



Invited Guest Editorial: Envisioning the next fifty years of research on the exercise–affect relationship



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ABSTRACT

Objectives: To summarize the major accomplishments of research on the relationship between exercise and affect over the past five decades and to outline an expanded research agenda for the future.

Design: Literature review.

Method: Illustrative and historically significant publications on the exercise–affect link were examined.

Results: The main accomplishments over the past fifty years include (a) a growing recognition that exercise can have a positive and clinically meaningful influence on affect, with possible implications for the treatment of mental health problems, and (b) the incorporation of affect in exercise prescription guidelines as a method of monitoring exercise intensity and a possible determinant of adherence. Emerging research directions include efforts to understand (a) the role of affect in exercise behavior, (b) the cognitive and biological mechanisms of affective responses, (c) individual differences in affective responses, including the contribution of genetic polymorphisms, (d) the application of exercise in the treatment of addictions through the process of “hedonic substitution,” (e) the possible connection between affective responses and cognitive function, and (f) the processes underlying the sense of fatigue.

Conclusions: The study of the exercise–affect relationship remains one of the most vibrant and prolific areas of research within exercise psychology. The last few years, in particular, have witnessed a dramatic expansion of the research agenda, addressing questions of great societal importance, increased interdisciplinary interest, and direct implications for practice.

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The link between physical exercise and affective responses, such as exhilaration and fatigue, is a theme that transcends writings about exercise since antiquity. For example, in his exercise-prescription guidelines, Hippocrates (c. 460–370 BC) stated that, to achieve the goal of “forsaking the disinclination to exertion” (*Epidemics*, Book Six), one should increase the dose of exercise only up to the point that it induces the “pain of fatigue.” He explained that “this is the sign that I teach laymen” (*Regimen*, III, LXXVIII: 67) because the “pain of fatigue” subsequently causes people to “adopt a treatment of inactivity or indolence” (*Regimen*, III, LXXII: 5).

Twenty-five centuries later, exercise prescription guidelines by the American College of Sports Medicine (2013) reflect the same essential theme, underscoring the timeless insight it encapsulates. According to these guidelines, “individuals are more likely to

adhere to lower intensity programs” (p. 356). At least in part, this may be because higher exercise intensity results in less positive affective responses and, in turn, “feelings of fatigue and negative affect... can act as a deterrent to continued participation” (p. 374). Echoing the teachings of Hippocrates, these guidelines suggest that affect “may be a useful tool in prescribing exercise intensity” (p. 375).

The scientific study and clinical application of the exercise–affect connection has certainly waxed and waned over different historical periods. Particularly in the last two centuries, as both psychology and exercise science underwent paradigmatic transformations, this topic witnessed unprecedented attention by scholars toward the end of the 19th century, then almost complete neglect during the reign of behaviorism and cognitivism in psychology, and, within the last half century, a dynamic and prolific revival (Ekkekakis, 2013).

The seed of this revival was planted by William P. Morgan in the late 1960s. Morgan (1968) reminded readers that “physical exercise has often been prescribed as a method of controlling

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tensions” (p. 26) and that “individuals who exercise regularly claim ‘a general feeling of well-being’” (p. 27). Noting that “researchers have had difficulty in substantiating this claim with objective evidence” (p. 27), he called for an ambitious research agenda aiming to investigate the acute and chronic psychological effects of exercise, the possible role of exercise in preventing emotional illness, and the mechanisms underlying the exercise-associated “feeling better” effect.

The present paper has the following objectives. First, it presents an overview of recent achievements regarding the study and the application of exercise-induced affective responses. Second, it presents possible thematic areas for a renewed and expanded research agenda.

Landmark achievements

The main focus of research on affective responses to exercise until the last decade or so was on mental health. Findings of a “feel-better” effect resulting from bouts of exercise were seen as having possible implications for the application of exercise in the treatment of such mental health problems as psychosocial stress, anxiety, and mood disorders (e.g., depression). The importance of this research remains self-evident. Particularly given the incorporation of physical activity in clinical guidelines for the treatment of adult depression issued by the American Psychiatric Association in the United States and the National Institute for Health and Clinical Excellence in Britain, it is reasonable to expect that this line of research will remain prolific.

The clinical relevance of the studies in this category has been strengthened in the last decade by the examination of patient samples, as opposed to the formerly prevalent practice of recruiting healthy “analogue” samples. Recent studies have examined patients with depression (Bartholomew, Morrison, & Ciccolo, 2005; Bodin & Martinsen, 2004; Knapen et al., 2009; Mata, Hogan, Joormann, Waugh, & Gotlib, 2013; Mata et al., 2012; Weinstein, Deuster, Francis, Beadling, & Kop, 2010), anxiety and panic disorders (Esquivel et al., 2008; Ströhle et al., 2009), and neurologic conditions, including multiple sclerosis (Petruzzello & Motl, 2011; Petruzzello, Snook, Gliottoni, & Motl, 2009), intellectual disability (Vogt, Schneider, Abeln, Anneken, & Struder, 2012), spinal cord (Martin Ginis & Latimer, 2007) and traumatic brain injury (Driver, 2006).

Over the last decade, the focus of most published studies has shifted. Researchers have started to consider the role of affective responses as essential ingredients of the exercise experience. Two notable trends have emerged. First, studies have examined whether affective responses can be used as a practical method of monitoring and self-regulating exercise intensity. Second, increasing attention is placed on the implications of affective responses for adherence.

The progress that has already been made on these fronts is substantial. The most prominent indicator of this progress has been the insertion of references to affective responses in the exercise prescription guidelines issued by one of the largest scientific and professional organizations in the field of exercise science, the American College of Sports Medicine (ACSM). Because these guidelines are followed by thousands of exercise practitioners worldwide, their practical impact is substantial (Walsh, 2012). Moreover, these statements may be indicative of a paradigmatic transition with even broader implications for the field of exercise science. While exercise prescriptions have traditionally been based on the biomedical model, taking into consideration only the maximization of effectiveness and the minimization of risk, the recent acknowledgment of the importance of affective responses may be an auspicious sign that the field of exercise science may be ready to begin the process of mind-body reintegration.

For the first time in 2010, in the eighth edition of the *Guidelines for Exercise Testing and Prescription*, the ACSM recommended the use of rating scales of affective valence, such as the Feeling Scale (Hardy & Rejeski, 1989), as an adjunct method of monitoring exercise intensity, alongside heart rate and ratings of perceived exertion. Although the guidelines offered no elaboration on the rationale for this use, this was based on findings that self-ratings of pleasure exhibit a quadratic decline at intensities exceeding the ventilatory or lactate threshold (Ekkekakis, Parfitt, & Petruzzello, 2011). Acevedo, Kraemer, Haltom, and Tryniecki (2003) had proposed that “the documented nonlinear drop in [Feeling Scale ratings]... may be clearly identified by exercisers” (p. 272). Similarly, Ekkekakis, Hall, and Petruzzello (2004) had suggested that the “quadratic declines in affective valence ... may have implications for exercise intensity prescription” (p. 156), enabling exercisers to detect “when they begin to feel substantially worse than they felt before, and [regulating] their pace accordingly” (p. 157). The value of ratings of affective valence for regulating intensity has since been supported by additional evidence (Parfitt, Alrumh, & Rowlands, 2012; Parfitt, Blisset, Rose, & Eston, 2012; Rose & Parfitt, 2008).

A call for using ratings of affective valence for monitoring and regulating exercise intensity was also included in the 2011 update of the ACSM position statement entitled *Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise*. According to this text, “measures of the pleasantness/unpleasantness of exercise (i.e., affective valence) hold promise as a means to regulate and monitor exercise intensity because they can accurately identify the transition across the lactate threshold during cardiorespiratory exercise” (p. 1344). This point was again acknowledged in the ninth edition of the ACSM guidelines, which state that exercisers can use the decline in pleasure as a “sign exercise intensity may be too high and they should decrease exercise intensity to reduce these feelings” (p. 375).

Official position statements have also addressed the possible implications of maintaining positive affective experiences for exercise adherence. In the joint statement issued by the ACSM and the American Diabetes Association (2010) on exercise and Type 2 Diabetes, it was acknowledged that “affective responses to exercise may be important predictors of adoption and maintenance, and encouraging activity at intensities below the ventilatory threshold may be most beneficial” (p. 2295). This point was reiterated in the 2011 update of the ACSM *Quantity and quality* position statement: “More negative affect is reported when exercising above the ventilatory threshold. Thus, prescribing exercise at an intensity below the ventilatory threshold may enhance affective responses to exercise and improve exercise adherence and/or maintenance” (p. 1347).

Finally, research on affective responses to exercise is having an impact even beyond the confines of exercise science. A growing number of references to recent results are made in the fields of prevention and rehabilitation. For example, according to a review from the field of cardiovascular prevention (Guiraud, Labrunee, Gayda, Juneau, & Gremeaux, 2012), pleasure should become the third pillar of exercise prescriptions, alongside effectiveness and safety:

As regards exercise prescription, the recommendations of the American College of Sports Medicine (ACSM) employ a somewhat limited model that may be considered incomplete insofar as it takes into account only two considerations, namely maximized efficiency (improved physical aptitudes and/or health) and minimized risks (myocardial damage, muscle and bone injuries). A connection between physical activity compliance and

pleasurable exercise sessions has nonetheless over recent years been more and more convincingly shown to exist. It would consequently appear necessary to reconsider the ACSM model by incorporating the notion of pleasure and thereby combating patient non-compliance subsequent to a cardiovascular rehabilitation program (p. 357).

Similarly, in a review focusing on cardiac rehabilitation, Hansen, Stevens, Eijnde, and Dendale (2012) noted that “in order to achieve optimal exercise therapy adherence in the long term, some studies indicate that lower exercise intensities might be preferred, as well as effective types of physical activity that are a pleasant experience for the patient” (p. 24).

Envisioning an expanded research agenda

Nearly 30 years after his initial call to the nascent field of exercise psychology to make affective responses to exercise one of its focal issues, Morgan (1997) reassessed the state of the research, stating that “there is no need for further research or reviews dealing with the question of whether or not physical activity results in improved mood... There are, however, many questions that remain unanswered, and these questions will hopefully be addressed in the decade ahead” (p. 230). More than 15 years have passed since then and the evidence on the ability of exercise to improve affect has been strengthened even further (Reed & Ones, 2006). Although several of the “unanswered questions” are now being addressed, the potential for new discoveries in this area remains great. The aim of this section is to illustrate this point by highlighting areas with significant prospects of future growth.

Affect as “the driving factor of physical activity motivation”

Research on the exercise–affect link is superbly positioned to advance the ongoing efforts to address what de Geus and de Moor (2008) described as the “most vexing questions in the field of exercise intervention,” namely “why exercisers exercise, and why non-exercisers do not” (p. 57). On this crucial issue, exercise psychology currently appears to be undergoing its first period of critical introspection, or what Kuhn (1962/1996) described as a “crisis.” All of its dominant theories up to this point have been derivatives of the cognitivist paradigm, according to which humans make decisions on the basis of the information they collect, the rational analysis of pros and cons, and predictions about the future consequences of their actions.

Perhaps as a result of the frustratingly low percentages of behavioral variance explained by cognitive constructs and the persistent gap between intentions and actual behavior, exercise psychologists are beginning to question the assumption of rationality, as well as to consider possible determinants of behavior beyond the cognitive sphere. Thus, in the last few years, variables with a strong affective component, including enjoyment, affective associations, and the affective component of attitude have been shown to explain variation in exercise behavior, or to predict exercise behavior, at levels typically higher than those associated with cognitive constructs (Calitri, Lowe, Eves, & Bennett, 2009; Gellert, Ziegelmann, & Schwarzer, 2012; Kiviniemi, Voss-Humke, Seifert, 2007; Lawton, Conner, & McEachan, 2009; Mohiyeddini, Pauli, & Bauer, 2009; Nasuti & Rhodes, 2013; Rhodes, Fiala, & Conner, 2009). Furthermore, studies have found that inducing positive or negative affect influences exercise intention (Allen Catellier & Yang, 2013) and emphasizing the affective benefits of exercise can increase exercise behavior more than emphasizing its benefits for physical health (Conner, Rhodes, Morris, McEachan, & Lawton, 2011). It has also been shown that anticipated positive affective

experiences predict future exercise behavior (Fridlund Dunton & Vaughan, 2008), whereas anticipating that exercise will be less pleasant than it actually turns out to be is a predictor of sedentariness (Ruby, Dunn, Perrino, Gillis, & Viel, 2011).

The mounting recognition of the importance of affect in exercise motivation has led to statements in the literature that would have seemed unimaginable a decade ago: “the affective qualities of [physical activity] are the driving factor of [physical activity] motivation” (Rhodes & Nigg, 2011, p. 116). In the United States, the notoriously traditionalist National Institutes of Health have funded interventions based on “positive affect induction” to increase the physical activity of cardiac patients after percutaneous coronary intervention (Peterson et al., 2012) and adults with asthma (Mancuso et al., 2012). These studies have been hailed as representing “outside the box” thinking that holds great promise: “we need to find a way to make doing the right thing ‘feel good’ to patients” (Shrank & Choudhry, 2012, p. 264). Scholars in physical education now suggest that pleasure should be considered a “potential pillar of disciplinary coherence in physical education” (Booth, 2009, p. 133) and that “a prime justification for the educative value of [physical education] can rest on its ability to induce pleasure” (Pringle, 2010, p. 120).

Now that the importance of affect in influencing exercise behavior is gradually being recognized, the next major challenge will be to investigate how reason and affect interact to codetermine behavioral decisions. This is an issue with which researchers investigating the processes underlying judgment and decision-making have grappled for years (Evans, 2008; Kahneman, 2003; Stanovich & West, 2000). The main theoretical insight that has emerged from these efforts is that behavioral decisions are determined by a dual system, comprising (a) a rational and reflective component and (b) a fast, intuitive, affect-based component. The two components likely have different evolutionary histories, largely distinct neuroanatomical substrates, different designs and principles of operation, and serve different priorities. So, perhaps unsurprisingly, they often conflict. As a case in point, population surveys indicate that nearly everyone in western societies is aware of the health benefits of exercise, yet relatively few people exercise regularly. This may indicate that exercise has registered in the memory of most individuals as unpleasant (Bluemke, Brand, Schweizer, & Kahlert, 2010; Ekkekakis & Dafermos, 2012).

In the last few years, several studies linking affective responses to exercise with concurrent or subsequent exercise behavior have appeared in the literature (Berger, Darby, Owen, & Carels, 2010; Carels, Berger, & Darby, 2006; Kwan & Bryan, 2010a; Schneider, Dunn, & Cooper, 2009; Williams et al., 2008; Williams, Dunsiger, Jennings, & Marcus, 2012). Given that both the predictor (i.e., affective responses, assessed only from a single bout or a single point in time) and the criterion (i.e., physical activity, assessed by self-report in most cases) are measured with considerable error, which always has an attenuating effect on indices of association, the presence of significant results is a testament to the robustness of this relationship. On the basis of this emerging empirical literature, authors have put together the initial blueprints of a “hedonic” theory of exercise motivation (Ekkekakis & Dafermos, 2012; Williams, 2008). Although researchers focusing on exercise motivation are discovering the importance of affect, they have either overlooked this literature altogether or have found it hard to integrate it with conceptual models that are still anchored by cognitive constructs and the assumption of rationality (Nasuti & Rhodes, 2013; Rhodes et al., 2009).

This may be seen as a demonstration of segmentation and compartmentalization in the exercise literature. At the same time, however, this situation poses a challenge that must be met if we, as a field of inquiry, are to fulfill our mission of helping society address

the problem of physical inactivity. Part of the challenge lies in translating the findings from the exercise–affect literature to implications that motivation researchers can more directly integrate with current conceptual models. Examples may include studies that link affective responses to constructs from the theory or planned behavior (e.g., attitude, norms, intention; Bryan, Hutchison, Seals, & Allen, 2007; Focht, 2009; Kwan & Bryan, 2010b), social-cognitive theory (e.g., self-efficacy; Ekkekakis, Lind, & Vazou, 2010; Focht, Knapp, Gavin, Raedeke, & Hickner, 2007), or self-determination theory (e.g., Guérin & Fortier, 2012; Rose & Parfitt, 2012).

The mechanisms and the malleability of affective responses

In most contemporary textbooks of exercise psychology, the exercise–affect relationship is described only as exercise-induced reduction in state anxiety or enhancement in various mood states. In other words, other aspects of this – by all indications – complex and multifaceted relationship are typically overlooked, including such phenomena as dose–response patterns, negative affective responses, and interindividual variability. Likewise, the mechanisms underlying this relationship cover only those theorized to explain the positive effects that exercise has on how people feel. Thus, when most researchers think of possible mechanisms underlying the exercise–affect relationship, they tend to recall those proposed almost thirty years ago by Morgan (Morgan, 1985; Morgan & O'Connor, 1988), including, among others, the distraction hypothesis, the monoamine hypothesis, and the endorphin hypothesis. However, the evidence that has emerged in recent years shows that the “feel-better” effect is not the only effect that exercise has on the affective domain. There is now reliable evidence of a dose–response pattern, including negative changes for several segments of the population, as well as evidence of large interindividual differences (Ekkekakis et al., 2011; Parfitt & Hughes, 2009). It is, therefore, time to revisit the question of the underlying mechanisms and to begin to consider hypotheses with a broader scope, extending beyond the “feel-better” effect (Ekkekakis & Acevedo, 2006). Uncovering the mechanisms underlying the exercise–affect relationship, besides its inherent academic interest, will have a direct influence on application (Walsh, 2012). If exercise practitioners can successfully manipulate the determinants of affective responses, it is possible that adherence would also improve. As was the case with the directions for future research described in the previous section, mechanistic research also presents excellent opportunities for innovation and substantial impact.

The directions that mechanistic research will take in the near future are impossible to anticipate, as the range is virtually limitless. Here, we sample five, both emergent and established, that show strong signs of growth and hold considerable promise. First, it is certain that research on the role of a wide range of theory-derived cognitive constructs will continue unabated. Although this is far from an exhaustive list, researchers in recent years have examined the interaction of the social environment with elements that exacerbate the perception of evaluative threat (e.g., mirrors; Lamarche, Gammage, & Strong, 2009; Martin Ginis, Burke, & Gauvin, 2007), the behavior of the exercise leader (Loughead, Patterson, & Carron, 2008; Raedeke, Focht, & Scales, 2007), appraisals of self-efficacy (Barnett, 2013; Focht et al., 2007), knowledge of exercise duration (Baden, McLean, Tucker, Noakes, & St Clair Gibson, 2005; Eston, Stansfield, Westoby, & Parfitt, 2012; Welch, Hulley, & Beauchamp, 2010), telic versus paratelic metamotivational states (Legrand & Thatcher, 2011), and constructs from self-determination theory, including perceived autonomy (Rose & Parfitt, 2012; Vazou-Ekkekakis & Ekkekakis, 2009; Wilson, Mack, Blanchard, & Gray, 2009). Studies that examine the effects of manipulating attentional focus and the processing of sensory data

through music (Karageorghis et al., 2009), virtual-reality environments (Legrand, Joly, Bertucci, Soudain-Pineau, & Marcel, 2011), and imagery (Stanley & Cumming, 2010) also fall in this category.

Second, an important line of research examines the role of biological mediators of affective responses. This field of inquiry exhibits great diversity, extending from basic neuroscience using animal models (Rasmussen & Hillman, 2011) to non-invasive studies in humans using blood assays (Raichlen, Foster, Gerdeman, Seillier, & Giuffrida, 2012), electroencephalography (Dishman, Thom, Puetz, O'Connor, & Clementz, 2010; Hall, Ekkekakis, & Petruzzello, 2010; Schneider, Askew, et al., 2009; Schneider, Graham, Grant, King, & Cooper, 2009; Woo, Kim, Kim, Petruzzello, & Hatfield, 2010) or functional neuroimaging (Boecker et al., 2008). An associated line of applied studies examines the influence of manipulating specific peripheral and central physiological variables, such as hydration, carbohydrate supplementation, or stimulation with caffeine (Backhouse, Biddle, Bishop, & Williams, 2011; Peacock, Thompson, & Stokes, 2012).

Third, a direction of research with significant theoretical and practical implications, which so far remains unexplored, pertains to the question of how cognitive and somatosensory factors (e.g., acidosis, core temperature, hypoglycemia) interact in influencing affective responses across different levels of intensity (e.g., Ekkekakis et al., 2010). It has been theorized that cognitive factors maintain their primacy as determinants of affective responses only within a finite range of intensity, beyond which somatosensory factors become dominant (Ekkekakis, 2003, 2009a; Ekkekakis & Acevedo, 2006). The implication of this postulate for practice is that, for individuals who begin to exercise after a long period of sedentary living, cognitive techniques aimed at enhancing their affective responses (e.g., attentional dissociation, cognitive reframing, boosting self-efficacy) may be ineffective as long as the intensity approaches their (limited) maximal capacity. Although qualitative studies have started to explore the phenomenology of cognitive and somatosensory influences (Rose & Parfitt, 2007, 2010), future research in this area should aim to employ experimental designs. Emerging technologies, including near-infrared spectroscopy for the assessment of oxygenation in the prefrontal cortex (Ekkekakis, 2009b) and transcranial direct-current stimulation for the non-invasive increase of regional cerebral blood flow, can be used to facilitate an interdisciplinary experimental approach.

Fourth, a direction of research that has received considerably less attention than it warrants pertains to the role of personality traits and other individual-difference variables. Recent studies have examined such variables as the predisposition toward perceived evaluative threat (Focht, 2011), behavioral activation and inhibition (Schneider & Graham, 2009), telic dominance (Legrand, Bertucci, & Thatcher, 2009), and the preference for and tolerance of exercise intensity (Ekkekakis, Hall, & Petruzzello, 2005). Importantly, authors have also called for the initiation of research into the role of genetic factors (De Geus & de Moor, 2008, 2011; Garland et al., 2011), including specific polymorphisms in genes relevant to the modulation of affect and somatosensory perception (de Geus & de Moor, 2011; Ekkekakis, 2008). This type of research could pave the way for a more individualized approach to exercise prescription in the future. Although the first genetic-association studies have started to appear (Bryan et al., 2007; Karoly et al., 2012), a lot remains to be done for this line of research to evolve from exploratory (with its well-established susceptibility to Type I and Type II errors) to hypothesis-driven on the basis of psychobiological mechanisms underlying the genesis and regulation of affect. Experience from other fields of inquiry has demonstrated that initial findings of genetic associations based on small samples and exploratory analyses tend to be unreliable. As de Geus and de Moor (2008) noted, for many individuals, “repeating over and over that ‘exercise will

make you feel better” (p. 58) is unlikely to be a convincing (or truthful) message. Instead, “some individuals may require a different exercise program which emphasizes the appetitive aspects ... and reduces the aversive aspects” (p. 58).

Fifth, very little is known about the process by which exercise registers in memory as pleasant or unpleasant. Research in behavioral economics has shown that the duration of episodes is inconsequential (a phenomenon called “duration neglect”). Instead, what appears to be most influential in subsequent decision-making is the level of pleasure or displeasure experienced at the end of the episode (the so-called “end rule”), the amplitude of the (positive or negative) affective peak (the so-called “peak rule”), and the slope of change in pleasure–displeasure during the latter half of the episode (Ariely, 1998; Kahneman, 2003). These principles may have direct implications for how exercise sessions are structured, including the importance of avoiding large negative peaks (as in high-intensity interval training), ensuring a pleasant ending, and ramping down the intensity over the latter half of the session. Researchers are exploring these implications in the context of exercise (Brewer, Manos, McDevitt, Cornelius, & Van Raalte, 2000; Hargreaves & Stych, 2013; Parfitt & Hughes, 2009).

Hedonic substitution and implications for the treatment of addictions

A major emerging line of research focuses on the role of affective responses to exercise in helping individuals deal with addictions. This research began with observations that the introduction of running in animals addicted to various substances significantly reduced the self-administration of these substances or behavioral indices of reward associated with exposure to these substances (e.g., morphine, amphetamine, ethanol, cocaine, “ecstasy,” heroin). This led to neurophysiological investigations that revealed a large overlap between the mechanisms underlying the rewarding and addictive properties of these chemical agents and those of running (Brené et al., 2007). Eventually, these developments have led to the formalization of the hypothesis that exercise acts initially as a competitor against and ultimately as a “hedonic substitute” for drugs of abuse (Ozburn, Harris, Blednov, 2008). In other words, the affective responses to exercise are theorized to mediate the process of reducing the dependence to the addictive substances.

In the last few years, research has made the transition from basic studies on animals to applied studies involving human beings (Smith & Lynch, 2012; Zschucke, Heinz, & Ströhle, 2012). The behavior that has received the most attention so far has been cigarette smoking, with recent reviews showing beneficial effects of exercise on cravings and the management of withdrawal symptoms (Haasova et al., 2012; Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012; Taylor, Ussher, & Faulkner, 2007). From early on, this research was conceptualized within the framework of affect self-regulation. For example, it has been suggested that, while temporary smoking abstinence brings about a “decrease in arousal and an increase in emotional stress,” exercise can reverse this response by “[increasing] emotional arousal such as energy or vigor, and [reducing] emotional symptoms of stress such as tension” (Taylor, Katomeri, & Ussher, 2006, p. 19), in effect mimicking what smokers hope to achieve through nicotine. Building upon the positive results that have been published on using exercise as an aid for smoking cessation, researchers are turning their attention to other addictions, such as alcohol (Brown et al., 2009; Kendzor, Dubbert, Olivier, Businelle, & Grothe, 2008; Ussher, Sampuran, Doshi, West, & Drummond, 2004), opiates (Bailey, Hall, & Fareed, 2011; Weinstock, Wadson, & VanHeest, 2012), and sugar snacks (Oh & Taylor, 2012; Taylor & Oliver, 2009).

The possible link between affective responses and cognitive function

No studies to date have examined whether there is an association between affective responses to exercise and the effects of acute and chronic exercise on cognitive function. However, several signs point to the possibility that positive affective responses may, in fact, promote brain plasticity and cognitive adaptations. Increases in the endocannabinoid anandamide, which have been found to be associated with affective responses to exercise ($r = 0.96$; Raichlen et al., 2012), are also correlated with increases in brain-derived neurotrophic factor ($r = 0.71$; Heyman et al., 2012). In animal research using either receptor blockade or receptor deletion by genetic mutation, the cannabinoid receptors have been shown to be necessary for exercise-induced neurogenesis (Hill et al., 2010; Wolf et al., 2010). Taken together, these findings outline a possible, though still unconfirmed, scenario, in which endocannabinoid-mediated positive affective responses to exercise may facilitate neurogenesis and promote gains in cognitive performance.

The unsolved enigma of fatigue

An issue of tremendous societal importance on which research on the exercise–affect link could have considerable impact, but so far has had virtually none, is the study of the sense of fatigue. Estimates of the prevalence of fatigue symptoms in western countries reach or exceed 30%. Moreover, fatigue is a very common and severely debilitating symptom associated with a broad range of diseases, including cardiac and pulmonary diseases, diabetes, cancer, kidney failure, lupus, rheumatoid arthritis, fibromyalgia, stroke, multiple sclerosis, Parkinson’s, and depression, among many others. Despite its extraordinary societal impact, the mechanisms of fatigue remain unknown. In turn, this translates to the absence of credible treatment options.

Although exercise psychology would seem the most appropriate scientific field to address the issue of fatigue, this has not been the case. Fatigue is currently the topic of an exceedingly heated debate among two camps in exercise physiology, representing the two sides of the mind–body dualistic divide. On one side are researchers who believe that the phenomenon of fatigue can be adequately explained by limitations in the peripheral bioenergetic system, with no need to invoke the brain or psychological constructs. On the other side of the debate are researchers who assert that fatigue is primarily a subjective state regulated by the brain. Noakes (2012), arguably the most prominent proponent of the latter point of view, has stated that “fatigue is principally an emotion ... part of a complex regulation... the goal of which is to protect the body from harm” (p. 2). If fatigue is indeed a primordial emotion, then scientists who study affective responses to exercise should be in an advantageous position to shed light on its mechanisms.

Indeed, one might argue that input from researchers working on the exercise–affect link in the ongoing debate on the nature of fatigue is urgently needed. In the absence of input from scientists with a substantial background in psychology or psychophysiology, research on fatigue is at risk of veering off course. As one example, it has been suggested that perceived exertion is a “marker of fatigue” (Swart et al., 2009, p. 782). Perceptions of exertion scale linearly with indices of exercise intensity, such as heart rate or oxygen uptake. However, since the first systematic investigation of fatigue by the 19th century Italian physiologist Angelo Mosso (1891/1904), it had been observed that the sense of fatigue emerges only when the exercise stimulus “has attained a certain intensity” (p. 154). Below this threshold, afferent sensory impulses carrying information about the physiological condition of the body are subject to neural gating.

Therefore, fatigue cannot be reflected in a perception that scales linearly with physiological indices of exercise intensity. Instead, it should be reflected in a subjective variable that exhibits a threshold-like pattern in response to increasing exercise intensity and, presumably, one that exhibits a threshold coincident with a level of intensity associated with a critical perturbation of homeostasis in one or more physiological systems. Ratings of pleasure–displeasure (i.e., affective valence) are supremely positioned for this role, since pleasure–displeasure is the main vehicle by which critical departures from homeostatic balance enter consciousness.

This point is indirectly acknowledged by authors who point out that exercise is terminated when the perception of exertion “becomes more intense than is tolerable” (Jones & Killian, 2000, p. 635) or “reaches levels that are intolerably high or uncomfortable” (Tucker, 2009, p. 394). These statements suggest that the crucial factor in exercise termination (and, presumably, pacing) is not the perception of exertion but rather an “intolerably” or “uncomfortably” low level of pleasure. Indeed, several independent laboratories have now established that ratings of affective valence show a quadratic decline at exercise intensities that exceed the ventilatory or lactate threshold, a level of exercise intensity associated with extensive changes in the internal environment of the body (see Ekkekakis et al., 2011, for a review). This quadratic decline in pleasure is arguably the most meaningful indicator of the sense of fatigue during physical effort. In that sense, the research literature that has emerged on the exercise–affect link is also perhaps the most informative body of knowledge on the issue of fatigue available to date.

It is, therefore, yet another disheartening symptom of the fragmentation and compartmentalization of the contemporary scientific literature that there is presently no cross-pollination between the literature on affective responses to exercise and the literature in which fatigue is conceptualized as an “emotional” construct (Noakes, 2012). Arguably, such cross-pollination would be mutually beneficial and would help the common cause of advancing the scientific understanding of fatigue. As an inherently interdisciplinary topic, fatigue cannot be fully understood unless research builds on a sound foundation based not only in physiology but also in psychology. For example, as the research moves forward, it would be important to clarify not only that fatigue and perceived exertion are distinct constructs (as explained above) but also that perceived exertion is not the same as negative affect (Baron, Moullan, Deruelle, & Noakes, 2011), the statistical association between perceived exertion and affect at high intensities does not mean that perceived exertion “has an affective component” (Baden et al., 2005, p. 742), and that affect is not “the emotional perception of the cognitive sensations induced by the exercise bot” (Baden et al., 2005, p. 745).

Conclusion

A lot has happened since Morgan’s (1968) call to the nascent field of exercise psychology to examine the influence of exercise on the affective domain. Although a lot certainly remains to be done, researchers should heed Morgan’s (1997) advice, issued thirty years later, 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). As demonstrated in this review, research has since moved in several new and important directions that necessitate and warrant the investment of substantial research resources and intellectual capital. The areas of growth identified in the previous sections are arguably among the most fascinating, rapidly evolving, and potentially rewarding in any field of exercise science. Developments that scientists and practitioners can realistically expect to see in the decades ahead include (a) the

proliferation and expansion of clinical guidelines on the use of exercise for the treatment of mental health problems, (b) the incorporation of affect as one of the fundamental pillars underpinning exercise prescription guidelines, (c) the evolution of “post-rationalist” theoretical models of exercise behavior that recognize the crucial role of affect in behavioral decision-making, (d) the emergence of effective methods for regulating affective responses, particularly among segments of the population at high risk of exercise dropout, (e) the advent of reliable information on genetic influences on affective responses to exercise, (f) the development of clinically relevant exercise interventions for the treatment of a wide range of addictions, (g) the investigation of a possible link between affective responses to exercise and gains in cognitive performance associated with brain plasticity, and (h) the first substantive discoveries on the mechanisms underlying the sense of fatigue and the first foundation for the development of therapies.

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