



## Review

# Affective responses to and automatic affective valuations of physical activity: Fifty years of progress on the seminal question in exercise psychology

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## ABSTRACT

**Objective:** To critically review developments over the first fifty years of research (1967–2017) on (a) how people feel when they participate in exercise and physical activity, and (b) the implications of these responses for their willingness to become and remain active.

**Design:** Non-systematic narrative review.

**Method:** Representative sources were selected through a combination of computer searches and cross-referencing.

**Results:** For over three decades, exercise psychology exhibited a fixation on the idea that exercise and physical activity make people feel better. This notion, however, seemed to contrast with evidence that most adults in industrialized countries exhibit low levels of activity. In the last two decades, a critical examination and overhaul of the methodological platform resulted in the delineation of a dose-response pattern that encompasses positive as well as negative affective responses, and revealed marked interindividual differences. An emerging literature is aimed at refining and testing integrative dual-process models that can offer specific predictions about the behaviors that may result from the interaction of automatic processes (theorized to be heavily influenced by past affective experiences) and deliberative processes (such as cognitive appraisals).

**Conclusions:** Affective responses to exercise and physical activity are more complex than the long-popularized "feel-better" effect, encompassing both pleasant and unpleasant experiences and exhibiting marked interindividual variation. The potential of affective experiences to influence subsequent behavior offers an opportunity for an expanded theoretical perspective in exercise psychology.

How does exercise make people feel? This question provided the impetus for the genesis of the field of exercise psychology in the late 1960s and early 1970s. Therefore, the line of research examining the relationship between exercise and affect is the longest continuously running line of inquiry within this field, having tracked its entire 50-year history. During this time, this research has gone through several stages, including a protracted early phase characterized by numerous replications of the essential finding that “exercise makes people feel better,” a subsequent critical overhaul of the methodological platform, a thorough revision of its knowledge base, the development of cross-disciplinary bridges, and a struggle to achieve societal relevance by devising pragmatic and scalable interventions that can benefit public health on a global scale (Ekkekakis, 2013a; Ekkekakis, Hargreaves, & Parfitt, 2013; Ekkekakis, Hartman, & Ladwig, in press). Arguably, this history represents a process of maturation that may be considered a

prototype for the evolution of the field of exercise psychology as a whole. Therefore, reflecting on the lessons learned from both failures and successes, and drawing inspiration from the prospects of this line of research may offer useful insights to investigators across the many subdomains of exercise-psychological research. Thus, the aim of the present review is to provide (a) an overview of the history of this research, (b) a synopsis of current knowledge, and (c) an outline of future steps.

## 1. Fifty years ago: how it all began

In the late 1960s, interest in exercise as a lifestyle health behavior was on the rise. In April 1968, Dr Kenneth Cooper published *Aerobics*, a spectacularly popular book that is credited, to a large extent, with sparking the jogging and fitness craze of the 1970s in the United States.

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In March 1969, the American College of Sports Medicine published the inaugural issue of *Medicine and Science in Sports and Exercise*. Editor-in-chief Bruno Balke (1969) wrote that the launch of the new journal was in response to the “considerable momentum” generated by the “national and international interest in more active living habits” and the “medical and physiological recognition of the necessity for man to maintain an ‘active’ life” (p. viii, sexist language in the original).

While this movement was gaining steam, in December 1967, psychiatrists Ferris Pitts and James McClure published an article in the high-profile *New England Journal of Medicine*, in which they showed that infusions of sodium lactate (but not glucose) resulted in anxiety symptoms and anxiety attacks in patients with anxiety (but not among healthy controls). Their publication captured the attention of the medical community and the public at large because Pitts and McClure claimed to have uncovered, for the first time, the biochemical basis of a major psychiatric disorder. As it turned out, the publicity was relatively short-lived. The notion of a causal link between elevated concentrations of lactate in the blood and anxiety symptoms was quickly refuted by other researchers who argued that the observed anxiety symptoms were merely manifestations of a phobic reaction to peripheral physiological symptoms (e.g., dyspnea, tachycardia, perspiration) that the patients had learned to associate with their past anxiety attacks. In the few years that intervened until the noise subsided, however, the Pitts-McClure proposal was widely promoted as implying that vigorous exercise may raise the risk of anxiety attacks among individuals with a history of or a predisposition to anxiety (Pitts, 1971).

To proponents of exercise and physical activity as preventive lifestyle behaviors, the publicity surrounding the Pitts and McClure (1967) article was a possible impediment to the growing momentum of their cause. Thus, producing empirical data showing that exercise does not cause (or raise the risk of) anxiety or panic attacks was important in allaying the concerns of physicians and the public. William P. Morgan, who is now generally regarded as the “father” of exercise psychology in North America (Dishman & O'Connor, 2005) was a pioneer in undertaking such studies.

In the first study explicitly motivated by the Pitts-McClure proposal, Morgan, Roberts, and Feinerman (1971) wrote that the notion of exercise precipitating anxiety symptoms seems implausible insofar as it conflicts with accounts of “normal” individuals [who] invariably report that they feel better following physical activity” (p. 423). However, two experiments (comparing exercise of different intensities and exercise versus supine rest) failed to substantiate these anecdotal accounts, showing no significant group differences in depression and anxiety. In their Discussion, Morgan et al. (1971) insisted that “even though significant psychologic changes were not observed, the majority of the subjects tested in these studies reported that the exercise bouts were exhilarating and they ‘felt better’ following the exercise” (p. 425). The failure to find significant positive effects was attributed to the self-report measures used: “It is possible that the psychometric instruments were not sensitive enough to measure psychological changes in normal subjects” (p. 425).

The serendipitous occurrence that helped propel this line of research forward was the publication, around that time, of two questionnaires that, unlike earlier options, were appropriate for use with respondents without psychopathology and for the assessment of psychological states rather than traits. These were the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970) and the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971). Using these new questionnaires, Morgan (1973) found that bouts of vigorous exercise resulted in reductions in state anxiety and mood disturbance. He concluded that these results “seriously challenge the Pitts-McClure hypothesis” by showing that “muscular exertion reduces, not increases, state anxiety” (Morgan, 1973, p. 114).

Over the next decades, hundreds of replications were published, echoing the conclusion that “exercise makes people feel better,” even though the questionnaires used to operationalize this “feel-better” effect

were primarily designed to assess whether respondents felt “less bad” (defined as reductions in state anxiety and mood disturbance) rather than “better” per se (Tuson & Sinyor, 1993). In these studies, the modes of exercise and the characteristics of participants differed but the methodological approach was identical in all its essential details. Most studies were within-subjects experiments, with one administration of self-report measures (mainly the STAI, the POMS, or both) a few minutes before the beginning of an exercise bout and another a few minutes after the end. Most samples consisted of students from exercise-science programs and were, therefore, biased toward individuals who were not only unlikely to be entirely naive to the research question but were also characterized by young age, good health, athletic backgrounds, and relatively high levels of physical fitness. Finally, the exercise stimuli were mostly consistent with traditional exercise prescription guidelines, focusing on cardiovascular modalities of exercise (e.g., running, jogging, cycling, swimming), relatively vigorous intensities (e.g., > 70% of maximal aerobic capacity), and durations of 20–30 min.

Summarizing the results of this literature, Morgan (1985) concluded that “under normal circumstances, most individuals report that they ‘feel good’ or ‘feel better’ following vigorous exercise” (p. 94). Thirty years after the publication by Pitts and McClure (1967), Morgan (1997) encouraged the field to move on, writing that “there is no need for further research or reviews dealing with the question of whether or not physical activity results in improved mood” (p. 230). At that time, the “feel-better” effect was considered nearly universal and so robust that it occurs regardless of the level of exercise intensity (e.g., “studies of both acute and chronic exercise indicate that intensity may not be an important factor for psychological benefits,” according to Dunn & Blair, 1997, p. 58).

The belief in a universal and robust exercise-induced “feel-better” effect also influenced how exercise scientists thought about the implications of how participants feel in response to exercise for whether they may be inclined to adhere to or discontinue exercise programs. Morgan and O'Connor (1988) argued that pursuing investigations on a possible causal link from how people feel in response to exercise to exercise adherence may seem reasonable but will ultimately prove futile, since nearly everyone “feels better” after exercise:

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 it is quite probable that many or most individuals who discontinue may do so even though they too enjoy an improved mood state following exercise. This hypothesis could be tested empirically but it is probably not necessary because roughly 80%–90% of individuals in exercise programs report within 8–10 weeks that exercise makes them feel better, but 50% drop out within a few months (p. 116).

## 2. Fifty years on, still a polarizing issue

Fifty years after the initiation of this line of research, the question of how exercise makes people feel remains controversial. On the one hand, the belief in the “feel-better” effect remains strong among many researchers, as well as segments of the public. In clinical psychology, authors cite findings indicating that “moderate and vigorous exercise bouts ranging from 5 to 30 min are associated with improved psychological well-being and positive affective responses relative to controls” (Hogan, Mata, & Carstensen, 2013). According to a comprehensive review in neuroscience, “acute exercise has been shown to enhance affective, mood, and emotional states” (p. 128) and “acute exercise is one of the most effective behavioral techniques for self-regulation of mood in healthy populations” (Basso & Suzuki, 2016/2017, p. 131). Likewise, according to a leading textbook of exercise psychology, “there is a general consensus in the literature that exercise improves affect” (Buckworth, Dishman, O'Connor, & Tomporowski, 2013, p. 144). Finally, in an article in *The New York Times*, the author wrote: “Why does

exercise make us happy and calm? Almost everyone agrees that it generally does, a conclusion supported by research” (Reynolds, 2011).

On the other hand, negative experiences, including pain (e.g., Boutevillain, Dupeyron, Rouch, Richard, & Coudeyre, 2017; Kanavaki et al., 2017), breathlessness (e.g., Robinson, Williams, Curtis, Bridle, & Jones, 2018), and fear (e.g., Lidegaard, Schwennesen, Willaing, & Færch, 2016), are commonly reported in qualitative studies, especially by adults who are chronically hypoactive, nonathletic, overweight, or suffering from diseases that limit exercise capacity. Thus, in direct contrast to the belief in a nearly ubiquitous “feel-better” effect, some researchers assume that exercise “is unlikely to be construed as inherently pleasurable or enjoyable” (Wilson, Rodgers, Blanchard, & Gessell, 2003, p. 2375). This portrayal of exercise aligns well with many representations in the mass media. In an article in TIME magazine, the author described his personal experiences as follows (Cloud, 2009):

On Wednesday, a personal trainer will work me like a farm animal for an hour, some times to the point that I'm dizzy an abuse for which I pay as much as I spend on groceries in a week. Thursday is “body wedge” class, which involves another exercise contraption, this one a large foam wedge from which I will push myself up in various hateful ways for an hour. Friday will bring a 5.5-mile run, the extra half-mile my grueling expiation of any gastronomical indulgences during the week.

The contrast between the different viewpoints is striking and suggests that the exercise-affect relation is unlikely to be as monolithic as the “exercise makes people feel better” mantra would suggest. However, while more researchers are coming to grips with the notion that the relation is likely complex, research is only beginning to understand its nature, its mechanistic bases, and its behavioral implications.

### 3. Overhaul of the methodological platform

A critical parsing of the early research on the exercise-affect relation raises several concerns (also see Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007). First, as was evident from the historical overview, the initiation of this line of research was prompted by the controversial claims of Pitts and McClure that exercise can induce anxiety symptoms and anxiety attacks. Although science is never truly objective, conducting research with the intention of garnering evidence to substantiate a conclusion one believes to be true, such as a belief in the “feel-better” effect, tends to limit the ability of researchers to maintain a modicum of scientific impartiality. Approaching research with a set to prove an intuition can preclude researchers from taking a genuinely critical stance toward their methods, findings, and interpretations.

Second, much like the so-called “shotgun” approach to sampling that characterized the early “personology” days of sport psychology, most of the studies evaluating the effects of exercise bouts on affective outcomes used samples consisting of exercise-science college students or athletic young adults. This practice was justified in the early days by claiming that this approach represents “analogue research” (e.g., Martinsen & Morgan, 1997). “Analogue research” is a term that was used in clinical psychology and psychiatry to describe early “proof-of-concept” studies designed to test basic theoretical propositions or to evaluate alternative methodologies without exposing vulnerable participants to potentially risky procedures unnecessarily. Although this argument may have had some merit initially, using young, healthy, and fit participants gradually came to be regarded as an acceptable methodological practice despite the fact that it limited the generalizability of any conclusions drawn from such studies.

Third, research on the exercise-affect relation violated the normal progression from choosing conceptually appropriate target constructs to selecting measures for these constructs. In this case, the measures (namely, the POMS and the STAI) were selected *de facto*, because they were the only ones available at the time that purported to assess state

variables in non-clinical samples. Years later, Morgan (1984) acknowledged that attempting to assess how individuals feel when they exercise through “inventories designed to measure constructs such as anxiety and depression” was merely a solution of convenience. Because “the extent to which these inventories can tap the psychometric domain of significance to the exerciser has not been evaluated” (p. 134), results based on these inventories can be misleading. As Morgan explained, the effects of a particular exercise stimulus on a particular respondent may occur in a sector of the affective domain that is not tapped by these measures: “an investigator may employ an objective, reliable, valid test of anxiety or depression to quantify the psychologic effects of exercise, only to find that no ‘effects’ have taken place when, in fact, there may have been numerous effects” (p. 134). This warning, however, came too late and could not counteract the well-documented tendency of researchers to reproduce previously published methods rather than critically appraise their appropriateness.

Consequently, over the past fifty years, researchers have continued to use the STAI and the POMS on the basis of the argument that these measures have been used extensively before. For example, the STAI is still being used because it is allegedly “the most cited anxiety instrument in the context of exercise and sport science” (Viana et al., 2017, p. 367) and the POMS is being used because “it is the most common measure of mood states for studies of single sessions of exercise” (Ensari, Sandroff, & Motl, 2016, p. 3). A detailed analysis of the conceptual and psychometric problems associated with the use of these measures in the context of acute exercise are beyond the scope of this review but interested readers are encouraged to consult relevant sources (e.g., Ekkekakis, 2013b; Ekkekakis & Zenko, 2016a, b).

Fourth, just like the selection of outcome measures was dictated by pragmatic considerations (i.e., the availability of appropriate questionnaires) rather than conceptual reasoning, the timing of the assessment protocol in most studies was determined by logistical concerns. Specifically, given the length of the POMS (65 items) and the state-anxiety portion of the STAI (20 items), a pretest-posttest protocol was deemed the only realistic option since completing lengthy questionnaires during exercise (especially at a vigorous intensity) would be overly intrusive. Therefore, questionnaires were typically administered once several minutes before the start and again one or more times several minutes after the end of an exercise bout.

Although the logistical argument for this timing was evidently considered compelling for decades, this practice is problematic. Sampling the affective experience of participants once before and once after the exercise bout can only be justified if researchers accept that the change taking place between these two time points is linear and monotonic. In any other case, the pre-post assessment protocol would misrepresent the true shape of the affective response, potentially leading to false conclusions. Subsequent investigations utilizing single-item rating scales to repeatedly sample affect during exercise bouts (despite the theoretically higher susceptibility of such scales to random measurement error compared to multi-item questionnaires) showed that (a) affect reliably exhibits a quadratic decline over time during vigorous exercise, and (b) affect shows a robust and nearly instantaneous post-exercise rebound toward positivity that is proportional to, but larger than, any during-exercise decline (Ekkekakis, Parfitt, & Petruzzello, 2011). The combination of these two factors rendered the original pre-post assessment protocol misleading (Backhouse et al., 2007; Bixby, Spalding, & Hatfield, 2001). Since dynamic changes in affect during exercise were not assessed, any during-exercise declines went undetected and unreported. Moreover, given the robust post-exercise affective rebound, by the time the post-exercise assessments were taken, participants typically tended to report feeling better than they did before the bout began, thus falsely appearing to confirm the “feel-better” effect in most cases (e.g., regardless of exercise intensity).

Fifth, analyses of change in studies investigating the exercise-affect relation have followed the general linear modeling approach, with

repeated-measures analyses of variance (i.e., group-by-time or condition-by-time). In this approach, the focus is on the change of the group aggregate (i.e., the average of the sample). While this approach may be reasonable when the affective responses of individuals within the group vary in terms of the degree of change, it can become misleading when individuals also differ in terms of the direction of change. In a demonstration of this problem, researchers found that, in response to a “moderate” exercise stimulus (cycle ergometry at 60% of maximal oxygen uptake for 30 min), approximately 44% of participants reported progressive improvements in how they felt, 41% reported progressive declines, while the remaining 15% reported no change (Van Landuyt, Ekkekakis, Hall, & Petruzzello, 2000). As a result of these divergent trends, the group average appeared to remain unchanged, a pattern that only represented a small minority of participants. It is reasonable to assume that variability in affective responses is not merely a statistical “nuisance” but may rather reflect psychologically significant individual differences, such as predispositions to prefer lower or higher levels of exercise intensity, or a lower or higher tolerance of imposed levels of intensity that are experienced as unpleasant or uncomfortable (Ekkekakis, Hall, & Petruzzello, 2005a).

Sixth, in the initial study by Morgan et al. (1971), the researchers attempted to standardize exercise intensity across participants by having them exercise at the same level of heart rate (e.g., conditions of 150, 160, 170, and 180 beats per minute) or at the same workload (e.g., treadmill walk at 3.5 miles per hour and 5% grade). It quickly became apparent that this approach can introduce a major confound since it fails to take into account individual differences in cardiorespiratory fitness. Therefore, this method was supplanted by the use of exercise stimuli that were individualized as percentages of estimated or measured maximal exercise capacity (i.e., maximal heart rate or maximal oxygen uptake). This method of individualization appeared reasonable, especially since it was and still remains the method used in the exercise prescription guidelines issued by the American College of Sports Medicine for the classification of exercise intensity. Authors, for example, have selected 65% of maximal oxygen uptake for 30 min as “the most commonly recommended duration and intensity of exercise for general health” (Bryan, Hutchison, Seals, & Allen, 2007, p. 32). Indeed, according to the American College of Sports Medicine (2018), p. 65% of maximal oxygen uptake is at the cusp of the “moderate” (i.e., 46–63%) and “vigorous” (i.e., 64–90%) ranges of intensity, which are recommended for the improvement and maintenance of cardiorespiratory fitness and health.

In time, it became evident that percentages of maximal capacity represent a poor choice for standardizing exercise intensity across individuals, and some percentages may be more problematic than others. The reason is that this approach does not take into account individual differences in crucial metabolic landmarks, such as the ventilatory (or lactate) threshold and the respiratory compensation threshold (Gaesser & Poole, 1996). Exceeding these thresholds even by a small margin can significantly alter the function of multiple physiological systems (e.g., cardiovascular, endocrine, immune, neurotrophic) and thus transform the internal environment. Since affective responses to exercise likely represent adaptations that closely track the severity of homeostatic (i.e., metabolic) perturbations, it would be reasonable to expect that the affective responses of someone working at 10 Watts above the ventilatory threshold would be different from those of someone working at 10 Watts below the threshold. Since the ventilatory threshold is estimated to occur at 50–60% of maximal oxygen uptake in most healthy but nonathletic individuals (Meyer, Lucía, Earnest, & Kindermann, 2005), setting exercise intensity within or proximal to this range (e.g., 65%) can reintroduce the same confound that plagued the initial study by Morgan et al. (1971), namely a failure to standardize intensity. At this point, experts in exercise physiology contend that “assigning work intensity either as multiples of resting metabolic rate or as percentages of [maximal aerobic capacity] seems no longer justifiable” (Whipp, 1996, p. 88) or is “fundamentally flawed” (Gaesser & Poole, 1996, p.

43). Instead, they recommend transitioning to a typology based on metabolic domains that are demarcated by the ventilatory or lactate threshold, and the respiratory compensation threshold or the maximal lactate steady state (Lansley, Dimenna, Bailey, & Jones, 2011; Mezzani et al., 2013).

When combined, these problematic methodological elements compose an overall platform that probably biased research toward finding a “feel better” effect over several decades. Therefore, it became apparent that a new methodological platform was warranted. Instead of focusing on a few discrete states, such as state anxiety, depression, and other mood states, the domain of affect should be studied from a broad perspective that encompasses all varieties of affect. The proposed solution has been the transition to dimensional models, such as the affect circumplex, which attempt to represent the differences and similarities between affective states in terms of a small set of constituent dimensions (Ekkekakis, 2013b; Ekkekakis & Zenko, 2016a, b). Moreover, given its dynamic nature, affect should be sampled repeatedly, not only before and after the exercise bout, but also during the bout. Affective changes should be examined not only at the level of the group aggregate but also at the level of individuals and subgroups, and patterns of individual variation should be studied as reflecting underlying psychological mechanisms, such as individual-difference variables and momentary cognitive appraisals. Finally, exercise intensity must be standardized by taking into account individually determined metabolic landmarks, such as the ventilatory threshold and the respiratory compensation threshold.

#### 4. Dual-mode theory and emergence of a dose-response model

In the 2000s, more than thirty years after the advent of research on the exercise-affect relation, researchers started adopting the new methodological platform outlined in the previous section. This was guided by a new dual-mode theory (DMT) that (a) linked affective responses to metabolic domains with important adaptational implications, (b) acknowledged the occurrence of negative effects, (c) included specific postulates about the pattern and sources of interindividual variation, (d) proposed a dose-response pattern, and (e) offered testable hypotheses about the mechanistic basis of affective responses by incorporating emerging evidence from neuroscience (Ekkekakis, 2003, 2009a, 2013a; Ekkekakis & Acevedo, 2006; Ekkekakis, Hall, & Petruzzello, 2005b).

Within a decade, researchers were able to decipher and reliably demonstrate a dose-response pattern linking exercise intensity to affective responses (Ekkekakis et al., 2011). Specifically, the DMT postulates three metabolic domains (moderate, heavy, severe), in accordance with proposals from exercise physiology (Gaesser & Poole, 1996; Mezzani et al., 2013). Each is theorized to have distinct implications for survival and adaptation, and therefore a distinct pattern of affective responses.

The moderate domain encompasses exercise intensities below and up to the ventilatory threshold (i.e., the point at which the volume of expired carbon dioxide starts to exceed the volume of oxygen consumed). Within the moderate domain, physiological parameters (e.g., heart rate, oxygen consumption, blood lactate) can maintain a steady-state over time and, therefore, homeostasis is not compromised. Physical activities within the moderate range are presumed to have occupied the vast majority of time in primordial “hunter-gatherer” environments since most subsistence activities (e.g., searching for and tracking prey, harvesting fruits and grains) had to be performed for several hours per day without exhaustion. Presumably, while engaging in foraging, especially over long distances and diverse territory, it would be advantageous to be alert and aware of surroundings (Raichlen & Polk, 2012), and to experience a sense of physical energy that would facilitate continuation (Thayer, 1989). Indeed, research has shown that an increase in perceived activation while exercising within the moderate domain of intensity (e.g., self-paced walking) is associated with

increases in pleasure and perceived energy among most participants (Ekkekakis et al., 2011). While the mechanistic basis of this phenomenon remains largely unexplored, one possibility is that endocannabinoids (i.e., anandamide) may be involved (Raichlen, Foster, Gerdeman, Seillier, & Giuffrida, 2012).

The heavy domain encompasses exercise intensities between the ventilatory threshold and the respiratory compensation threshold (or between the lactate threshold and the maximal lactate steady state). Within this domain, the appearance of a so-called “slow component” of oxygen uptake (in contradistinction to the “fast” rise in oxygen consumption that characterizes the first few minutes of exercise), precludes the maintenance of a physiological steady-state over time. If the rate of the slow component is not too high for the level of cardiorespiratory fitness of a given individual (which would lead to exhaustion), a physiological steady state may be reestablished after several minutes (once the rate of hepatic clearance of lactate catches up with the rate of production from the working muscles). The heavy domain of exercise intensity triggers a generalized stress response, as indicated by the activation of the neuroendocrine stress axes (sympathetic adrenomedullary system, hypothalamic pituitary adrenocortical system; Schneider, McLellan, & Gass, 2000; Soya et al., 2007). The adaptational implications of exercise in this domain are ambiguous. On the one hand, tolerating heavy-intensity exercise may confer an advantage during a fight, during short-term pursuit of prey, or in adverse environmental conditions that increase metabolic strain (e.g., heat, humidity, altitude). On the other hand, exercise in the heavy domain (especially if prolonged) raises the level of risk (of injury, exhaustion, hyperthermia, etc). As a consequence of this ambivalence, affective responses within the domain of heavy-intensity exercise tend to be heterogeneous. Some individuals continue to report increases in pleasure, whereas others begin to report decreases (Ekkekakis et al., 2005b).

Both psychological and biological mechanisms have been proposed for these affective responses. From a psychological perspective, the increased level of challenge that exercise within the heavy domain entails implies that the sense of agency (i.e., self-efficacy) becomes relevant. Indeed, when the intensity poses a challenge (e.g., perceived exertion rated between “hard” and “very hard”), experimental manipulations of self-efficacy result in changes in affective responses in the hypothesized direction (McAuley, Talbot, & Martinez, 1999). Other types of cognitive appraisals may also be relevant. For example, since overt signs of exertion may be unavoidable at vigorous intensities (e.g., 70–80% of maximal heart rate), individuals with a sensitivity to social evaluation (e.g., appearance-related concerns causing social-physique anxiety) may feel worse when exercising in public than in private (Focht & Hausenblas, 2006). From a biological standpoint, affective responses begin to exhibit significant associations with physiological indices of metabolic strain, such as blood lactate and the respiratory exchange ratio (Ekkekakis, 2003).

Finally, the domain of severe intensity encompasses the intensities from the respiratory compensation threshold (or maximal lactate steady state) to the point of peak oxygen consumption (i.e., the ultimate limit of exercise tolerance). Within this domain, the maintenance of physiological steady-state is no longer possible. Physiological parameters (i.e., blood lactate, oxygen consumption) rise continuously to their maximal values and exercise is terminated within a few minutes due to volitional exhaustion. The adaptational implications of exercise in this domain are clear. Exercise is metabolically unsustainable and must be terminated (or the intensity must be reduced) in order to avoid causing irreparable harm to muscles. This imperative is imposed via a surge of displeasure that creates the sense that continuation would be insufferable. Therefore, affective responses in the severe domain are characterized by universal and robust declines in pleasure (Ekkekakis et al., 2005b). Within the severe domain, the portion of variance in affective responses accounted for by cognitive variables (e.g., self-efficacy, self-presentational concerns) declines, whereas the portion accounted for by physiological variables (e.g., blood lactate, respiratory exchange ratio)

increases (Ekkekakis, 2003). These results suggest that, in the severe domain, affect becomes a strong indicator of the severity of homeostatic perturbation and is less amenable to cognitive influences.

Thus, according to the DMT, the range of exercise intensity can be conceptualized as consisting of three domains, each with distinct adaptational implications and, therefore, corresponding patterns of affective responses. Specifically, (a) relative homogeneity is predicted within the moderate domain, with the dominant response being increases in pleasure, (b) marked heterogeneity is predicted within the heavy domain, with some individuals reporting increases and others decreases in pleasure, and (c) homogeneity is again predicted within the severe domain, but in this case the dominant, nearly universal, trend is a decline in pleasure. Moreover, evidence suggests that the dorsolateral prefrontal cortex, a brain region presumed to be a critical part of the network involved in the cognitive regulation of negative affective responses, receives less oxygenated blood as individuals approach their maximal exercise capacity and begin to contemplate the decision to discontinue an incremental exercise test (Ekkekakis, 2009b; Rooks, Thom, McCully, & Dishman, 2010). The practical implication of this deoxygenation is that cognitive methods commonly recommended for regulating affective responses to exercise, including attentional dissociation through music and video (e.g., Hutchinson, Karageorghis, & Jones, 2015), cognitive reappraisal (e.g., Giles et al., 2018), motivational imagery (e.g., Tempest & Parfitt, 2013), and efficacy-focused self-talk (e.g., Blanchfield, Hardy, De Morree, Staiano, & Marcora, 2014), may show diminishing effectiveness when exercise intensity is within the severe range (Ekkekakis, 2009b).

The research emerging from the DMT is helping reshape views of the exercise-affect relation within the field of exercise psychology, by raising important caveats and clarifying that, while “feel-better” effects are possible, they should be considered conditional. The new findings have opened the door to research examining the possible motivational implications of exercise-associated affective experiences since it has now become apparent that the earlier belief in nearly universal “feel-better” effects (i.e., “roughly 80%–90% of individuals”; see Morgan & O’Connor, 1988, p. 116) is not consistent with current evidence. If individuals exhibit variable affective responses to exercise and, importantly, if the differences between individuals are not merely a matter of degree (i.e., gradations of “feel-better”) but are also a matter of direction (i.e., negative as well as positive), then it becomes plausible that affective responses may account for a portion of the variance in exercise and physical activity behavior.

It is also important to emphasize that, while the preceding summary focused on how pleasure-displeasure responses are influenced by exercise intensity, these are certainly not the only affective experiences associated with exercise behavior, nor should they be assumed to be the most personally meaningful or consequential for subsequent behavioral decisions. As commonly practiced, exercise and physical activity are embedded within a social and a broader cultural context that exerts a powerful influence on thoughts (i.e., emotion-antecedent cognitive appraisals) and feelings (i.e., cognitively driven and culturally framed emotions). These include, but are likely not limited to, competence-related (e.g., Wienke & Jekauc, 2016) and body-related (e.g., Sabiston et al., 2010) emotions, such as pride, shame, and embarrassment.

## 5. Affective-reflective theory: the duality of automatic and reflective processes

Early research on the role of affect in exercise and physical activity behavior consisted of correlational studies, in two main directions. One line of research has focused on the relation between naturally occurring (and oscillating) affective states and physical activity behavior. Using continuous, real-time assessments (e.g., smartphone applications for ecological momentary assessment of affective states, accelerometers for physical activity), studies have found that periods characterized by elevated pleasant affect, especially in the form of perceived energy, are

followed by periods of increased physical activity (Liao, Shonkoff, & Dunton, 2015).

A second line of research has focused on the associations between affective responses to bouts of exercise or physical activity and (self-reported or objectively measured) physical activity behavior, using both cross-sectional and longitudinal study designs. While the methods of these studies are still evolving and standards of best practice are still in flux, the early evidence suggests that affective responses, especially those during exercise, are (weakly but significantly) associated with physical activity (Ekkekakis & Dafermos, 2012; Rhodes & Kates, 2015; Schneider, Dunn, & Cooper, 2009).

On the basis of this preliminary evidence, the first intervention studies have started to emerge, comparing traditional methods of exercise prescription (i.e., recommending specific ranges of intensity) to methods designed to facilitate positive affective experiences. For example, instructing participants to exercise at an intensity that “feels good” has been found to improve parameters of cardiorespiratory fitness, thus demonstrating that pleasure during exercise is not inherently incompatible with effectiveness in stimulating salubrious physiological adaptations (Parfitt, Alrumh, & Rowlands, 2012). Moreover, early randomized controlled trials in which participants assigned to the experimental groups were instructed to regulate their intensity to “feel good” (Baldwin et al., 2016) or to self-regulate their intensity, which resulted in enhanced affective responses during exercise (Williams et al., 2016), found increased physical activity participation compared to control groups given standard moderate-intensity exercise prescriptions.

While these results have helped reestablish affect as a motivational force in the field of exercise psychology, the more interesting (and far more complex) challenge lies in delineating how affective experiences of exercise are encoded in associative memory (i.e., the learning, through repeated pairings, of associations between stimulus concepts such as “exercise” and related attributes such as “pain”) and how these associations are functionally integrated into a broader system that also processes “propositional” data, such as knowledge of the benefits of exercise for health. Researchers (e.g., Bluemke, Brand, Schweizer, & Kahlert, 2010; Ekkekakis & Dafermos, 2012) have suggested that the case of exercise may represent a scenario analogous to what has been postulated for individuals who abuse illicit drugs: on the one hand, people may have the necessary knowledge to evaluate drug abuse as detrimental to their lives and may have formed an honest commitment to behavior change; but, on the other hand, the (presumably) pleasant associations created through the effects of the drugs on hedonic centers of the brain create a powerful counter-urge that ultimately overpowers any rational intention to remain sober. Applied to exercise, this scenario would suggest that, on the one hand, most individuals may be sufficiently aware of the health benefits of exercise, may hold generally positive attitudes, and may consider themselves (physically and logistically) capable of performing exercise; but, on the other hand, they may be hindered by a combination of (a) life histories of consistently non-positive (or worse, negative) experiences from exercise and related contexts (e.g., school physical education, youth sports, or weight-loss programs) and (b) consistently pleasant experiences associated with sedentary lifestyle behaviors (e.g., social media, web surfing, television viewing).

In this line of theorizing, if both postulated motivational vectors point in the same direction, the behavioral outcomes should be easily predictable. For example, if one simultaneously holds positive deliberative evaluations of exercise (e.g., stemming from knowledge of health benefits, appraisals of personal capability, perceptions of available social support) and has a history of pleasant affective experiences (e.g., stemming from a sense of physical exhilaration, proud past accomplishments), the outcome should be a gravitation toward a physically active lifestyle. Conversely, if one holds negative or neutral evaluations and is burdened by a history of unpleasant experiences (e.g., physical pain, fear of injury, emotional scars from shame or

embarrassment), the predicted outcome would be a propensity for sedentary behavior. The theoretical challenge lies in making predictions about the outcomes in cases of conflict.

As research on the exercise-affect relation reached the point at which the relevance of affect to behavior was becoming evident, research on the psychological processes underlying exercise participation and adherence was reaching the point at which the limitations of cognitivist theories (e.g., theory of planned behavior, social-cognitive theory) were being recognized by a growing number of investigators (Ekkekakis & Zenko, 2016b). At the same time, other domains of psychology were witnessing increasing interest in so-called “dual-process” theoretical models, including the associative-propositional processes in evaluation (APE) model (Gawronski, Brannon, & Bodenhausen, 2017) and the reflective-impulsive model (RIM; Strack & Deutsch, 2015). Despite considerable differences in specific postulates and terminology, dual-process models posit the existence of two closely integrated and continuously interacting processes. One type (“type 1”) is theorized to be quick, automatic, univariate, reflex-like (i.e., affording limited behavioral flexibility), relies heavily on past (pleasant or unpleasant) affective experiences, and generates action impulses (to approach or avoid). Consistently deriving pleasure or displeasure from an activity (such as exercise) is theorized to establish an associative pairing between that concept and the attendant affective response. Then, given how associative memories are stored (i.e., as interlinked networks), any subsequent activation of that stimulus concept is believed to automatically reactivate its attendant, positive or negative, affective designation, along with a perhaps milder version of the associated physiological reaction (e.g., a knot in the stomach in the case of academic examination anxiety or a sense of physical exhaustion in the case of strenuous exercise). The processes of the second type (“type 2”) are theorized to be evolutionarily recent, sophisticated, multivariate, capable of probabilistic projections into the future, mostly accessible to conscious awareness, and mostly subject to deliberate cognitive control. The output of type 2 processes consists of behavioral action plans. In other words, type 2 processes are mental operations consistent with those postulated in cognitivist theories, such as reflective or deliberative appraisals (e.g., of benefits versus barriers, of agency, of competence, of support) and estimations of possible future outcomes associated with different courses of action.

Dual-process theories specific to exercise and physical activity behavior represent a recent development that promises to propel exercise psychology to the postcognitivist era (Brand & Ekkekakis, 2018; Conroy & Berry, 2017). A common assumption of these theories is that type 1 and type 2 processes “will not always converge and, in some cases, may be discordant” (Conroy & Berry, 2017, p. 231; for empirical demonstrations, see; Berry, Rodgers, Divine, & Hall, 2018; Brand & Antoniewicz, 2016). The Affective-Reflective Theory (ART) of exercise and physical inactivity (Brand & Ekkekakis, 2018) postulates that repeated experiences of pleasure or displeasure in the context of exercise or physical activity (spanning the gamut from somatic pain versus exhilaration to complex, cognitively driven emotions, such as pride or shame) form an *automatic affective valuation*, namely a tacit assignment of a plus or minus sign to these concepts. Pleasure and displeasure are intrinsically linked to corresponding impulses to approach or avoid, respectively. Thus, subsequent evocation of these concepts automatically recalls the positivity or negativity associated with the concepts, along with the inherent propensity to approach or avoid them. For example, in a common scenario, past unpleasant experiences from exercise may have resulted in the formation of a negative automatic affective valuation for the concept of “exercise,” such that the thought of exercise triggers a negative visceral reaction and the urge to remain tethered to the sofa (i.e., a type 1 process). The ART further postulates that, given adequate self-control resources, it is possible that this urge may be overridden by type 2 processes (e.g., contemplation of information in a news article, evaluation of the advice of a physician), resulting in a plan to initiate exercise. However, depletion of self-

control resources, which is a common occurrence due to stress or competing pressures, results in the more efficient type 1 process acting as the default option.

## 6. Looking to the future

The next challenge in this fifty-year old line of investigation lies in (a) elaborating predictions for the interactions of type 1 and type 2 processes, and (b) developing methods to replace negative automatic valuations of exercise and physical activity with positive ones. A major obstacle to progress is the measurement of type 1 processes. Although a wide array of tests of automatic associations have already been used in exercise-psychological research, showing significant correlations with measures of physical activity in most cases (Schinkoeth & Antoniewicz, 2017), considerable psychometric challenges remain. At present, the degree of susceptibility of these tests to random measurement error and their links to underlying type 1 processes remain poorly understood. Therefore, while theories posit that type 1 processes are shaped, to a large extent, by past affective experiences, a direct test of this fundamental postulate is still lacking. Nevertheless, preliminary proof-of-concept studies have demonstrated that computer-based training using pleasant or approach-related images (versus unpleasant or avoidance-related images) can influence performance on tests of automatic associations and, in turn, influence exercise-related behaviors (Antoniewicz & Brand, 2016; Cheval, Sarrazin, Pelletier, & Friese, 2016). From a practical perspective, this emerging research underscores the importance of considering affective experiences when designing exercise and physical activity interventions across the lifespan, from physical education and youth sports, to health and weight-loss programs, to rehabilitation regimens. It is becoming increasingly clear that the process of developing exercise prescriptions and physical activity recommendations should be based on a tripartite rationale, aiming to maximize effectiveness, safety, and pleasure.

## Declarations of interest

None.

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