

# Theoretical integration in the study of affective responses to acute exercise: The dual mode model

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In 1977, William Morgan noted that, in order to promote regular participation in physical activity, „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). Several more authors over the years have hypothesized a causal chain linking (a) the intensity of physical activity, (b) the pleasant or unpleasant affective responses resulting from physical activity, and (c) long-term adherence. However, no experimental investigation to date has examined this causal pathway in its entirety, so the interplay between intensity and affect and the ultimate impact of these factors on adherence remain poorly understood.

An essential initial step in the process of examining the causal pathway linking intensity, affect, and adherence is improving our present understanding of the first link, namely the relationship between exercise intensity and affect. A review of this literature (Ekkekakis & Petruzzello, 1999) identified several conceptual and methodological shortcomings in previous research, but clearly the main obstacle for progress is the absence of a comprehensive theoretical framework. Such a framework should satisfy the following five desiderata: (a) reintegrate the „mind“ and the „body,“ (b) take into account the information that is emerging from related scientific fields such as affective neuroscience and genetics, (c) go beyond the simplistic notion that the only affective change elicited by exercise is to „make people feel good,“ (d) account for dose-response patterns, and (e) account for patterns of inter-individual variability in affective responses.

## The dual-mode theory: Basic assumptions

In an effort to develop a theoretical framework that satisfies these five desiderata, Ekkekakis (2003) has proposed the dual-mode model of exercise-induced affective changes. The formulation draws heavily from evolutionary theory and affective neuroscience and rests on the following assumptions. First, physical activity constitutes an important component of the human Environment of Evolutionary Adaptedness (EEA; Tooby & Cosmides, 1990a), having been an integral component of human life from the beginning. Second, affective responses represent manifestations of evolved psychological mechanisms, selected for their ability to promote health and well-being or to solve recurrent adaptational problems within a particular ecological domain. In this context, pleasure signifies utility and displeasure signifies danger. Third, consistent with evidence from affective psychology and neuroscience, it is assumed that affective responses 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 modern,

cortical pathways producing complex, flexible, and highly individualized responses at the top. Within this hierarchical system, control can shift from more complex to simpler mechanisms, depending on which can provide the appropriate response to a given situation. 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). It is also assumed that „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“ (p. 38). Applied to affective responses, this notion entails that the presence of variability in such responses (i.e., some involving pleasure whereas others displeasure) 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 (i.e., either with pleasure or with displeasure), it can be assumed that the situation is one that has significant, positive or negative, implications for adaptation.

### Exercise from an adaptational standpoint

With these assumptions in mind, it is instructive to consider the adaptational implications associated with the different levels of exercise intensity. Gaesser and Poole (1996) proposed that the functional range of exercise intensity can be divided in 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. Because of the abundance of energy stores available for aerobic metabolism, activities in the moderate range can be maintained for a long period of time while the organism remains 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. 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.

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 neutral with respect to adaptational implications. 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. Several authors have noted that the primary means by which critical disruptions in homeostasis enter consciousness is through salient surges of displeasure. 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 insula) directly, bypassing the frontal cerebral cortex and, therefore, allowing little or no influence from top-down or cognitive processes.

## Dual-mode theory: Postulates and Current Evidence

The dual-mode theory posits that affective responses to exercise are the products of the continuous interplay between two general factors, namely (a) relevant individual differences and cognitive processes originating primarily in the frontal cortex (e.g., 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 interoceptors stimulated by exercise-related 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.

Three sources of evidence in support of the dual-mode formulation presently exist. First, using repeated assessments of affective valence (pleasure-displeasure), a series of recent studies have independently confirmed that the point of transition from aerobic to anaerobic metabolism represents a turning point toward affective negativity. For example, Hall et al. (2002) examined the minute-by-minute affective responses of a group of 30 volunteers as they progressed through the stages of a graded treadmill test to volitional exhaustion. After the ventilatory threshold (VT) was determined (as an index of the point of transition from aerobic to anaerobic metabolism), eight data points were retained for analysis, presumably representing metabolically comparable phases across all participants: the first 2 minutes, the minute before the VT, the minute of the VT, the 2 minutes following the VT, and the last 2 minutes. A trend analysis of the repeated measures revealed a significant quadratic component and follow-up analyses showed that the quadratic trend was, in fact, significant only for the segment including the VT and the two subsequent minutes. This finding supports the hypothesis that the aerobic-anaerobic transition is a critical adaptational turning point that instigates a generalized shift in affective responding.

Second, 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 responses. Specifically, inter-individual variability appears to be relatively low when the intensity is either low, such as in the case of

walking, or high, such as in the case of maximal exercise. On the other hand, variability appears to be high when the intensity is moderate, such as in the case of a 30-min bout of cycling at 60%  $\text{VO}_2\text{max}$ . 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.

Third, a series of correlational analyses have shown that (a) the magnitude of the positive correlations between ratings of affective valence and self-efficacy are stronger near the point of transition from aerobic to anaerobic metabolism and weaker when exercise intensity is either low or high and (b) the magnitude of the negative correlations between ratings of affective valence and indices of metabolic strain (e.g., the respiratory exchange ratio or the percentage of maximal heart rate) become stronger as exercise intensity increases. These patterns again support the postulate of the dual-mode model that cognitive factors should be most influential when the challenge posed by exercise is appreciable but not overwhelming, and direct interoceptive cues should gain primacy when the individual approaches his or her functional limits.

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