changes (e.g., ventilatory, cardiovascular, neuroendocrine) must take place to allow the maintenance of the work rate. As a direct or indirect consequence of the accumulation of lactic acid, the amount and intensity of interoceptive information increase exponentially and a barrage of bodily signals enter consciousness, alerting to the homeostatic perturbation. Presumably, like the ability to tolerate pain, the ability to tolerate these bodily cues, which may depend on individual differences in sensory modulation (e.g., facilitation-inhibition) or cognitive factors (e.g., physical self-efficacy), would, on average, be adaptively neutral.

On the one hand, this tolerance could aid a hunter or gatherer to perform more physical work. On the other hand, the higher level of exertion would make one more susceptible to injury or exhaustion.

The final range of intensity, termed the range of very heavy or severe physical activity, extends from the maximal lactate steady state to the level of maximal aerobic capacity. In this range, oxygen consumption and blood lactate rise continuously until the activity is terminated due to exhaustion. Energy supply in this range relies heavily on the limited resources available to anaerobic metabolism (mainly the phosphagen pool and anaerobic glycolysis). Several authors have noted that the primary means by which critical disruptions in homeostasis enter consciousness is through salient surges of displeasure (Cabanac, 1971, 1979, 1995; Damasio, 1995; Panksepp, 1998a, 1998b). Affective responses to physical activity performed at this intensity likely depend on pathways that link somatosensory afferents to the affective centers of the brain (i.e., the amygdala, anterior cingulate and insular cortex) directly, bypassing the frontal cerebral cortex and, therefore, allowing little or no influence from top-down or cognitive processes.

The dual-mode theory: Basic postulates

The dual-mode theory (Ekkekakis, 2003) posits that affective responses to exercise are the products of the continuous interplay between two general factors, namely (a) relevant cognitive processes originating primarily in the frontal cortex and involving such processes as appraisals of the meaning of exercise, goals, self-perceptions including self-efficacy, attributions, and considerations of the social context of exercise and (b) interoceptive cues from a variety of receptors stimulated by exercise-induced physiological changes, which reach the affective centers of the brain via oligosynaptic subcortical pathways. The relative salience of these two factors is hypothesized to shift systematically as a function of exercise intensity. Specifically, cognitive factors should be dominant in the domain of heavy intensity, whereas interoceptive cues should gain salience in the domain of severe exercise.

The preliminary supporting evidence comes from three sources.

First, the pattern of affective responses across increasing levels of exercise intensity will be examined. According to the dual-mode theory, pleasure responses are expected to be meaningfully associated with utility (i.e., the range of exercise intensity that is closely linked to successful adaptation, presumably the moderate range) and displeasure responses are expected to be meaningfully associated with danger (i.e., the range of exercise intensity that entails critical disruptions of homeostasis, presumably the severe range).

Second, patterns of inter-individual variability in affective responses will be examined. According to the dual-mode theory, trends toward universality should exist when the intensity of the activity is either reliably adaptive (presumably, in the moderate range) or reliably maladaptive (presumably, in the severe range). Conversely, trends toward variability should emerge when the intensity of the activity is neither reliably adaptive nor reliably maladaptive (presumably, in the heavy range).

Third, correlations of affective valence with cognitive and physiological variables across increasing levels of exercise intensity will be examined. According to the dual-mode theory, affective valence should exhibit strong correlations with cognitive factors (such as physical self-efficacy) when the intensity of the activity presents an appreciable challenge, but is not yet overwhelming (presumably, in the heavy range).

Conversely, the theory posits that affective valence should exhibit strong correlations with physiological factors (such as the respiratory exchange ratio or the percentage of peak heart rate) when the intensity of the activity approaches an individual's maximal capacity (presumably, in the severe range).

Pattern of affective responses

First, it is important to consider which range of physical activity intensity is likely to be consistently adaptive and which is likely to be consistently maladaptive. One clue is the amount of energy resources in the human body that are available to aerobic versus anaerobic metabolism. As noted earlier, the resources available to aerobic metabolism are vast in comparison to those available to anaerobic metabolism. Another clue is the amount of time spent in activities of different intensities by hunters and gatherers. Most studies suggest that the vast majority of daily activity in ancestral environments involved moderate intensity (e.g., walking, digging, etc). This is illustrated in an observation by Åstrand (1994):

> Some years ago, I visited the bushmen in the Kalahari desert, probably the last remaining Stone-Age people (…). Gathering sufficient food meant trudging long distances for the men in their hunting efforts and in the women and children in their collection of berries, melons, roots, and various plants. This walking, stopping, and squatting to dig, and walking again, is physically demanding (…). To get enough to eat, the bushmen have to exercise for hours almost every day (…). I never saw an adult bushman out jogging, but the walking was fast! (p. 102)

On the other hand, an intensity that significantly exceeds the level of the aerobic-anaerobic transition entails a substantial disruption of homeostasis, which is associated with several risks. As a consequence of the rise in the levels of lactate and H^+ dissociated from lactate, the pH falls and the internal environment becomes acidic. The recruitment of additional, low-efficiency muscle fibers raises the O_2 cost of work (the so-called slow component of O_2 uptake). A physiological steady state becomes difficult or impossible to maintain. The risk of muscular and skeletal injuries increases because of the higher speed of locomotion and the disruption in coordination patterns. There is also increased risk of cardiovascular problems and sudden cardiac death, as well as a suppression of immune system function. If pleasure is to signify utility and displeasure is to signify danger, then pleasure responses should be expected to accompany activity performed in the moderate range of intensity, whereas displeasure should be expected to accompany activity performed in the severe range of intensity.

The evidence seems to support these predictions. On the one hand, several studies have shown that low-intensity, short-duration physical activity produces transient but significant positive changes in affect (Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000; Saklofske, Blomme, & Kelly, 1992; Thayer, 1987a, 1987b; Thayer, Peters, Takahashi, & Birkhead-Flight, 1993). The predominant response in these studies is a change toward an activated pleasant affective state, characteristic of perceived energy.

On the other hand, a series of recent studies have examined affective responses to exercise in relation to the point of transition from aerobic to anaerobic metabolism (operationalized as the ventilatory threshold, the point at which there is a systematic increase in the ventilatory equivalent of O_2 without a corresponding increase in the ventilatory equivalent of CO_2). Bixby et al., (2001) compared the effects of two bouts of exercise on a cycle ergometer, one below the ventilatory threshold (75% of the oxygen uptake at the ventilatory threshold) and one at the ventilatory threshold. The results showed that, although the former intensity led to an improvement in affect valence during exercise, the latter led to a decline. In another study (Hall et al., 2002), the affective valence responses of 30 volunteers were examined every minute during an incremental treadmill test performed until volitional exhaustion. The data points that were used in statistical analyses were selected to represent metabolically comparable stages across all individuals, namely the first two minutes, the minute before the occurrence of the ventilatory threshold, the minute of the ventilatory threshold, the two minutes following the ventilatory threshold, and the final two minutes (i.e., the minute before and the minute of volitional exhaustion). Trend analysis of the affective valence ratings showed a curvilinear (quadratic) trend specifically during the two minutes following the ventilatory threshold. These results were replicated with two different treadmill protocols (shorter stages with higher increment or vice versa) to eliminate the possibility that the initiation of the quadratic pattern of decline following the ventilatory threshold was protocol-specific. Regardless of the incremental protocol, there was a quadratic pattern of decline that was initiated with the ventilatory threshold (Ekkekakis, Hall, & Petruzzello, in press).

Finally, the importance of the aerobic-anaerobic transition in influencing affective responses was confirmed in a study involving constant-speed treadmill running (as opposed to incremental treadmill protocols used in the aforementioned studies). Ekkekakis, Hall, and Petruzzello (accepted) examined the responses of 30 volunteers who ran on a treadmill for 15 minutes at 3 intensities: 20% of maximal aerobic capacity below, at, and 10% above their ventilatory threshold. The results showed that only the responses during the run above the ventilatory threshold showed a quadratic declining trend.

Patterns of inter-individual variability

Re-analyses of affective responses to increasing intensities of exercise at the level of individuals rather than group aggregates have revealed a systematic, intensity-dependent change in the patterns of inter-individual variability in affective valence ratings. Specifically, inter-individual variability is lower when the intensity is either low, such as in the case of walking (Ekkekakis et al., 2000), or high, such as in the case of maximal exercise (Hall et al., 2002). On the other hand, variability is high when the intensity is moderate, such as in the case of a 30-min bout of cycling at 60% VO_2max (VanLanduyt, et al., 2000). As noted earlier, signs of response homogeneity could be indicative of adaptive significance (positive for pleasure, negative for displeasure), whereas increased variability might indicate that the response is neutral with respect to adaptational implications. Furthermore, these systematic changes in inter-individual variability could be indicative of shifts in the underlying mechanisms, with homogeneous responses suggesting involvement of automatic, oligosynaptic, and mostly subcortical pathways and variable responses suggesting mediation by higher-level, polysynaptic, and plastic pathways involving individual traits and cognitive factors.

Patterns of correlations with cognitive and physiological variables

Studies examining the relationship between ratings of affective valence and physiological variables (heart rate, ventilation, respiratory rate, oxygen consumption, blood lactate) have consistently shown that the magnitude of the negative correlations increases as the intensity of exercise increases (Acevedo et al., 1994; Hardy & Rejeski, 1989). These findings suggest an increasingly stronger link between valence and interoceptive afferents. On the other hand, the relationship between affect and cognitive variables (of which self-efficacy is the most extensively studied) is not as clear. McAuley and Courneya (1992) had suggested that the relationship between physical self-efficacy and affective responses should be significant when the intensity of exercise presents an appreciable challenge (e.g., 70% of maximal heart rate). Later, however, this position was slightly modified by clarifying that the relationship cannot be expected to be strong if the intensity is too high because "physiological cues ... override cognitive processing" (McAuley, Blissmer, Katula, & Duncan, 2000, p. 352). However, the data on this issue are inconsistent. Treasure and Newbery (1998) showed that self-efficacy was related to physical exhaustion when the intensity was 70-75%, but not when it was 45-50% of heart rate reserve. Conversely, Tate, Petruzzello, and Lox (1995) found that self-efficacy was related to scores on the tense arousal during exercise performed at 55%, but not at 70% of maximal aerobic capacity. Finally, in a study of older adults, McAuley et al., (2000) found that changes in self-efficacy were unrelated to changes in affect in a moderate exercise intensity condition, but were related to changes in affect in a light and in a maximal exercise intensity condition.

The inconsistency in the findings may be due to differences in the age and physical condition of the participants, the measures of affect, and the exercise loads. Another possible explanation for the inconsistent findings is that the aforementioned studies assessed affect before and after exercise, rather than repeatedly during the bouts, and failed to standardize exercise intensity by taking into account the aerobic-anaerobic transition. In a study that addressed these two limitations, Ekkekakis, Hall, and Petruzzello (1999) assessed affective valence every minute during an incremental treadmill test until the participants reached the point of volitional exhaustion. Self-efficacy was significantly correlated with affective valence near the middle of the range of exercise intensity (from one minute before the ventilatory threshold to one minute before exhaustion), but not in the early stages or at the point of volitional exhaustion. On the other hand, the correlation between the respiratory exchange ratio and affective valence reached statistical significance from the first minute after the ventilatory threshold and until the point of exhaustion. A series of regression analyses with self-efficacy and the respiratory exchange ratio data as predictors of the valence ratings at different time points during the incremental protocol showed that, below the ventilatory threshold, self-efficacy was responsible for almost all (approximately 80% to 100%) of the total accounted variance in affective valence (total R^2 between 12% and 23%). On the other hand, at intensities above the ventilatory threshold, the respiratory exchange ratio began to account for increasingly larger amounts of variance. From the second minute after the ventilatory threshold and until exhaustion, the respiratory exchange ratio was responsible for most (approximately 65% to 80%) of the total accounted variance in affective valence (total R^2 between 34% and 55%).

Conclusions

The following conclusions can be drawn from the data summarized herein.

First, exercise does not necessarily "make people feel better." In fact, the positive affective responses are limited to (a) during and after low-intensity, self-paced physical activity and (b) recovery from vigorous activity. On the contrary, exercise intensity that exceeds the ventilatory threshold (or the level of intensity associated with the onset of other symptoms, such as muscular or skeletal aches and pains) is associated with declines in affective valence.

Second, moderate-intensity exercise (i.e., not too low, not too high) is not necessarily the optimal stimulus for positive affective change. It is only the recovery from such activity that brings about unified positive responses. In fact, during activity performed at mid-range intensity, there is great inter-individual variability, with some individuals experiencing positive and others experiencing negative changes in affective valence.

Third, findings do not necessarily apply to all or most individuals (e.g., 80 or 90%). In fact, there are systematic, intensity-dependent patterns of inter-individual variability in affective responses. Specifically, homogeneity exists during low (positive responses) and high (negative responses) intensity, whereas variability exists during activity performed at mid-range intensity.

Fourth, how one thinks (i.e., cognitive factors) is not always the most important determinant of how one feels in response to exercise. Cognitive factors (e.g., self-efficacy) may be the strongest determinants at mid-range (primarily) and low (secondarily) intensities. On the other hand, interoceptive factors are the primary determinants at high (relative) intensities.

Implications for the Promotion of Physical Activity

People usually do what makes them feel good and avoid what makes them feel bad. This fundamental principle may have important implications for exercise adherence and dropout. The inability of beginner exercisers to properly self-monitor and self-regulate the intensity of their exercise efforts may lead to negative affective responses and these, in turn, may decrease adherence and increase the risk of dropout.

Based on the data reviewed here, affective valence shows reliable declines when the intensity of exercise exceeds the ventilatory threshold. This finding may have important implications for exercise prescription. Importantly, it has been shown that exercise performed at intensities that exceed the ventilatory and lactate thresholds does not confer any additional fitness benefits, compared to exercise performed at or slightly below these thresholds in previously untrained individuals (Belman & Gaesser, 1991; Weltman et al., 1991). It appears, therefore, that exercising at the level of intensity that corresponds to the ventilatory threshold could provide the optimal training stimulus for previously untrained individuals. Thus, it is possible that novice exercisers could be taught to recognize the aerobic-anaerobic transition using the decline in affective valence as a marker (Ekkekakis et al., in press). Having said this, the exact point of initiation of the decline in affective valence will differ from individual to individual, and these differences could be attributed to a variety of physiological and psychological factors that determine the preference for and tolerance of the somatosensory cues associated with the aerobic-anaerobic transition. Very little is presently known about these individual differences, so additional research on this topic is necessary.

Another implication of the findings reviewed herein is that they raise the possibility of limits in the range of effectiveness of some of the popular techniques for coping with the unpleasant sensations associated with exercise, particularly among novice exercisers. Since the magnitude of the correlation between cognitive variables (self-efficacy in the studies reviewed here) and affect is reduced at intensities that exceed the aerobic-anaerobic transition, this may imply that cognitive techniques may only be effective at mid-range intensities and may become ineffective as the intensity approaches an individual's maximal capacity. Such techniques include attentional dissociation (i.e., "turn your attention away from the body"), cognitive restructuring (i.e., "think of these unpleasant symptoms as something positive, as signs of improvement"), and bolstering one's sense of physical self-efficacy (i.e., "believe that you can do it"). On the other hand, it is possible that some type of biofeedback training (i.e., the intensification of feedback from bodily cues associated with the aerobic-anaerobic transition) might be helpful by teaching novice exercisers to recognize the aerobic-anaerobic transition and to adjust their intensity accordingly (Ekkekakis & Petruzzello, 2002b).

Future research directions

Future research should continue to investigate the cognitive and interoceptive correlates of affective responses across the entire range of exercise intensities. Studies should also examine the effectiveness of cognitive (e.g., attentional dissociation, cognitive restructuring, self-efficacy) and somatic (e.g., biofeedback) techniques in regulating affective responses across a range of intensities. Finally, the hypothesized intensity-affect-adherence causal chain should be examined in its entirety.

References

Acevedo, E.O., Rinehardt, K.F., & Kraemer, R.R. (1994). Perceived exertion and affect at varying intensities of running. *Research Quarterly for Exercise and Sport, 65,* 372-376.

Åstrand, P.O. (1986). Why exercise? An evolutionary approach. *Acta Medica Scandinavica Supplementum, 711,* 241-242.

Åstrand, P.O. (1994). Physical activity and fitness: Evolutionary perspective and trends for the future. In C. Bouchard, R.J. Shephard, & T. Stephens (Eds.), *Physical activity, fitness, and health: International proceedings and consensus statement* (pp. 98-105). Champaign, IL: Human Kinetics.

Belman, M.J., & Gaesser, G.A. (1991). Exercise training below and above the lactate threshold in the elderly. *Medicine and Science in Sports and Exercise, 23,* 562-568.

Berger, B.G., & Motl, R.W. (2000). Exercise and mood: A selective review and synthesis of research employing the Profile of Mood States. *Journal of Applied Sport Psychology, 12,* 69-92.

Berntson, G.G., Boysen, S.T., & Cacioppo, J.T. (1993). Neurobehavioral organization and the cardinal principle of evaluative bivalence. *Annals of the New York Academy of Sciences, 702,* 75-102.

Berntson, G.G., & Cacioppo, J.T. (2000). Psychobiology and social psychology: Past, present, and future. *Personality and Social Psychology Review, 4,* 3-15.

Bixby, W.R., Spalding, T.W., & Hatfield, B.D. (2001). Temporal dynamics and dimensional specificity of the affective response to exercise of varying intensity: Differing pathways to a common outcome. *Journal of Sport & Exercise Psychology, 23,* 171-190.

Cabanac, M. (1971). Physiological role of pleasure. *Science, 173,* 1103-1107.

Cabanac, M. (1979). Sensory pleasure. *Quarterly Review of Biology, 54,* 1-29.

Cabanac, M. (1995). What is sensation? In R. Wong (Ed.), *Biological perspectives on motivated activities* (pp. 399-418). Norwood, NJ: Ablex.

Cordain, L., Gotshall, R.W., & Eaton, S.B. (1997). Evolutionary aspects of exercise. *World Review of Nutrition and Dietetics, 81,* 49-60.

Cordain, L., Gotshall, R.W., Eaton, S.B., & Eaton, S.B. (1998). Physical activity, energy expenditure and fitness: An evolutionary perspective. *International Journal of Sports Medicine, 19,* 328-335.

Cox, R.H. (2002). *Sport psychology: Concepts and applications* (5th ed.). Boston, MA: McGraw-Hill.

Craig, A.D. (1996). An ascending general homeostatic afferent pathway originating in lamina I. *Progress in Brain Research, 107,* 225-242.

Craig, A.D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews Neuroscience, 3,* 655-666.

Damasio, A.R. (1995). Toward a neurobiology of emotion and feeling: Operational concepts and hypotheses. *Neuroscientist, 1,* 19-25.

Dishman, R.K. (2001). The problem of exercise adherence: Fighting sloth in nations with market economies. *Quest, 53,* 279-294.

Dishman, R.K. (2003). The impact of behavior on quality of life. *Quality of Life Research, 12* (Suppl. 1), 43-49.

Dishman, R.K., & Buckworth, J. (1996). Increasing physical activity: A quantitative synthesis. *Medicine and Science in Sports and Exercise, 28,* 706-719.

Dishman, R.K., & Buckworth, J. (1997). Adherence to physical activity. In W.P. Morgan (Ed.), *Physical activity and mental health* (pp. 63-80). Washington, DC: Taylor & Francis.

Eaton, S.B., Shostak, M., & Konner, M. (1988). *The paleolithic prescription: A program of diet and exercise and a design for living.* New York: Harper & Row.

Eikelboom, R. (1999). Human parallel to voluntary wheel running: Exercise. *Animal Behaviour, 57,* F11-F12.

Ekkekakis, P. (2003). Pleasure and displeasure from the body: Perspectives from exercise. *Cognition and Emotion, 17,* 213-239.

Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (1999). Cognitive and physiological correlates of affect during a maximal exercise test. *Journal of Sport and Exercise Psychology, 21,* S40.

Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (in press). Practical markers of the transition from aerobic to anaerobic metabolism during exercise: Rationale and a case for affect-based exercise prescription. *Preventive Medicine.*

Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (accepted). Intensity of acute exercise and affect: A critical reexamination of the dose-response relationship. *Health Psychology.*

Ekkekakis, P., Hall, E.E., Van Landuyt, L.M., & Petruzzello, S.J. (2000). Walking in (affective) circles: Can short walks enhance affect? *Journal of Behavioral Medicine, 23,* 245-275.

Ekkekakis, P., & Petruzzello, S.J. (1999). Acute aerobic exercise and affect: Current status, problems, and prospects regarding dose-response. *Sports Medicine, 28,* 337-374.

Ekkekakis, P., & Petruzzello, S.J. (2000). Analysis of the affect measurement conundrum in exercise psychology: I. Fundamental issues. *Psychology of Sport and Exercise, 2,* 71-88.

Ekkekakis, P., & Petruzzello, S.J. (2002a). Analysis of the affect measurement conundrum in exercise psychology: IV. A conceptual case for the affect circumplex. *Psychology of Sport and Exercise, 3,* 35-63.

Ekkekakis, P., & Petruzzello, S.J. (2002b). Biofeedback in exercise psychology. In B. Blumenstein, M. Bar-Eli, & G. Tenenbaum (Eds.), *Brain and body in sport and exercise: Biofeedback application in performance enhancement* (pp. 77-100). Chichester, England: John Wiley & Sons.

Eysenck, H.J. (1983). A biometrical-genetical analysis of impulsive and sensation-seeking behavior. In M. Zuckerman (Ed.), *Biological bases of sensation seeking, impulsivity, and anxiety* (pp. 1-27). Hillsdale, NJ: Laurence Erlbaum.

Flegal, K.M., Carroll, M.D., Ogden, C.L., & Johnson, C.L. (2002). Prevalence and trends in obesity among U.S. adults, 1999-2000. *Journal of the American Medical Association, 288,* 1723-1727.

Fodor, J.A. (1983). *The modularity of mind.* Cambridge, MA: MIT Press.

Fox, K.R. (1999). The influence of physical activity on mental well-being. *Public Health and Nutrition, 2,* 411-418.

Fulker, D.W., Eysenck, S.B.G., & Zuckerman, M. (1980). A genetic and environmental analysis of sensation seeking. *Journal of Research in Personality, 14,* 261-281.

Gaesser, G.A., & Poole, D.C. (1996). The slow component of oxygen uptake kinetics in humans. *Exercise and Sport Sciences Reviews, 24,* 35-70.

Gauvin, L., & Rejeski, W.J. (1993). The Exercise-induced Feeling Inventory: Development and initial validation. *Journal of Sport and Exercise Psychology, 15,* 403-423.

Geary, D.C., & Huffman, K.J. (2002). Brain and cognitive evolution: Forms of modularity and functions of mind. *Psychological Bulletin, 128,* 667-698.

Griffiths, P.E. (1990). Modularity and the psychoevolutionary theory of emotion. *Biology and Philosophy, 5,* 175-196.

Hall, E.E., Ekkekakis, P., & Petruzzello, S.J. (2002). The affective beneficence of vigorous exercise revisited. *British Journal of Health Psychology, 7,* 47-66.

Hardy, C.J., & Rejeski, W.J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport and Exercise Psychology, 11,* 304-317.

Institute of European Food Studies (1999). *A pan-EU survey on consumer attitudes to physical activity, body-weight and health.* Luxemburg: Commission of the European Union.

Jones, D.A., Ainsworth, B.E., Croft, J.B., Macera, C.A., Lloyd, E.E., & Yusuf, H.R. (1998). Moderate leisure-time physical activity: Who is meeting the public health recommendations? A national cross-sectional study. *Archives of Family Medicine, 7,* 285-289.

Katch, V., Weltman, A., Sady, S., & Freedson, P. (1978). Validity of the relative percent concept for equating training intensity. *European Journal of Applied Physiology, 39,* 219-227.

LeDoux, J.E. (1986). Sensory systems and emotion: A model of affective processing. *Integrative Psychiatry, 4,* 237-248.

McAuley, E., Blissmer, B., Katula, J., & Duncan, T.E. (2000). Exercise environment, self-efficacy, and affective responses to acute exercise in older adults. *Psychology and Health, 15,* 341-355.

McAuley, E., & Courneya, K.S. (1992). Self-efficacy relationships with affective and exertion responses to exercise. *Journal of Applied Social Psychology, 22,* 312-326.

Mogil, J.S. (1999). The genetic mediation of individual differences in sensitivity to pain and its inhibition. *Proceedings of the National Academy of Sciences, 96,* 7744-7751.

Morgan, W.P. (1977). Involvement in vigorous physical activity with special reference to adherence. In L.I. Gedvilas & M.E. Kneer (Eds.), *Proceedings of the National Conference of the National College Physical Education Association for Men and The National Association for Physical Education of College Women* (pp. 235-246). Chicago: University of Illinois at Chicago.

Morgan, W.P. (1981). Psychological benefits of physical activity. In F.J. Nagle & H.J. Montoye (Eds.), *Exercise in health and disease* (pp. 299-314). Springfield, IL: Charles C. Thomas.

Morgan, W.P., & O'Connor, P.J. (1988). Exercise and mental health. In R.K. Dishman (Ed.), *Exercise adherence: Its impact on public health* (pp. 91-121). Champaign, IL: Human Kinetics.

Nesse, R.M. (1990). Evolutionary explanations of emotions. *Human Nature, 1,* 261-289.

Panksepp, J. (1998a). *Affective neuroscience: The foundations of human and animal emotions.* New York: Oxford University Press.

Panksepp, J. (1998b). The periconscious substrates of consciousness: Affective states and the evolutionary origins of the self. *Journal of Consciousness Studies, 5,* 566-582.

Parfitt, G., & Eston, R. (1995). Changes in ratings of perceived exertion and psychological affect in the early stages of exercise. *Perceptual and Motor Skills, 80*, 259-266.

Parfitt, G., Eston, R., & Connolly, D. (1996). Psychological affect at different ratings of perceived exertion in high-and low-active women: A study using a production protocol. *Perceptual and Motor Skills, 82,* 1035-1042.

Parfitt, G., Markland, D., & Holmes, C. (1994). Responses to physical exertion in active and inactive males and females. *Journal of Sport and Exercise Psychology, 16,* 178-186.

Reber, A.S. (1993). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious.* New York: Oxford University Press.

Rejeski, W.J., & Hobson, M.L. (1994). A framework for enhancing exercise motivation in rehabilitative medicine. In H.A. Quinney, L. Gauvin, & A.E.T. Wall (Eds.), *Toward active living: Proceedings of the international conference on physical activity, fitness, and health* (pp. 107-113). Champaign, IL: Human Kinetics.

Rowland, T.W. (1998). The biological basis of physical activity. *Medicine and Science in Sports and Exercise, 30,* 392-399.

Russell, J.A. (1978). Evidence of convergent validity on the dimensions of affect. *Journal of Personality and Social Psychology, 36,* 1152-1168.

Russell, J.A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39,* 1161-1178.

Saklofske, D.H., Blomme, G.C., & Kelly, I.W. (1992). The effects of exercise and relaxation on energetic and tense arousal. *Personality and Individual Differences, 13,* 623-625.

Sher, L. (1998). The endogenous euphoric reward system that reinforces physical training: A mechanism for mankind's survival. *Medical Hypotheses, 51,* 449-450.

Solomon, R.L. (1991). Acquired motivation and affective opponent-processes. In J. Madden (Ed.), *Neurobiology of learning, emotion, and affect* (pp. 307-347). New York: Raven.

Sparling, P.B., Owen, N., Lambert, E.V., & Haskell, W.L. (2000). Promoting physical activity: The new imperative for public health. *Health Education Research, 15,* 367-376.

Tate, A.K., Petruzzello, S.J., & Lox, C.L. (1995). Examination of the relationship between self-efficacy and affect at varying levels of aerobic intensity. *Journal of Applied Social Psychology, 25,* 1922-1936.

Thayer, R.E. (1987a). Problem perception, optimism, and related states as a function of time of day (diurnal rhythm) and moderate exercise: Two arousal systems in interaction. *Motivation and Emotion, 11,* 19-36.

Thayer, R.E. (1987b). Energy, tiredness, and tension effects of a sugar snack versus moderate exercise. *Journal of Personality and Social Psychology, 52,* 119-125.

Thayer, R.E., Peters, D.P., Takahashi, P.J., & Birkhead-Flight, A.M. (1993). Mood and behavior (smoking and sugar snacking) following moderate exercise: A partial test of self-regulation theory. *Personality and Individual Differences, 14,* 97-104.

Toates, F. (1996). Cognition and evolution: An organization of action perspective. *Behavioural Processes, 35,* 239-250.

Toates, F. (1998). The interaction of cognitive and stimulus-response processes in the control of behavior. *Neuroscience and Biobehavioral Reviews, 22,* 59-83.

Toates, F. (2002). Application of a multilevel model of behavioural control to understanding emotion. *Behavioural Processes, 60*, 99-114.

Tooby, J., & Cosmides, L. (1990a). The past explains the present: Emotional adaptations and the structure of ancestral environments. *Ethology and Sociobiology, 11,* 375-424.

Tooby, J., & Cosmides, L. (1990b). On the universality of human nature and the uniqueness of the individual: The role of genetics and adaptation. *Journal of Personality, 58,* 17-67.

Treasure, D.C., & Newbery, D.M. (1998). Relationship between self-efficacy, exercise intensity, and feeling states in a sedentary population during and following an acute bout of exercise. *Journal of Sport and Exercise Psychology, 20,* 1-11.

United States Department of Health and Human Services (1996). *Physical activity and health: A report of the Surgeon General.* Atlanta, GA: United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

United States Department of Health and Human Services (2000). *Healthy People 2010* (2nd ed., vol. 2). Washington, DC: United States Government Printing Office.

United States National Center for Health Statistics (1999). *Healthy People 2000 Review, 1998-1999.* Hyattsville, MD: Public Health Service.

Van Landuyt, L.M., Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (2000). Throwing the mountains into the lakes: On the perils of nomothetic conceptions of the exercise-affect relationship. *Journal of Sport and Exercise Psychology, 22,* 208-234.

Wells, J.G., Balke, B., & Van Fossan, D.D. (1957). Lactic acid accumulation during work: A suggested standardization of work classification. *Journal of Applied Physiology, 10,* 51-55.

Weltman, A., Seip, R.L., Snead, D., Weltman, J.Y., Haskvitz, E.M., Evans, W.S., Veldhuis, J.D., & Rogol, A.D. (1992). Exercise training at and above the lactate threshold in previously untrained women. *International Journal of Sports Medicine, 13,* 257-263.