



Analysis of the affect measurement conundrum in exercise psychology: IV. A conceptual case for the affect circumplex

Panteleimon Ekkekakis^{a,*}, Steven J. Petruzzello^b

^a Department of Health and Human Performance, 253 Barbara E. Forker Building, Iowa State University, Ames, IA 50011, USA

^b Department of Kinesiology, Louise Forker Building, 906 South Goodwin Avenue, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

Received 15 October 1999; received in revised form 20 July 2001; accepted 10 August 2001

Abstract

Background and purpose: In previous articles in this 4-part series, we presented an analysis of some of the main problems surrounding the measurement of affect in exercise psychology. The purpose of the present paper is to integrate this experience into a proposed solution by presenting arguments in support of the circumplex model of affect.

Methods: The circumplex model is considered a suitable solution because (a) it targets the broadest concept in the affective hierarchy, namely basic affect, (b) as a dimensional model, it offers unparalleled breadth of scope and parsimony, (c) it is domain-general, thus not likely to produce assessments that are biased against or in favor of a certain treatment, and (d) it is based on specific conceptual postulates, thus allowing a deductive approach to measurement. The basic assumptions of the circumplex model are discussed, the available circumplex-based self-report measures are reviewed, and a series of applied studies in the context of acute exercise are summarized.

Results and conclusions: Two important caveats are emphasized: (a) the measurement of the circumplex dimensions presents certain unique challenges which advances in statistical modeling should soon address and (b) the circumplex should not be seen as a panacea for all types of research contexts as its strength lies mainly in its parsimony, not its specificity. Provided that these points are taken into consideration, the circumplex model can offer a useful framework for conceptualizing and assessing the effects of acute exercise on the affective domain. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Affect; Exercise; Dimensional models of affect; Circumplex

* Corresponding author. Tel.: +1-515-294-8766; fax +1-515-294-8740.

E-mail addresses: ekkekaki@iastate.edu (P. Ekkekakis), petruzze@uiuc.edu (S.J. Petruzzello).

The size of the literature examining the effects of exercise on the affective domain has grown tremendously during the last three decades. However, in spite of the proliferation of information, critical reviews emphasize that what remains as the Achilles' heel of this line of research is the lack of attention to or relatively superficial treatment of theoretical issues. One of the aspects in which this weakness manifests itself most profoundly is the conceptualization and measurement of affective responses (Byrne & Byrne, 1993; Ekkekakis & Petruzzello, 1999; Gauvin & Brawley, 1993; Gauvin & Spence, 1998; McAuley & Rudolph, 1995; Mutrie & Biddle, 1995; Steptoe, 1992; Tuson & Sinyor, 1993). The general purpose of our 4-paper series has been to dissect the relevant literature in a systematic manner, to identify the most critical issues, and to integrate this experience into a proposed solution.

In the introductory paper (Ekkekakis & Petruzzello, 2000), we outlined a conceptual framework that was to serve as the basis for our subsequent discussions. In that paper, after examining the most prevalent trends with regard to the measurement of affect in exercise psychology, we posed and discussed four questions that we considered of fundamental importance. Here, we will only offer a synopsis, but interested readers are encouraged to refer to the original source for a more extensive treatment.

First, we suggested that there are important conceptual distinctions between the various constructs that fall under the affective umbrella and that it is crucial that these distinctions be taken into account when designing a study in the context of exercise. After presenting some widely, albeit not unanimously, agreed upon definitions for the constructs of emotion, mood, and basic affect, we argued that the affective domain can be conceptualized as having a hierarchical structure. This extends from *basic affect* as the core of the subjective experience that accompanies all valenced (positive or negative) responses to distinct *emotions* as the stimulus-linked affective states that are elicited following specific patterns of cognitive appraisals. Given the sketchy present understanding of the nature, dynamics, and cognitive antecedents (if any) of affective responses to exercise in various populations and under various conditions, we further argued that it would be reasonable for research to follow a systematic progression from the general to the specific and from the (relatively) simple to the complex. Therefore, we proposed that, at the present stage of knowledge development, measurement in descriptive studies should focus primarily on basic affect.

Second, we considered whether the measurement of affective responses should be approached from a categorical or from a dimensional perspective. In agreement with other authors, we argued that the two approaches are not mutually exclusive but rather compatible and complementary. Both have relative advantages and limitations, depending on the nature of the research question being considered. The primary strength of categorical models is their specificity and their ability to distinguish between affective states with similar and yet distinct antecedents and experiential features. Because of these strengths, categorical models are generally deemed preferable in the study of distinct emotions. On the other hand, the main advantage attributed to dimensional models is their breadth of scope and parsimony. In other words, theoretically, dimensional models can offer adequate representations of the entire affective space by relying on only a small number of basic dimensions (as few as two). Of course, this breadth of scope comes at the expense of some specificity. This may make dimensional models inadequate templates for the study of distinct emotions, but they are considered well suited for the study of basic affect from a global perspective. Assuming a focus on basic affect (see previous paragraph), the breadth and parsimony of

dimensional models may make it feasible to detect salient affective changes in response to a variety of exercise stimuli without advance knowledge of the exact nature or direction of these changes. This can be of substantial value for descriptive research and it is something that, realistically, cannot be accomplished through the use of categorical models.

Third, we examined the notion of “exercise-specific affect,” a concept that provided the impetus for the development of a series of new measures during the past decade (Gauvin & Rejeski, 1993; Lox, Jackson, Tuholski, Wasley, & Treasure, 2000; McAuley & Courneya, 1994). We suggested that the goal of simply increasing the responsiveness or sensitivity of a measure to a given treatment generally cannot be construed as adequate rationale for the development of domain-specific measures. Instead, evidence must be provided that, due to certain properties of the treatment, the nature or structure of the affective domain is somehow uniquely transformed. In the case of exercise, this evidence is clearly lacking and, in its absence, the arguments in favor of measures of “exercise-specific affect” seem unsubstantiated. Moreover, there are several additional problems that warrant attention. First, there can be no such thing as a global “exercise-specific affect” inasmuch as research compellingly indicates that not all individuals experience the same affective responses to all types of exercise conditions. Attempting to delineate the components of “exercise-specific affect” by examining the experiences of only one demographic group or the responses to only one set of experimental conditions is inadequate and potentially misleading. Second, assuming that a measure of “exercise-specific affect” would tap only those aspects of affect that are presumably uniquely influenced by exercise, it would be inappropriate to use that same measure to assess the effects of other, non-exercise, treatments, such as comparison or control conditions. In essence, such a measure would be engineered to ensure that the effects of exercise would be maximized whereas the effects of all other treatments would be minimized. In sum, a critical re-examination of the notion of “exercise-specific affect” and its implications seem in order.

Fourth, we discussed whether a measurement model to be used in the context of exercise should be based on an inductive or a deductive approach. In other words, whether it would be more appropriate and beneficial to ignore previous theoretical formulations regarding the structure of affect and start anew or to adopt and utilize an existing conceptual model. Our position is that the progress in affective psychology over the past century has produced a wealth of invaluable information on the structure of the affective domain and, most importantly, has already uncovered a number of potential pitfalls. Therefore, particularly in the absence of evidence that the nature and structure of affect in the context of exercise are somehow unique, an attempt to start over seems like a long, laborious quest to reinvent the proverbial wheel. Furthermore, as our analysis of previous measures indicated (Ekkekakis & Petruzzello, 2001a), inductive approaches, because they rely heavily on methodological decisions that may have a substantial element of arbitrariness or may not be fully informed by certain intricacies of psychometrics or relevant findings of previous research, are susceptible to errors. In general, when working without the benefit of a guiding theoretical framework, the exclusive reliance on methodological decisions may easily send the process off on a wild-goose chase. On the other hand, a deductive approach, having the benefit of some clearly specified theoretical postulates, generally provides a more secure foundation for measurement because methodological decisions can be made on the basis of theory and need not rely on subjective judgement or speculation.

In addition to these four fundamental issues, in previous work we have also discussed some

other important considerations. For instance, we have reviewed evidence that, contrary to a widely held belief, pleasure and displeasure are polar opposites, not independent or orthogonal dimensions (Ekkekakis & Petruzzello, 2001b). Furthermore, we have provided evidence that, given the ability of exercise to induce changes in perceived activation and the fact that such changes may be experienced as either positive or negative, it is important for a measurement model to distinguish between activation on the one hand and positivity–negativity of effect on the other (Ekkekakis, Hall, & Petruzzello, 1999).

In essence, the aforementioned considerations can be thought of as the steps of a decision-making process — with each answer, the pool of possible measurement options narrows. If one agrees that what is needed is a model that (a) focuses on basic affect, (b) has a dimensional structure, (c) is domain-general, and (d) has a well-developed theoretical foundation that can be used as the basis for deductive research, then it could be argued that one is left with only one reasonable option, namely the circumplex model of affect (Russell 1978, 1980). Despite its popularity in other areas of psychological investigation (see Larsen & Diener, 1992; Russell, 1997 for reviews) and despite some sporadic calls for its application in the context of exercise (Biddle, 2000; Biddle & Mutrie, 2001; Gauvin & Brawley, 1993; Mutrie & Biddle, 1995), the circumplex model “has been virtually ignored by researchers in exercise psychology” (Gauvin and Brawley, 1993, p. 153). The basic features of the model, as well as a summary of evidence in support of its validity and utility, are presented next.

The affect circumplex: basic features

The extant literature on affective phenomena includes several dimensional models (Daly, Lancee, & Polivy, 1983; Mehrabian & Russell 1974, 1980; Plutchik 1970, 1980; Russell, 1978; Russell & Mehrabian, 1977; Tellegen, 1985; Thayer, 1989; Watson & Tellegen, 1985; Zevon & Tellegen, 1982). Setting the numerous and often deeply perplexing differences in terminology aside, most dimensional models have at least two dimensions in common, namely affective valence (also termed *pleasure–displeasure* or *hedonic tone*) and perceived activation (also termed *arousal*). These two dimensions, theorized to be bipolar and orthogonal, form the basis of the circumplex model. Different affective states are considered combinations of varying degrees of these two constituent dimensions, such that affective states can be conceptualized as located around the perimeter of a circle defined by the two dimensions (see Fig. 1). Experientially similar affective states (e.g., *happy* and *glad*) are closer together on the circle, whereas affective states perceived as antithetical (e.g., *happy* and *sad*) are opposite on the circle (180° apart). Divisions of the circumplex into halves differentiates between pleasant and unpleasant states or between states characterized by high and low activation. A division of the circumplex space into quadrants produces four meaningful variants of affective experience:

1. high-activation pleasant affect, which corresponds to an excitement-like state
2. high-activation unpleasant affect, corresponding to tension and distress
3. low-activation unpleasant affect, characteristic of boredom and depression
4. low-activation pleasant affect, a combination characteristic of calmness and relaxation.

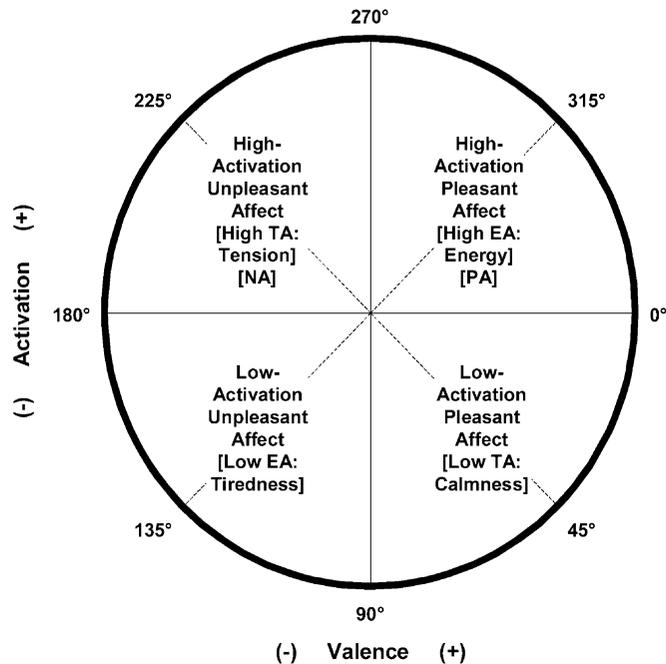


Fig. 1. The circumplex model of affect. The horizontal axis represents affective valence (negative to positive) and the vertical axis represents the degree of perceived activation (low to high). An alternative rotation of these axes by 45° results in one dimension extending from high activation pleasant to low activation unpleasant affect and another extending from high activation unpleasant to low activation pleasant affect. TA stands for Tense Arousal and EA stands for Energetic Arousal (Thayer, 1989). PA stands for Positive Activation and NA stands for Negative Activation (Watson et al., 1988, 1999).

The issue of rotation

The affect literature contains two main variants of the circumplex structure. The difference between them is the rotation of the dimensions that define the affective space (see Larsen & Diener, 1992, for a review). The variant just described, in which the affective space is defined by a dimension of affective valence and a dimension of perceived activation (Russell 1978, 1980), is often referred to as the “unrotated” model. In contrast, in the second variant, the affective space is defined by two dimensions that represent a 45° rotation of the dimensions of affective valence and activation. In this model, one dimension extends from high-activation pleasant to low-activation unpleasant affect and the other extends from high-activation unpleasant to low-activation pleasant affect (see Fig. 1; Tellegen, 1985; Watson & Tellegen 1985, 1999; Watson, Wiese, Vaidya, & Tellegen, 1999; Zevon & Tellegen, 1982). The former dimension has been labeled *Positive Activation* (previously referred to as *Positive Affect*) and the latter has been labeled *Negative Activation* (previously referred to as *Negative Affect*). To avoid confusion, it is important to note here that the labels that were given to these “rotated” dimensions refer only to their high-activation poles (hence the terms *Positive Activation* and *Negative Activation*), despite the fact that the dimensions themselves are actually bipolar (also see Ekkekakis & Petruzzello, 2001b, for more on this issue). Thus, *Positive Activation* is characterized by pleasure on the high-activation

end, but also by displeasure on the low-activation end. Conversely, Negative Activation is characterized by displeasure on the high-activation end, but also by pleasure on the low-activation end.

Two points are important to consider regarding the rotation issue. First, one should keep in mind that, in a true circumplex, any rotation of the basic dimensions is defensible from a statistical standpoint. In other words, in a true circumplex, any rotation should account for equal amounts of variance. Therefore, the decision regarding which rotational variant to use as a frame of reference is a function of the researcher's specific interests and purpose (Larsen & Diener, 1992; Meyer & Gaschke, 1988).

Second, both the proponents of the unrotated and those of the rotated scheme agree that the two structures are conceptually compatible. Watson and Tellegen (1985) have noted the "basic compatibility of the structures defined by these two alternative rotations" (p. 222) and Russell and his coworkers have made the same point several times (e.g., Feldman Barrett & Russell, 1999; Russell & Carroll, 1999a,b; Russell & Feldman-Barrett, 1999; Yik, Russell, & Feldman-Barrett, 1999).

The issue of additional dimensions

What is perhaps one of the greatest strengths of the circumplex model is its parsimony or its ability to reflect the basic differences and similarities among affective states in terms of only two dimensions (Larsen & Diener, 1992). Nevertheless, these two dimensions leave a percentage of the variance between affective states unaccounted for and, consequently, researchers have attempted to account for it by incorporating additional dimensions in the circumplex, most notably a *potency* (also referred to as *dominance–submissiveness*) dimension (McKinnon & Keating, 1989; Mehrabian, 1995; Mehrabian & Russell, 1974; Morgan & Heise, 1988; Russell & Mehrabian 1974, 1977). Russell and Mehrabian (1977) initially supported this third dimension, because it "makes it possible to distinguish angry from anxious, alert from surprised, relaxed from protected, and disdainful from impotent" (p. 292). Later, however, Russell (1980, 1989) argued that additional dimensions may, in fact, refer to antecedents or consequences of the affective experience, rather than the affect per se.

At the core of this dilemma lies the issue of parsimony versus diminishing returns. Additional dimensions may account for more variance and may allow the model to discriminate between experientially distinct affective states, particularly unpleasant ones (Morgan & Heise, 1988). However, in terms of additional accounted variance, the contribution of the third dimension is small compared to that of the first two dimensions, whereas, on the other hand, the additional complexity associated with the transition from a two-dimensional to a three-dimensional structure is considerable. As we have noted previously (Ekkekakis & Petruzzello, 2000), the purpose of dimensional models, including the circumplex, is to account for as much of the variability between affective states as possible by as few dimensions as possible. This is because the role of dimensional models is to offer primarily breadth of scope and parsimony, not specificity. When specificity and the ability for fine discriminations are required, researchers should turn to categorical models.

A summary of evidence

Wundt (1912) was perhaps the first author to comment on the structure of the affective domain, noting that affective experiences are “composites” of “exciting or quieting feeling” and “pleasure or displeasure” (see pp. 60–62). Following these pioneering observations, Schlosberg found evidence of a dimensional structure in his studies of facial emotional expression (Schlosberg 1952, 1954). Schlosberg’s findings have since been replicated by several independent researchers (Abelson & Sermat, 1962; Bush, 1973; Osgood, 1966; Triandis & Lambert, 1958). Russell (1978, 1980) also found a circumplex structure in his analyses of self-reported affect data using principal components and multidimensional scaling analyses. A circumplex has since been derived repeatedly from structural analyses of self-reported affect data (Faith & Thayer, 2001; Feldman, 1995a,b; Feldman Barrett, 1996; Haslam, 1995; Mano, 1991). Similarly, analyses of emotional ratings of the environment have also revealed a circumplex structure (Russell, Ward, & Pratt, 1981). It is also noteworthy that two dimensions representing either the unrotated or the 45° rotated orthogonal and bipolar dimensions of the circumplex have been found across developmental stages in the judgments of facial emotional expressions (Russell & Bullock 1985, 1986) and in diverse cultures, including Chinese, Croatian, Gujarati (Russell, 1983), Greek, Polish, Estonian (Russell, Lewicka, & Niit, 1989), Israeli (Almagor & Ben-Porath, 1989), British (Mackay, Cox, Burrows, & Lazzerini, 1978; Matthews, Jones, & Chamberlain, 1990), Swedish (Sjoberg, Svensson, & Persson, 1979), German (Abele-Brehm & Brehm, 1986), Japanese (Watson, Clark, & Tellegen, 1984), Russian (Balatsky & Diener, 1993), Spanish (Joiner, Sandin, Chorot, Lostao, & Marquina, 1997), and Filipino (Church, Katigbak, Reyes, & Jensen 1998, 1999).

One of the most intriguing pieces of evidence for the non-arbitrariness of the circumplex model is that the dimensions of activation and affective valence and their rotational variants also manifest themselves at multiple aspects of the psychophysiology of affective responses. Tellegen (1985) first pointed out a possible analogy between the dimensions of Positive Activation and Negative Activation and Gray’s (1970, 1991) Behavioral Activation System (BAS) and Behavioral Inhibition System (BIS), respectively. Heller (1990, 1993) has proposed and reviewed evidence that the asymmetric activation of the frontal lobes of the cerebral hemispheres may be a biological marker of affective valence whereas the activation of the right parietal lobe may be a marker of activation. Furthermore, studies on the human acoustic startle response have provided initial evidence that the amplitude of the electromyographical response of the orbicularis oculi muscle may be related to affective valence whereas the latency of the response may be related to activation (Lang, 1995; Lang, Bradley, & Cuthbert, 1997). Finally, research from independent investigators in the area of psychoneuroendocrinology, in both animals (Henry, 1986; Henry & Meehan, 1981; Henry & Stephens, 1977; Selye, 1983) and humans (Frankenhaeuser 1986, 1991) has led to strikingly similar conclusions, namely that the response of the hypothalamic pituitary adrenocortical axis (whose end product is the hormone cortisol) is associated primarily with affective valence whereas the activation of the sympathetic adrenomedullary axis (whose end products are the hormones epinephrine and norepinephrine) is associated primarily with activation.

In summary, there is considerable evidence that the circumplex model is not an arbitrary conceptualization. The emergence of a structure mainly characterized by the two bipolar and orthogonal dimensions of affective valence and activation and the circular arrangement of affective states appear to be findings of remarkable consistency across affective response channels, cultures,

developmental stages, and analytic methodologies. Such findings led Russell (1997) to contend that “a circumplex structure is ubiquitous in psychology. It is an empirical finding that a circumplex emerges in all these domains. Nothing logical or mathematical forces that same structure to emerge” (p. 213).

The circumplex and the measurement of affect in the context of exercise

Having completed an analysis of the primary problems surrounding the measurement of affect in the context of exercise and a review of the main conceptual features of the circumplex model, it is now possible to summarize the potential advantages of introducing the circumplex as a conceptual and measurement template for the study of affect in exercise. What should be considered perhaps the most essential strength of the circumplex is its parsimony or its ability to provide an encompassing and adequate representation of the entire affective space in terms of only two elemental dimensions. Previous research in general psychology has shown that, once acquiescence (i.e., the influence of response sets) is taken into account, the two dimensions of the circumplex account for the majority of the reliable variation among affective states. Specifically, affective valence and activation have been shown to account for most of the variance in the intercorrelations among ratings on 28 affect terms (Russell, 1980), the scales of the Profile of Mood States (Russell & Steiger, 1982), and even 42 popular measures of various affective states (Russell & Mehrabian, 1977).

Besides their theoretical significance, these findings also have some important practical implications for applied research. In studies designed to investigate the nature and the magnitude of affective changes that occur in response to various exercise stimuli (i.e., in *descriptive* studies), it is practically impossible to assess all the *distinct* affective states that may be influenced. For example, the six distinct “mood states” assessed by the Profile of Mood States (McNair, Lorr, & Droppleman, 1971) or the four distinct “feeling states” assessed by the Exercise-induced Feeling Inventory (Gauvin & Rejeski, 1993) do not encompass the entire domains of “mood” and “feeling” respectively. Instead, they only reflect a small number of distinct states out of a presumably much larger number of distinct states that collectively comprise these broad domains. Moreover, there is no evidence that the states that are assessed by these measures are in some way more basic or important than other states that were not included. Therefore, if these measures are used in an exercise study, it would be inappropriate to assume that exercise effects on the broad domains of “mood” or “feeling” are limited to any changes reflected in these measures. There is always the possibility that a certain exercise stimulus will bring about changes in some other distinct “mood” or “feeling” state, not assessed by these measures. In contrast, a measure based on the circumplex model can, on the basis of changes along its two basic dimensions, provide a snapshot of the entire affective domain — of course, in exchange for some loss of specificity. Consider the following excerpt by Russell (1989), in which he discusses the potential advantages of the circumplex for studying the effects of drugs on mood, and simply substitute the word “exercise” for the word “drug”:

To understand the mood-altering effects of a drug (or anything else) requires more than experimental evidence that differences in scores on a verbal scale of, say, anxiety are attribu-

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

The analogies to the context of exercise should be obvious. As in Russell's example, it is common practice for exercise psychology researchers to use various combinations of measures of distinct affective states and to report significant changes in all or most of them (see Ekkekakis & Petruzzello, 2000, for additional comments on this issue). Thus, after decades of research, we have been able to demonstrate that most types of exercise bring about generally positive changes in a large array of measures of various affective states, and yet we remain uncertain as to what the main affect-altering effects of these exercise stimuli are and what, if any, differences exist between the effects of various exercise stimuli or experimental conditions. As exercise psychology researchers venture into theory-testing and deciphering dose-response and other important mediating effects, adopting an encompassing and unifying template like the circumplex model seems highly desirable, if not necessary.

A second important strength of the circumplex is that it is supported by a very extensive body of research, larger than any other dimensional model (Larsen & Diener, 1992; Russell, 1997). As a result, considerable light has been shed over the years on a number of important conceptual and psychometric issues that pertain to it. If the value of this resource is appreciated by exercise psychology researchers, it could help unify the many presently disparate measurement approaches and bring some much needed clarity and consistency in the study of the exercise–affect relationship. As one example, much confusion exists regarding the relationship between pleasure and displeasure, the popular notion being that these are unipolar and independent dimensions (see Ekkekakis & Petruzzello, 2001b, for an extensive discussion of this issue). Research inspired by the circumplex model, however, has demonstrated that pleasure and displeasure are, in fact, opposite ends of a single bipolar dimension and that findings pointing to two unipolar and independent dimensions may be due to a number of conceptual ambiguities and statistical artifacts. Russell (1997) has claimed that “the clearest success of the circumplex is its prediction of bipolarity rather than unipolarity” (p. 212). Conceptual clarity, the extensive research base, and the almost universal agreement on a basic set of structural postulates may prove to be the factors that will help unite the presently disparate approaches into a cohesive and systematic research effort.

A third strength of the circumplex is that, by providing a broad and balanced investigative scope, it can be highly conducive to idiographic investigations of affective responses (see Gurtman & Balakrishnan, 1998, for a relevant application in personality research). When assessment

is based on categorical models, individuals are forced to rate how they feel on a small predetermined set of scales and individual variation is expressed only as quantitative differences in such ratings. In contrast, the circumplex is essentially an encompassing map of the entire affective space and, as such, it allows a virtually unlimited number of individual profiles to emerge. Circumplex profiles can be created by jointly plotting valence and activation ratings in a two-dimensional space (see Fig. 2 for examples). This allows individuals the freedom to describe the nature of their affective experiences in an unrestricted manner. The pre-treatment starting point, the trajectory of affective change over time, and the post-treatment end point can be anywhere within this two-dimensional space. Indeed, research has shown that individuals differ in the degree to which they weigh changes in valence and activation (Feldman, 1995b; Feldman Barrett, 1998). The substantial amount of individual variation in affective responses to exercise is an issue that has been raised repeatedly by reviewers (e.g., Ekkekakis & Petruzzello, 1999; Gauvin & Brawley, 1993) and the circumplex may provide an appropriate template for its systematic study (Van Landuyt, Ekkekakis, Hall, & Petruzzello, 2000).

A fourth advantage of the circumplex, one that is of particular relevance to the study of the effects of exercise, is that it can disentangle changes in activation from changes in affective valence. As previous research has illustrated (Ekkekakis et al., 1999), failing to distinguish changes along the activation dimension from changes along the valence dimension may lead to misleading findings, a problem that has been shown to be especially pronounced in studies that utilized unidimensional measures of state anxiety, such as the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). Such measures do not allow for positively laden increases in activation or for negatively laden decreases in activation. Instead, all increases in activation are assumed to be negative (i.e., associated with increases in state anxiety) and all decreases in activation are assumed to be positive (i.e., associated with decreases in state anxiety or increases in calmness). However, in the context of exercise, high activation may be experienced as positive (e.g., vigor and exhilaration) or negative (e.g., tense effort). Likewise, low activation may be experienced as positive (e.g., calmness and relaxation) or negative (e.g., exhaustion or boredom). Based on the assumption that activation and valence are *independent* constituents of affect, the circumplex model allows for these variants of affective experience, thus reducing the likelihood of misleading findings (Ekkekakis et al., 1999).

Finally, measures based on the circumplex model, because they tap elemental dimensions of affect rather than affective states which might subsume separate subcomponents, are more likely to maintain their structural integrity and internal consistency in the context of acute exercise. As Izard (1993) noted, “on average it is easier to obtain reliable measures at the level of broad dimensions, such as valence... than at the level of discrete emotions. In the language of psychometrics, indices of discrete emotions are primary and indices of broad dimensions are secondary factors; hence the greater stability of the latter” (p. 632).

In summary, the circumplex appears to offer some considerable potential advantages for research in the context of exercise. Of course, it should be kept in mind that most of the evidence so far comes from contexts other than exercise. Therefore, whether these strengths carry over to the context of exercise and whether the circumplex can lead to a substantial improvement in the quality of the research on the relationship between exercise and affect are still open to empirical verification.

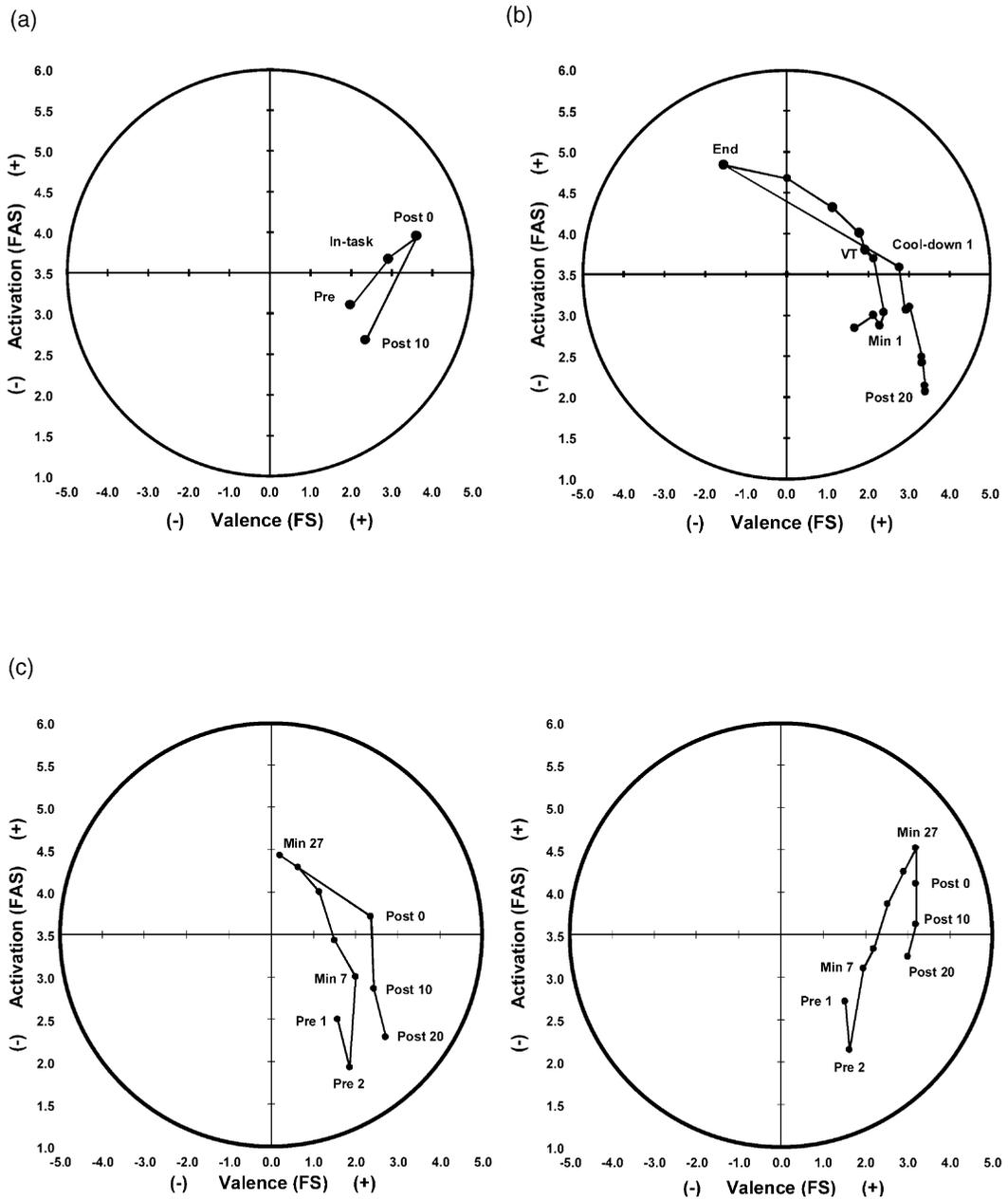


Fig. 2. Examples of affective responses to exercise represented in circumplex space. Valence was assessed with the FS (Hardy & Rejeski, 1989) and activation with the FAS (Svebak & Murgatroyd, 1985). Panel (a): Responses to a 15-min walk and 10-min recovery (data from Ekkekakis et al., 2000); Panel (b): Responses to a graded treadmill test and 20-min recovery (VT: ventilatory threshold; data from Hall et al., in press); Panel (c) Responses to a 27-min bout of cycle ergometry at 60% of estimated maximal aerobic capacity and 20-min recovery. The sample is divided into participants who reported progressive improvement (right panel) and progressive deterioration (left panel) in affective valence during exercise (data from Van Landuyt et al., 2000).

Important caveats

In spite of the aforementioned potential strengths of the circumplex, researchers should resist the temptation to consider this model as a panacea, appropriate for all research questions and contexts. Instead, the model should be seen for not only what it can offer, but also what it cannot. As we have noted previously, as a dimensional model, the circumplex can never offer the level of specificity of categorical models. In his critical evaluation of dimensional models, Lazarus (1991) noted that, by classifying affective states that may be similar in terms of valence and activation in the same circumplex quadrant or octant, one may overlook “important meanings about person-environment relationships, which the hundreds of emotion words were created to express” (p. 63). As one example, anger and anxiety, although both characterized by negative valence and high activation, differ substantially in their cognitive antecedents, experiential features, and response expressions. Even with the addition of more dimensions (Russell & Mehrabian 1974, 1977), there are important psychological distinctions that a dimensional approach is bound to miss. Most emotion theorists agree that dimensional models, including the circumplex, are generally inadequate templates for the study of distinct *emotions* (Clore, Ortony, & Foss, 1987; Lazarus, 1991).

Although it has been described as such by several authors in the past, the circumplex is not a model of *emotion* — it is a model that reflects a different level of the affective hierarchy, namely the level of *basic affect* (also see Ekkekakis & Petruzzello, 2000, for more on this issue). Importantly, even the main proponents of the circumplex note that “this dimensional structure [i.e., the circumplex] represents and is limited to the core affect involved” (Russell & Feldman-Barrett, 1999, p. 807) and that the “structure of core affect is much simpler than the structure of prototypical emotional episodes” (p. 809). In addition to “core affect” (what has been referred to in this series as “basic affect”), prototypical emotions, such as anger and anxiety, include other important components, beyond valence and activation. Consequently, “assessment devices based on the dimensional-circumplex approach capture core affect but miss the other components” (p. 807).

It is essential to consider this caveat against the background of statements that emphasize that the categorical and the dimensional approaches are compatible and not mutually exclusive. According to Frijda (1986), for example, “the two viewpoints are not alternative, competing interpretations. They are complementary... The dimensional and the categorical view are both valid because they apply to different levels of the emotion process, corresponding to different sets of phenomena” (pp. 258–259). Similarly, Watson and Clark (1997) noted that categorical and dimensional models “are not incompatible or mutually exclusive; rather, they essentially reflect different levels of a single, integrated hierarchical structure” (p. 269).

From a practical standpoint, these positions suggest that both approaches have their place and the question of which is more suitable to a given study depends on the specific aim and context of each study. The categorical approach is more suitable when an investigation focuses on a specific emotion. As an example, if a study involves an intervention designed to induce the pattern of cognitive appraisals hypothesized to underlie the specific emotion of social physique anxiety, it makes sense to assess anxiety. On the other hand, a dimensional approach may be more suitable in descriptive studies (which still make up the vast majority of the research on the affective responses to exercise). In these studies, what is primarily needed from a measure is the ability

to provide an encompassing map of the entire affective space (i.e., at the level of basic affect), so that any salient responses, regardless of their exact nature, would not escape detection. A circumplex-based measure should be able to provide a description of the main features of these responses, even in broad, rudimentary terms. For example, the nature of affective responses that will be elicited in a study that involves the manipulation of exercise intensity cannot be predicted at the present stage of knowledge development (particularly for analyses at the level of individuals). It would, therefore, be unrealistic to attempt to capture the resultant responses by using a large array of measures designed to assess distinct states. Instead, it is more efficient to tap the main underlying dimensions of basic affect (i.e., valence and activation) and obtain a perhaps imperfect but nonetheless encompassing and sensitive representation of these responses. Once some understanding of the basic nature of these responses is established, further research, most likely from a categorical perspective, can begin to unravel their antecedents and focus in on their precise experiential features.

Another important caveat will be underscored by the discussion in the following section. It refers to the fact that, as ostensibly simple as the circumplex structure may seem, it is not easy to evaluate formally through conventional statistical modeling. To be fully consistent with the circumplex, a data set must show a pattern of relationships that is highly specific and unique. As a consequence of this complexity, circumplex-specific statistical models, computational methods, and user-friendly software are still in the process of being developed (e.g., Browne, 1992; Tracey, 2000). This situation has led to the development of many self-report measures whose structure, although *hypothesized* to fit a circumplex pattern, has yet to be *formally evaluated with appropriate methods*. Therefore, researchers should consistently scrutinize the published information on and, whenever possible, independently evaluate the structural validity of the measure they choose to use. Some of the more popular circumplex-based self-report measures are examined next and this presentation is accompanied by additional comments on issues related to validity.

The affect circumplex as a measurement model

In their review of the circumplex literature, Larsen and Diener (1992) noted that, apart from being a conceptual model, “the circumplex model is also a measurement model” (p. 33). However, to date, formally standardized measures of the circumplex are scarce. One possible explanation for this phenomenon is that, as noted in the previous section, the circumplex model assumes a unique and very specific pattern of item and scale intercorrelations. The fit of such a model to empirical data cannot be properly evaluated through traditional methods of structural analysis. Nevertheless, several, both single-item and multiple-item, self-report instruments have been developed.

Single-item measures

Among the single-item measures, the Affect Grid (AG; Russell, Weiss, & Mendelsohn, 1989) is perhaps the most widely known. The AG is a 9 by 9 grid, with the horizontal dimension representing valence (ranging from unpleasantness to pleasantness) and the vertical dimension representing the degree of perceived activation (ranging from sleepiness to high arousal). Respon-

dents place a single “X” mark in one of the 81 cells of the grid and this response is scored along both the valence and the arousal dimensions. Despite the fact that, for a single-item measure, the psychometric attributes of the AG seem satisfactory, this measure has been used in only a few general psychology (Killgore, 1998) and sport psychology (Hardy, Hall, & Alexander, 2001; Raedeke & Stein, 1994) studies to date.

Lang (1980) and Hodes, Cook, and Lang (1985) described a computer-based interactive graphical instrument for the assessment of pleasure, arousal, and dominance, which was named the Self-Assessment Manikin (SAM). Each scale of the SAM consists of a series of cartoons that represent a manikin with visible expressions ranging from happiness (smiling face) to sadness (sad face), from sleepiness (eyes closed) to high arousal (shaking and heart pounding), and from submissiveness (small size) to dominance (large size). A paper-and-pencil version of the SAM is also available (Bradley & Lang, 1994). The SAM is being used extensively in psychophysiological research, particularly to assess responses to pleasant and unpleasant images (Bradley, Greenwald, & Hamm, 1993). Furthermore, because it does not rely on verbal descriptors and, instead, uses universally recognized cues and representations, it has also been suggested that it is appropriate for cross-cultural research (Morris, 1995).

Jacob et al. (1989, 1999) developed the Circular Mood Scale (CMS). The CMS is a circle surrounded by verbal descriptors as anchor points (e.g., *active* and *attentive* versus *uninvolved* and *inactive*). Respondents mark a point on the periphery of the circle that corresponds to their affective state, as well as a point along the line connecting the first mark to the center of the circle, indicating the intensity of that affect. The CMS has been used in a small number of studies, mainly in the area of behavioral medicine.

Apart from these measures, which were specifically developed on the basis of the circumplex model, researchers may also use separate bipolar scales of affective valence and perceived activation. For example, the Feeling Scale (FS; Hardy & Rejeski, 1989) can be used as a bipolar measure of affective valence and the Felt Arousal Scale (FAS) of the Telic State Measure (Svebak & Murgatroyd, 1985) can be used as a measure of perceived activation.

In deciding whether to use single-item measures, researchers should take into account and contemplate some of their inherent strengths and weaknesses. The most attractive feature of single-item measures is that they can be used repeatedly during an experimental session with only a small risk of respondent overload and inducing reactivity to testing. The wealth of information that has been accumulated with the use of the single-item Rating of Perceived Exertion (Borg, 1998), for example, illustrates the potential value of such measures. On the other hand, because the score is based on a single response, these measures are more susceptible to random measurement error compared to multi-item questionnaires and, as a result, their reliability is usually modest.

Although these considerations apply to all single-item measures, circumplex-based measures may present some additional challenges. First, respondents are not simply asked to identify and specify their affective state, but also to analyze it and isolate its constituent elements, namely valence and activation. Activation, in particular, is an extremely difficult concept to define and explain in layperson terms as it requires a considerable degree of abstraction. Care should be taken to ensure that respondents understand that valence and activation are unrelated, such that one may feel pleasant or unpleasant both when experiencing high and when experiencing low activation. Most instructions to respondents that accompany the circumplex-based measures place

strong emphasis on this point and include specific examples to illustrate it. Respondents should be strongly encouraged and given plenty of time to read the instructions. Furthermore, researchers should be aware that, although most respondents find such instructions intuitive, some may have difficulties, so they should be prepared to provide standard, clear, and simple additional instructions or examples.

Second, certain respondents may find the unfamiliar format of some of these scales (i.e., grids, circles, cartoons) confusing. For example, Gauvin and Brawley (1993) criticized the AG because “its complexity... may render it impractical” (p. 155). Along similar lines, Jacob et al. (1989) warned that the CMS should only be used following some practice. Because of these possible difficulties, the FS and the FAS, which utilize a more familiar rating-scale format, may prove more convenient for a larger portion of the population.

Multi-item measures

Other measures of the circumplex use the more familiar multi-item format. Mehrabian and Russell (1974) published the Semantic Differential Measures of Emotional State, which consist of 18 bipolar (“semantic-differential”) items organized in three scales: pleasure–displeasure (P), arousal–sleepiness (A), and dominance–submissiveness (D). Mehrabian and Russell (1974) and Russell et al. (1981) have reported results from principal components analyses followed by oblique rotations showing a clear three-factor structure and small and insignificant inter-scale correlations. Cronbach alpha coefficients were 0.81 to 0.91 for P, 0.50 to 0.81 for A, and 0.68 to 0.72 for D. This measure has since undergone two revisions aimed at expanding the PAD scales and refining their content (Mehrabian 1978, 1995).

The structure of the revised version of the Activation Deactivation Adjective Check List (AD ACL; Thayer, 1989) is also theorized to be consistent with the circumplex. Although Thayer (1967) initially posited four unipolar factors (labeled General Activation, High Activation, General Deactivation, and Deactivation–Sleep), theorized to “roughly approximate four points on a hypothetical activation continuum” (p. 668), he later revised his view. He found that “General Activation (energetic, vigorous) generally varied in reciprocal relation to Deactivation–Sleep (sleepy, tired). The same was true of High Activation (tense, anxious) and General Deactivation (quiet, placid)” (Thayer, 1985, p. 117). In fact, second-order principal axes factor analyses of the AD ACL revealed two bipolar factors (Thayer 1978, 1986). Thayer (1978) concluded that these data offered “strong support for the view that self-ratings of activation do not form four independent factors. There are definite indications of two general activation dimensions, each made up of important polar opposites” (p. 752). One dimension, extending from Energy to Tiredness, was named *Energetic Arousal*, and the other, extending from Tension to Calmness, was named *Tense Arousal*. Thayer (1989) noted that “the dimensions that Watson and Tellegen labeled Positive and Negative Affect substantially overlap energetic and tense arousal” (p. 164). Empirical evidence for this assertion has been reported by Yik et al. (1999).

Mackay et al. (1978) factor-analyzed items from an early version of Thayer’s (1967) AD ACL, modified for British respondents. This analysis, followed by a varimax rotation, revealed two bipolar factors. These factors were labeled *stress* (reflective of “hedonic tone”) and *arousal* (reflective of “wakefulness/drowsiness”). The *stress* factor includes items such as *tense*, *worried*, and *apprehensive* on one end and *peaceful*, *relaxed*, and *contented* on the other. The *arousal*

factor includes items like *lively*, *energetic*, and *active* on one end and *sleepy*, *drowsy*, and *sluggish* on the other. The questionnaire that was developed from these analyses, named Stress/Arousal Adjective Checklist (SACL; also see Cox & Mackay, 1985), has since been modified for low-vocabulary respondents (Cruickshank, 1984) and cross-validated with Australian (King, Burrows, & Stanley, 1983), New Zealander (McCormick, Walkey, & Taylor, 1985), and Canadian (Fischer & Donatelli, 1987; Fischer, Hansen, & Zemore, 1988) samples.

Based on the analyses of mood terms by Zevon and Tellegen (1982) and Watson and Tellegen (1985), which revealed a structure consistent with the two-dimensional circumplex, Watson, Clark, and Tellegen (1988) developed the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS provides measures of the orthogonal dimensions of Positive Affect (PA) and Negative Affect (NA). The primary item selection criterion employed in the development of the PANAS was that items should load $|.40|$ or higher on one factor and $|.25|$ or lower on the other, such that the correlation between factor scores would be kept as close to zero as possible. When the PANAS was administered with the “how do you feel right now, that is at this moment” time set, the correlation between PA and NA was only -0.15 . For the same data, alpha coefficients of internal consistency were 0.89 and 0.85 for PA and NA, respectively. Although these indices appear satisfactory, the PANAS has been criticized for two reasons. First, some authors have emphasized that the labels PA and NA are misleading because, although they imply unipolarity, they refer to bipolar dimensions (Feldman Barrett & Russell, 1998; Larsen & Diener, 1992; Thayer, 1989). Second, although the PA and NA dimensions within the conceptual model presented by Tellegen and his coworkers were bipolar (Tellegen, 1985; Watson & Tellegen, 1985; Zevon & Tellegen, 1982), the measures of PA and NA included in the PANAS only tap the high-activation poles of these dimensions, in essence reflecting only one half of the theoretical space that formed the basis of this instrument (Egloff, 1998; Larsen & Diener, 1992; Mossholder, Kemery, Harris, Armenakis, & McGrath, 1994; Nemanick & Munz, 1994).

Warr (1990) proposed a modification of the circumplex as a measurement model of affective well-being. Three dimensions were included in this conceptualization: *displeased–pleased* (equivalent to the affective valence dimension), *anxious–contented* (equivalent to the unpleasant high activation — pleasant low activation dimension), and *depressed–enthusiastic* (equivalent to the pleasant high activation — unpleasant low activation dimension). An *arousal* dimension was included in the model but it was given less weight than the other dimensions because “on its own [it] is not considered to reflect well-being” (p. 195). Based on pilot studies, Warr constructed two six-item scales representing the *anxious–contented* and the *depressed–enthusiastic* dimensions of his model. In principal components analyses, Warr (1990) and Sevastos, Smith, and Cordery (1992) were generally able to show the hypothesized two-factor structure, but with some items exhibiting cross-loadings (e.g., *contented*, *uneasy*). In confirmatory factor analyses of the two-factor solution for both an orthogonal and a correlated model, Sevastos et al. (1992) showed a poor fit, which was attributed to the aforementioned cross-loadings.

Based on a factor analysis of items from measures of mood dimensions (Mackay et al., 1978; Sjoberg et al., 1979; Thayer, 1967), Matthews et al. (1990) developed the University of Wales Institute of Science and Technology (UWIST) Mood Adjective Checklist. Three bipolar scales were revealed following an oblique rotation, namely *hedonic tone*, *tense arousal*, and *energetic arousal* (the latter two labeled after the corresponding bipolar dimensions of the AD ACL). A fourth *general arousal* bipolar factor, which was interpreted as indicative of “high and low arousal,

irrespective of pleasure–displeasure” (p. 24), was found before rotation and was also tentatively retained.

Following a multidimensional scaling analysis of 56 affective terms, Van Katwyk, Fox, Spector, and Kelloway (2000) selected 30 which formed the Job-related Affective Well-being Scale (JAWS). The criteria for selecting the items are not entirely clear. Van Katwyk et al. reported only that “for words that clumped together in the multidimensional scaling analysis and seemed to tap the same emotion, we chose the word that most represented the cluster and appeared most meaningful in terms of the job” (p. 225). All 30 items together yield a total JAWS score and, in addition, 20 of these items are divided into four 5-item scales, one for each quadrant of the circumplex (i.e., *high pleasure high arousal*, *high pleasure low arousal*, *low pleasure high arousal*, *low pleasure low arousal*). It should be noted, however, that the empirical relationships between these sets of items were not taken into account in the process of forming the scales. As a result, the scales did not show the pattern of relationships that would be expected on the basis of the circumplex model.

In addition to these instruments that were developed in the English language, relevant measures are also available in other languages, such as Swedish (Bohlin & Kjellberg, 1973; Kjellberg & Bohlin, 1974) and German (Abele-Brehm & Brehm, 1986). In evaluating the structural validity of measures theorized to be consistent with the circumplex structure, researchers should be aware of a number of important issues.

First, most of the available measures either tap each of the four circumplex quadrants or one pair of bipolar dimensions. However, Larsen and Diener (1992) suggested that, to achieve a more complete and accurate representation of the circumplex space, a measure should tap octants rather than quadrants. This can be done by including two pairs of orthogonal and bipolar scales, one representing the unrotated dimensions (as described by Russell, 1978) and one representing the 45° rotated dimensions (as described by Zevon & Tellegen, 1982), or, alternatively, eight unipolar scales (corresponding to each of the octants). According to Larsen and Diener, “such a measure would have more structural validity than found in currently available measures (e.g., the PANAS) because it would represent the entire circumplex structure instead of just a few octants and would represent the entire length of each dimension instead of just one end point” (p. 50). Nevertheless, such a measure has yet to be made available.

Second, the structural validity of many of the measures is unsatisfactory in that the pattern of interrelationships between the scales exhibits deviations from the pattern that would be expected on the basis of the circumplex model (Fabrigar, Visser, & Browne, 1997; Remington, Fabrigar, & Visser, 2000). In fact, most of the measures were developed either by using conventional factor analysis, which is not the most appropriate analytical model for circumplex data (Sjoberg et al., 1979; van Schuur & Kiers, 1994; van Schuur & Kruijtbosch, 1995) or by constructing scales solely on the basis of subjectively evaluated item content. In general, the circumplex structure is unique and its many and specific simultaneous constraints render most conventional models of structural analysis ineffective. Furthermore, as we discussed in a previous paper in this series (Ekkekakis & Petruzzello, 2001b), there is a plethora of methodological factors which, unless taken into account, can substantially influence the relationships between scales and distort the form of the resultant structure. Consequently, a bipolar dimension may appear as two unipolar and independent dimensions (e.g., Feldman Barrett & Russell, 1998; Green, Goldman, & Salovey, 1993; Russell & Carroll, 1999a). Alternative and more appropriate analytic approaches, such as

multidimensional scaling and multidimensional unfolding, have been used in several studies (Mano, 1991; Morgan & Heise, 1988; Russell 1978, 1980; Sjoberg et al., 1979), but not for the purpose of developing and validating measures. Similarly, the latest circumplex-specific models of structural analysis have yet to be used for the purpose of scale development (Browne, 1992; Fabrigar et al., 1997; Remington et al., 2000; Yik et al., 1999).

Third, some scales theorized to tap the main quadrants of the circumplex actually represent “mixes” or “fusions” of adjacent octants, thus exhibiting poor specificity and discriminant validity. Consider, for example, Mehrabian and Russell’s (1974) Semantic Differential Measures of Emotional State. The *pleasure* scale, in addition to standard exemplars of the pleasure–displeasure dimension (e.g., *happy* versus *unhappy*), also includes items with a significant activation content and questionable bipolarity, such as “*relaxed* versus *bored*”. Similarly, the *arousal* scale includes the apparently pure marker item “*aroused* versus *unaroused*,” but also includes the item “*excited* versus *calm*” which would probably seem unilaterally positive to most people in terms of its valence content. Similarly, in the case of the SACL (Mackay et al., 1978), although the *stress* scale is theorized to tap the dimension of affective valence and the *arousal* scale is theorized to tap the dimension of activation, an examination of item content indicates that the scales may in fact represent combinations of the two dimensions. For example, the item *tense* from the *stress* scale not only denotes displeasure but also high activation, and the item *sluggish* from the *arousal* scale not only reflects low activation but also displeasure. The AD ACL (Thayer, 1989), on which the SACL was based, is also not free of problems. For example, the *calmness* scale, which theoretically represents pleasant low activation, includes items like *still* and *quiet*, which others consider as being neutral in terms of valence (Larsen & Diener, 1992; Tellegen, 1985; Watson & Tellegen, 1985). Finally, the PANAS (Watson et al., 1988) only taps the high-activation poles of the bipolar Positive Affect and Negative Affect dimensions that it is supposed to measure (see Watson & Clark, 1997).

In general, the circumplex as a measurement model has yet to reach the level of development that the circumplex as a conceptual model has. Nevertheless, the tremendous progress in statistical modeling in the last decade and the rapid proliferation of interest in circumplex-patterned conceptual models in various areas of psychological investigation (Plutchik & Conte, 1997) have led to significant advances in the formulation of circumplex-specific data-analytic models and techniques (see Tracey, 2000, for a state-of-the-art review). It is noteworthy that, although Guttman’s first description of a circumplex was published in 1954, it was not until the late 1970s that analytical procedures began to appear (Browne, 1977; Joreskog 1974, 1978; Steiger 1979, 1980; also see Cudeck, 1986). Finally, in the 1990s, Browne developed a stochastic process model for the circumplex (Browne, 1992) and appropriate computer software (Browne & DuToit, 1992). These developments are expected to have a significant impact on circumplex-based scale development and validation practices in the near future.

Mapping the effects of exercise in circumplex affective space

To illustrate the use of the circumplex model in the context of exercise, we shall now discuss a series of studies in which the model has been used. The exercise stimuli involved in these studies run the gamut from self-paced, moderate-intensity walking (Ekkekakis, Hall, Van Land-

uyt, & Petruzzello, 2000), moderate-intensity running, aerobics (Ekkekakis et al., 1999), cycling (Van Landuyt et al., 2000), and maximal exercise (Hall, Ekkekakis, & Petruzzello, 2001), to exhaustive exercise (Ekkekakis et al. 1997, 1998). This work has been based on a variety of both single-item and multiple-item self-report instruments. The single-item instruments that have been used are the FS (Hardy & Rejeski, 1989) as a bipolar measure of affective valence and the FAS (Svebak & Murgatroyd, 1985) as a measure of activation, the Arousal and Valence scale of the Self-Assessment Manikin (Lang, 1980), and the Affect Grid (Russell et al., 1989). The multiple-item instruments that have been mainly used are the AD ACL (Thayer, 1989) and the Circumplex Affect Inventory (CAI; Ekkekakis, 2000), a newly developed measure that was validated using circumplex-specific psychometric procedures.

Affective impact of walking

Based on a few early studies examining the effects of low-intensity and short-duration exercise on state anxiety that produced null results, some researchers have suggested that activities such as walking generally are not sufficient to bring about significant changes in affect and that, in order to reliably produce such changes, exercise must exceed certain rather strenuous thresholds of intensity and duration (e.g., Dishman, 1986; Raglin & Morgan, 1985). One possible explanation for the early null findings is that measurement was limited to a single, specific emotional variable, namely state anxiety. This narrow focus does not permit the extrapolation that walking is ineffective for producing affective changes in general because it is possible that walking brings about changes in other affective states. To investigate this possibility, we assessed the effects of short (10–15 min) walks at a self-chosen pace (on average, 15–22% of heart rate reserve) using both single-item and multiple-item measures of the circumplex dimensions. In a series of four experimental studies, we found that walking was associated with significant shifts toward higher activation and more pleasant affective valence (see Fig. 2(a)). This was followed by a return toward a low activation pleasant state during 10–15 min of post-walk recovery. These responses were documented by multiple self-report measures, were found to occur in both outdoors and laboratory conditions, and were reliable within individuals across time. By offering an encompassing representation of the global affective space, the application of the circumplex in these studies helped to show that, contrary to what had been found previously by examining changes in distinct states, walking can bring about significant, albeit transient, changes in affect (Ekkekakis et al., 2000).

Exercise-associated changes in “state anxiety”

For more than three decades, state anxiety has been assessed in the context of exercise through the state anxiety subscale of the STAI (Spielberger et al., 1970). The validity of this measure in the context of exercise, however, has been questioned because, as a unidimensional measure of state anxiety, it fails to distinguish between exercise-induced, anxiety-unrelated changes in perceived activation and other components of state anxiety, such as worry (Rejeski, Hardy, & Shaw, 1991). As a result, to the extent that they influence the total score of the scale, changes in items that reflect perceived activation are scored and interpreted, inappropriately, as changes in state anxiety. Two studies were conducted with the purpose of reproducing common findings and analyzing them from a critical standpoint, including the concurrent assessment of affective responses

from a circumplex perspective. In one study involving moderate-intensity aerobics, no change in the total state anxiety score was found after 20 min and a significant decrease was found at the end of exercise (50 min). An examination of changes in individual items, however, revealed that the absence of a significant change in the total state anxiety score at 20 min came about as a result of approximately equal increases in the “activation” items and decreases in the “cognitive” items, whereas the decrease at 50 min came about mainly as a result of decreases in the “activation” items following the cool-down. The examination of affective responses from a circumplex perspective corroborated this pattern, showing that there was an increase in activation coupled with positive valence at 20 min and a decrease in activation coupled with a smaller improvement in valence at 50 min. In a second study involving a rather vigorous 30 min treadmill run at 75% of maximal aerobic capacity, an increase in the total state anxiety score was found immediately after the run, followed by a reduction during recovery. Again, an analysis of changes in individual items revealed that the increase in the total score was a reflection of large increases in the “activation” items, which exceeded the decreases in the “cognitive” items. Again, an examination of affective changes from a circumplex perspective showed that the prevailing affective response at the end of the run was a shift towards a high activation pleasant state. The application of the circumplex model in these studies, by distinguishing changes in perceived activation from changes in valence, helped to clarify that the state anxiety score of the STAI in the context of exercise is influenced to a substantial degree by changes in activation that are not associated with state anxiety (Ekkekakis et al., 1999).

Dynamics of affective responses to incremental exercise

Although it has traditionally been assumed that a graded exercise test performed to volitional exhaustion has a negative impact on affect, the findings from empirical research have been inconsistent. Again, a problem with this research is that measurement has focused on a few distinct states, primarily state anxiety and various moods. Moreover, the changes have been assessed from pre-exercise to various time points post-exercise, thus providing no information on the dynamic changes that may take place during exercise. To address these problems, we conducted a graded exercise test during which we obtained ratings of affective valence and perceived activation from the participants every minute. This was done using single-item measures of these dimensions (i.e., the FS and FAS). It was found that affective change during the initial stages was characterized primarily by an increase in perceived activation. Once exercise intensity exceeded each participant’s ventilatory threshold, however, the continued increase in perceived activation was accompanied by a progressive deterioration of valence. Finally, once the test was terminated, there was a dramatic, opponent-process-like rebound toward reduced activation and improved valence (see Fig. 2(b)). The application of the circumplex in this study helped to illustrate that affect responds dynamically to changes in the intensity of exercise. It would have been very difficult, if not impossible, to capture the diversity of the variants of affective experience that emerged in this situation through the assessment of multiple distinct affective states (Hall et al., in press).

Inter-individual variability in affective responses to exercise

Although it is generally recognized that the affective responses to exercise are the products of multiple interacting factors, the traditional conceptions of the exercise–affect relationship are nomothetic. In other words, all or most people are assumed to experience similar affective changes in response to the same exercise stimulus. One of the most frequently cited assumptions stemming from the traditional nomothetic view is that moderate-intensity exercise will lead to positive affective changes in all or most individuals. We investigated the veracity of this assumption by assessing affective responses both during and following exercise from a circumplex perspective. A homogeneous sample of undergraduate students exercised on a cycle ergometer at 60% of estimated maximal aerobic capacity for 30 minutes. Contrary to the assumption of response homogeneity, an examination of individual changes in valence and activation showed five distinct patterns during the exercise bout. In terms of affective valence, in particular, it was found that approximately one half of the sample exhibited progressive improvement, whereas the other half exhibited progressive deterioration during exercise (see the left and right panels of Fig. 2(c)). As a result, the average valence rating appeared to remain unchanged. Response homogeneity emerged only following the cessation of the exercise stimulus, when individual responses exhibited a unified trend towards improved valence. As noted previously, the circumplex, by providing a broad and balanced representation of the global affective space (i.e., not giving primacy to any variant of affect, such as pleasure or displeasure, low or high activation, or any combination thereof), can provide considerable insight into the diversity of individual affective responses to exercise (Van Landuyt et al., 2000).

Psychoneuroendocrine correlates of affective responses

Despite the voluminous evidence pointing to a link between affect and the modulation of the hypothalamic pituitary adrenocortical (HPA) axis, demonstrations of strong relationships in humans have been scarce, a problem that may be attributable to the measurement of affect. The available evidence suggests that not all variants of affective experience are associated with the activation of the HPA axis. According to Frankenhaeuser (1986, 1991) and Henry (Henry, 1986; Henry & Meehan, 1981; Henry & Stephens, 1977), the HPA axis is primarily responsive to situations involving a high degree of activation coupled with negative affective valence. This hypothesis was examined in the context of exercise by assessing both the unrotated (i.e., valence and activation) and the 45° rotated dimensions of the circumplex using the CAI. Changes in cortisol and adrenocorticotrophic hormone (ACTH) were found to correlate strongly in the expected direction ($r=-0.707$ for ACTH; $r=-0.816$ for cortisol) with changes along the circumplex dimension that extends from low activation pleasant to high activation unpleasant affect (i.e., larger increases in hormone concentrations were associated with larger shifts toward high activation unpleasant affect, and vice versa). The assessment of affective responses from a circumplex perspective also provided evidence for the specificity of this link. Consistent with Frankenhaeuser and Henry's hypotheses, the activation of the HPA axis was closely associated with high activation unpleasant affect, but not with other dimensions of affect (Ekkekakis et al., 1998).

Concluding comments and reflections

In this paper, and the 4-paper series as a whole, we presented the steps of a decision-making process that has led us to select the circumplex as a conceptual and measurement model for studying affect in the context of exercise. We based our reasoning on a number of conceptual criteria derived from a joint analysis of the history of investigations into the affective responses to exercise and the advances made in the study of affective phenomena in general psychology. We reached the following conclusions:

1. a hierarchical view of affective phenomena should be adopted, with basic affect being the primary target of study at the present stage of knowledge development in exercise psychology
2. because of their breadth of scope, balance, and parsimony, dimensional models are more appropriate for the descriptive study of basic affective responses to exercise
3. there is presently no reliable evidence that exercise assumes unique content and structure in the context of exercise, therefore a measurement model should have a global and not an exercise-specific scope
4. the tremendous progress that has been made in the study of the structure of affect makes it possible, if not necessary, to use a deductive and not an inductive approach to the measurement of affect in the context of exercise.

On the basis of these primary considerations, we selected the circumplex model as the most extensively studied and well-developed solution that satisfies these criteria. Although it is true that the circumplex has evolved more as a conceptual model rather than a measurement model, we submit that there are several viable measurement options currently available that could be readily used in the context of exercise and, more importantly, the rapid progress that is being made in this area will surely lead to further improvements in the near future.

In concluding this series, let us return to and restate our initial purpose. As we noted in the introductory paper, the controversy and confusion that surrounds the measurement of affect in the context of exercise is striking (Ekkekakis & Petruzzello, 2000). Authors rarely differentiate between the various constructs in the affective hierarchy (i.e., basic affect, mood, emotion), interchange terms rather haphazardly, and almost never provide a theoretical rationale for the measurement approach they use (e.g., why they measure a particular set of affective variables as opposed to others, why the measures they use are the most appropriate given the purpose of the study, etc.). It has become commonplace, for instance, to see published articles that mention “affect” in the title, concentrate on specific emotions, such as anxiety and depression, in the review of literature, and eventually present a measure of mood in the methods section, exclusively based on the argument that it “has been used extensively in the past.” In our view, this situation, if continued, does not hold much promise for substantial progress. The litmus test for the success of this series will be not the adoption of the circumplex model as a universal investigative platform, but rather whether there is a visible increase in the amount of attention paid to theoretical issues related to the conceptualization and measurement of affect in exercise psychology. We also genuinely hope that our analysis of the affect measurement conundrum as presented in this series will stimulate a more general discussion on this important issue. To repeat the final sentences from our introductory paper:

the ultimate objective of the project is to inject the elements of theoretical reasoning in the ongoing discourse on the measurement of affect in the context of exercise. We will consider this project successful when extensive theoretical discussions start to complement — in fact, *precede* — reports of psychometric indices and when researchers in exercise psychology begin to present theory-grounded rationales for selecting a particular measure of affect in their studies (Ekkekakis and Petruzzello, 2000, p. 84).

References

- Abele-Brehm, A., & Brehm, W. (1986). Zur Konzeptualisierung und messung von befindlichkeit. *Diagnostica*, *32*, 209–228.
- Abelson, R. P., & Sermat, V. (1962). Multidimensional scaling of facial expressions. *Journal of Experimental Psychology*, *63*, 546–554.
- Almagor, M., & Ben-Porath, Y. S. (1989). The two-factor model of self-reported mood: A cross-cultural replication. *Journal of Personality Assessment*, *53*, 10–21.
- Balatsky, G., & Diener, E. (1993). Subjective well-being among Russian students. *Social Indicators Research*, *28*, 225–243.
- Biddle, S. (2000). Exercise, emotions, and mental health. In Y. L. Hanin (Ed.), *Emotions in sport* (pp. 267–291). Champaign, IL: Human Kinetics.
- Biddle, S. J. H., & Mutrie, N. (2001). *Psychology of physical activity: Determinants, well-being and interventions*. London: Routledge.
- Bohlin, G., & Kjellberg, A. (1973). Self-reported arousal during sleep deprivation and its relation to performance and physiological variables. *Scandinavian Journal of Psychology*, *14*, 78–86.
- Borg, G. (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.
- Bradley, M. M., Greenwald, M. K., & Hamm, A. O. (1993). Affective picture processing. In N. Birbaumer, & A. Öhman (Eds.), *The structure of emotion: Psychophysiological, cognitive, and clinical aspects* (pp. 48–65). Seattle, WA: Hogrefe and Huber.
- Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The Self-Assessment Manikin and the Semantic Differential. *Journal of Behavioral Therapy and Experimental Psychiatry*, *25*, 49–59.
- Browne, M. W. (1977). The analysis of patterned correlation matrices by generalized least squares. *British Journal of Mathematical and Statistical Psychology*, *30*, 113–124.
- Browne, M. W. (1992). Circumplex models for correlation matrices. *Psychometrika*, *57*, 469–497.
- Browne, M. W., & DuToit, S. H. C. (1992). Automated fitting of nonstandard models. *Multivariate Behavioral Research*, *27*, 269–300.
- Bush, L. E. (1973). Individual differences multidimensional scaling of adjectives denoting feelings. *Journal of Personality and Social Psychology*, *25*, 50–57.
- Byrne, A., & Byrne, D. G. (1993). The effect of exercise on depression, anxiety, and other mood states: A review. *Journal of Psychosomatic Research*, *37*, 565–574.
- Church, A. T., Katigbak, M. S., Reyes, J. A. S., & Jensen, S. M. (1998). Language and organization of Filipino emotion concepts: Comparing emotion concepts and dimensions across cultures. *Cognition and Emotion*, *12*, 63–92.
- Church, A. T., Katigbak, M. S., Reyes, J. A. S., & Jensen, S. M. (1999). The structure of affect in a non-western culture: Evidence for cross-cultural comparability. *Journal of Personality*, *67*, 505–534.
- Clore, G. L., Ortony, A., & Foss, M. A. (1987). The psychological foundations of the affective lexicon. *Journal of Personality and Social Psychology*, *53*, 751–766.
- Cox, T., & Mackay, C. (1985). The measurement of self-reported stress and arousal. *British Journal of Psychology*, *76*, 183–186.
- Cruickshank, P. J. (1984). A stress and arousal mood scale for low vocabulary subjects: A reworking of Mackay et al. (1978). *British Journal of Psychology*, *75*, 89–94.

- Cudeck, R. (1986). A note on structural models for the circumplex. *Psychometrika*, *51*, 143–147.
- Daly, E. M., Lancee, W. J., & Polivy, J. (1983). A conical model for the taxonomy of emotional experience. *Journal of Personality and Social Psychology*, *45*, 443–457.
- Dishman, R. K. (1986). Mental health. In V. Seefeldt (Ed.), *Physical activity and well-being* (pp. 303–341). Reston, VA: American Alliance for Health, Physical Education, Recreation, and Dance.
- Egloff, B. (1998). The independence of positive and negative affect depends on the affect measure. *Personality and Individual Differences*, *25*, 1101–1109.
- Ekkekakis, P. (2000). Measuring affective responses to acute exercise the circular way: Development and validation of the Circumplex Affect Inventory. *Journal of Sport and Exercise Psychology*, *22*, S36.
- Ekkekakis, P., & Petruzzello, S. J. (1999). Acute aerobic exercise and affect: Current status, problems, and prospects regarding dose-response. *Sports Medicine*, *28*, 337–374.
- Ekkekakis, P., & Petruzzello, S. J. (2000). Analysis of the affect measurement conundrum in exercise psychology: I Fundamental issues. *Psychology of Sport and Exercise*, *1*, 71–88.
- Ekkekakis, P., & Petruzzello, S. J. (2001a). Analysis of the affect measurement conundrum in exercise psychology: II. A conceptual and methodological critique of the Exercise-induced Feeling Inventory. *Psychology of Sport and Exercise*, *2*, 1–26.
- Ekkekakis, P., & Petruzzello, S. J. (2001b). Analysis of the affect measurement conundrum in exercise psychology: III. A conceptual and methodological critique of the Subjective Exercise Experiences Scale. *Psychology of Sport and Exercise*, *2*, 205–232.
- Ekkekakis, P., Kavouras, S. A., Casa, D. J., Herrera, J. A., Armstrong, L. E., Maresh, C. M., & Petruzzello, S. J. (1997). Affective responses to a bout of exhaustive exercise in the heat in dehydrated and rehydrated states: In search of physiological correlates. In R. Lidor, & M. Bar-Eli (Eds.), (pp. 253–255). *Innovations in sport psychology: Linking theory and practice. Proceedings of the IX World Congress of Sport Psychology*, *1*. Netanya, Israel: International Society of Sport Psychology.
- Ekkekakis, P., Kavouras, S. A., Casa, D. J., Herrera, J. A., Armstrong, L. E., & Maresh, C. M. (1998). Affective modulation of HPA axis activation in response to exhaustive exercise. *Medicine and Science in Sports and Exercise*, *30*, S119.
- Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (1999). Measuring state anxiety in the context of acute exercise using the State Anxiety Inventory: An attempt to resolve the brouhaha. *Journal of Sport and Exercise Psychology*, *21*, 205–229.
- Ekkekakis, P., Hall, E. E., Van Landuyt, L. M., & Petruzzello, S. J. (2000). Walking in (affective) circles: Can short walks enhance affect? *Journal of Behavioral Medicine*, *23*, 245–275.
- Fabrigar, L. R., Visser, P. S., & Browne, M. W. (1997). Conceptual and methodological issues in testing the circumplex structure of data in personality and social psychology. *Personality and Social Psychology Review*, *1*, 184–203.
- Faith, M., & Thayer, J. F. (2001). A dynamical systems interpretation of a dimensional model of emotion. *Scandinavian Journal of Psychology*, *42*, 121–133.
- Feldman, L. A. (1995a). Variations in the circumplex structure of mood. *Personality and Social Psychology Bulletin*, *21*, 806–817.
- Feldman, L. A. (1995b). Valence focus and arousal focus: Individual differences in the structure of affective experience. *Journal of Personality and Social Psychology*, *69*, 153–166.
- Feldman Barrett, L. (1996). Hedonic tone, perceived arousal, and item desirability: Three components of self-reported mood. *Cognition and Emotion*, *10*, 47–68.
- Feldman Barrett, L. (1998). Discrete emotions or dimensions? The role of valence focus and arousal focus. *Cognition and Emotion*, *12*, 579–599.
- Feldman Barrett, L., & Russell, J. A. (1998). Independence and bipolarity in the structure of current affect. *Journal of Personality and Social Psychology*, *74*, 967–984.
- Feldman Barrett, L., & Russell, J. A. (1999). The structure of current affect: Controversies and emerging consensus. *Current Directions in Psychological Science*, *8*, 10–14.
- Fischer, D. G., & Donatelli, M. J. (1987). A measure of stress and arousal: Factor structure of the Stress Adjective Checklist. *Educational and Psychological Measurement*, *47*, 425–435.
- Fischer, D. G., Hansen, R. J., & Zemore, R. W. (1988). Factor structure of the Stress Adjective Checklist: Replicated. *Educational and Psychological Measurement*, *48*, 127–136.

- Frankenhaeuser, M. (1986). A psychobiological framework for research on human stress and coping. In M. H. Appley, & R. Trumbull (Eds.), *Dynamics of stress: Physiological, psychological, and social perspectives* (pp. 101–116). New York: Plenum.
- Frankenhaeuser, M. (1991). The psychophysiology of workload, stress, and health: Comparison between the sexes. *Annals of Behavioral Medicine*, *13*, 197–204.
- Frijda, N. H. (1986). *The emotions*. New York: Cambridge University Press.
- Gauvin, L., & Brawley, L. R. (1993). Alternative psychological models and methodologies for the study of exercise and affect. In P. Seragianian (Ed.), *Exercise psychology: The influence of physical exercise on psychological processes* (pp. 146–171). New York: John Wiley and Sons.
- Gauvin, L., & Rejeski, W. J. (1993). The Exercise-induced Feeling Inventory: Development and initial validation. *Journal of Sport and Exercise Psychology*, *15*, 403–423.
- Gauvin, L., & Spence, J. C. (1998). Measurement of exercise-induced changes in feeling states, affect, mood, and emotions. In J. L. Duda (Ed.), *Advances in sport and exercise psychology measurement* (pp. 325–336). Morgantown, WV: Fitness Information Technology.
- Gray, J. A. (1970). The psychophysiological basis of introversion–extraversion. *Behaviour Research and Therapy*, *8*, 249–266.
- Gray, J. A. (1991). Neural systems, emotion and personality. In J. Madden, *Neurobiology of learning, emotion, and affect* (pp. 273–306). New York: Raven.
- Green, D. P., Goldman, S. L., & Salovey, P. (1993). Measurement error masks bipolarity in affect ratings. *Journal of Personality and Social Psychology*, *64*, 1029–1041.
- Gurtman, M. B., & Balakrishnan, J. D. (1998). Circular measurement redux: The analysis and interpretation of interpersonal circle profiles. *Clinical Psychology: Science and Practice*, *5*, 344–360.
- Guttman, L. (1954). A new approach to factor analysis: The radex. In P. F. Lazarsfeld (Ed.), *Mathematical thinking in the social sciences* (pp. 258–348). Glencoe, IL: Free Press.
- Hall, E. E., Ekkekakis, P., & Petruzzello, S. J. (in press). The affective beneficence of vigorous exercise revisited. *British Journal of Health Psychology*.
- Hardy, J., Hall, G. R., & Alexander, M. R. (2001). Exploring self-talk and affective states in sport. *Journal of Sports Sciences*, *19*, 469–475.
- Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport and Exercise Psychology*, *11*, 304–317.
- Haslam, N. (1995). The discreteness of emotion concepts: Categorical structure in the affective circumplex. *Personality and Social Psychology Bulletin*, *21*, 1012–1019.
- Heller, W. (1990). The neuropsychology of emotion: Developmental patterns and implications for psychopathology. In N. L. Stein, B. Leventhal, & T. Trabasso (Eds.), *Psychological and biological approaches to emotion* (pp. 167–211). Hillsdale, NJ: Lawrence Erlbaum.
- Heller, W. (1993). Neuropsychological mechanisms of individual differences in emotion, personality, and arousal. *Neuropsychology*, *7*, 476–489.
- Henry, J. P. (1986). Neuroendocrine patterns of emotional response. In R. Plutchik, & H. Kellerman (Eds.), *Emotion: Theory, Research, and Experience*, *3* (pp. 37–60). San Diego, CA: Academic Press.
- Henry, J. P., & Meehan, J. P. (1981). Psychosocial stimuli, physiological specificity, and cardiovascular disease. In H. Weiner, M. A. Hofer, & A. J. Stunkard (Eds.), *Brain, behavior, and bodily disease* (pp. 305–333). New York: Raven.
- Henry, J. P., & Stephens, P. M. (1977). *Stress, health, and the social environment: A sociobiological approach to medicine*. New York: Springer Verlag.
- Hodes, R. L., Cook, E. W. III, & Lang, P. J. (1985). Individual differences in autonomic response: A conditioned association or conditioned fear? *Psychophysiology*, *22*, 545–560.
- Izard, C. E. (1993). Organizational and motivational functions of discrete emotions. In M. Lewis, & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 631–641). New York: Guilford.
- Jacob, R. G., Simons, A. D., Manuck, S. B., Rohay, J. M., Waldstein, S., & Gatsonis, C. (1989). The circular mood scale: A new technique for measuring ambulatory mood. *Journal of Psychopathology and Behavioral Assessment*, *11*, 153–173.
- Jacob, R. G., Thayer, J. F., Manuck, S. B., Muldoon, M. F., Tamres, L. K., Williams, D. M., Ding, Y., & Gatsonis,

- C. (1999). Ambulatory blood pressure responses and the circumplex model of mood: A 4-day study. *Psychosomatic Medicine*, *61*, 319–333.
- Joiner, T. E., Sandin, B., Chorot, P., Lostao, L., & Marquina, G. (1997). Development and factor analytic validation of the SPANAS among women in Spain: (More) cross-cultural convergence in the structure of mood. *Journal of Personality Assessment*, *68*, 600–615.
- Joreskog, K. G. (1974). Analyzing psychological data by structural analysis of covariance matrices. In D. H. Krantz, R. C. Atkinson, R. D. Luce, & P. Suppes (Eds.), (pp. 1–56). *Contemporary developments in mathematical psychology*, 2. San Francisco: W.H. Freeman.
- Joreskog, K. G. (1978). Structural analysis of covariance and correlation matrices. *Psychometrika*, *43*, 443–477.
- Killgore, W. D. S. (1998). The Affect Grid: A moderately valid, nonspecific measure of pleasure and arousal. *Psychological Reports*, *83*, 639–642.
- King, M. G., Burrows, G. D., & Stanley, G. V. (1983). Measurement of stress and arousal: Validation of the stress/arousal adjective checklist. *British Journal of Psychology*, *74*, 473–479.
- Kjellberg, A., & Bohlin, G. (1974). Self-reported arousal: Further development of a multi-factorial inventory. *Scandinavian Journal of Psychology*, *15*, 285–292.
- Lang, P. J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sadowski, J. H. Johnson, & T. A. Williams (Eds.), *Technology in mental health care delivery systems* (pp. 119–137). Norwood, NJ: Ablex.
- Lang, P. J. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist*, *50*, 372–385.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97–135). Mahwah, NJ: Lawrence Erlbaum.
- Larsen, R. J., & Diener, E. (1992). Promises and problems with the circumplex model of emotion. In M. S. Clark (Ed.), (pp. 25–59). *Review of personality and social psychology*, *13*. Newbury Park, CA: Sage.
- Lazarus, R. S. (1991). *Emotion and adaptation*. New York: Oxford University Press.
- Lox, C. L., Jackson, S., Tuholski, S. W., Wasley, D., & Treasure, D. C. (2000). Revisiting the measurement of exercise-induced feeling states: The Physical Activity Affect Scale (PAAS). *Measurement in Physical Education and Exercise Science*, *4*, 79–95.
- Mano, H. (1991). The structure and intensity of emotional experiences: Method and context convergence. *Multivariate Behavioral Research*, *26*, 389–411.
- Mackay, C., Cox, T., Burrows, G., & Lazzarini, T. (1978). An inventory for the measurement of self-reported stress and arousal. *British Journal of Social and Clinical Psychology*, *17*, 283–284.
- Matthews, G., Jones, D. M., & Chamberlain, A. G. (1990). Refining the measurement of mood: The UWIST Mood Adjective Checklist. *British Journal of Psychology*, *81*, 17–42.
- McAuley, E., & Courneya, K. S. (1994). The Subjective Exercise Experiences Scale (SEES): Development and preliminary validation. *Journal of Sport and Exercise Psychology*, *16*, 163–177.
- McAuley, E., & Rudolph, D. (1995). Physical activity, aging, and psychological well-being. *Journal of Aging and Physical Activity*, *3*, 67–96.
- McCormick, I. A., Walkey, F. H., & Taylor, A. J. W. (1985). The Stress Arousal Checklist: An independent analysis. *Educational and Psychological Measurement*, *45*, 143–146.
- McKinnon, N. J., & Keating, L. J. (1989). The structure of emotions: Canada–United States comparisons. *Social Psychology Quarterly*, *52*, 70–83.
- McNair, D. M., Lorr, M., & Droppleman, L. F. (1971). *Manual for the Profile of Mood States*. San Diego: Educational and Industrial Testing Service.
- Mehrabian, A. (1978). Measures of individual differences in temperament. *Educational and Psychological Measurement*, *38*, 1105–1117.
- Mehrabian, A. (1995). Framework for a comprehensive description and measurement of emotional states. *Genetic, Social, and General Psychology Monographs*, *121*, 339–361.
- Mehrabian, A., & Russell, J. A. (1974). *An approach to environmental psychology*. Cambridge, MA: MIT Press.
- Meyer, J. D., & Gaschke, Y. N. (1988). The experience and meta-experience of mood. *Journal of Personality and Social Psychology*, *55*, 102–111.
- Morgan, R. L., & Heise, D. (1988). Structure of emotions. *Social Psychology Quarterly*, *51*, 19–31.

- Morris, J. D. (1995). SAM: The Self-Assessment Manikin: an efficient, cross-cultural measurement of emotional response. *Journal of Advertising Research*, 35, 63–68.
- Mossholder, K. W., Kemery, E. R., Harris, S. G., Armenakis, A. A., & McGrath, R. (1994). Confounding constructs and levels of constructs in affectivity measurement: An empirical investigation. *Educational and Psychological Measurement*, 54, 336–349.
- Mutrie, N., & Biddle, S. J. H. (1995). The effects of exercise on mental health in nonclinical populations. In S. J. H. Biddle (Ed.), *European perspectives on exercise and sport psychology* (pp. 50–70). Champaign, IL: Human Kinetics.
- Nemanick, R. C., & Munz, D. C. (1994). Measuring the poles of positive and negative mood using the Positive Affect Negative Affect Schedule and Activation Deactivation Adjective Check List. *Psychological Reports*, 74, 195–199.
- Osgood, C. E. (1966). Dimensionality of semantic space for communication via facial expressions. *Scandinavian Journal of Psychology*, 7, 1–30.
- Plutchik, R. (1970). Emotions, evolution, and adaptive processes. In M. Arnord (Ed.), *Feelings and emotions* (pp. 3–24). New York: Academic Press.
- Plutchik, R. (1980). *Emotion: A psychoevolutionary synthesis*. New York: Harper and Row.
- Plutchik, R., & Conte, H. R. (1997). *Circumplex models of personality and emotions*. Washington, DC: American Psychological Association.
- Raedeke, T. D., & Stein, G. L. (1994). Felt arousal, thoughts/feelings, and ski performance. *Sport Psychologist*, 8, 360–375.
- Raglin, J. S., & Morgan, W. P. (1985). Influence of vigorous exercise on mood state. *Behavior Therapist*, 8, 179–183.
- Remington, N. A., Fabrigar, L. R., & Visser, P. S. (2000). Re-examining the circumplex model of affect. *Journal of Personality and Social Psychology*, 79, 286–300.
- Rejeski, W. J., Hardy, C. J., & Shaw, J. (1991). Psychometric confounds of assessing state anxiety in conjunction with acute bouts of vigorous exercise. *Journal of Sport and Exercise Psychology*, 13, 65–74.
- Russell, J. A. (1978). Evidence of convergent validity on the dimensions of affect. *Journal of Personality and Social Psychology*, 36, 1152–1168.
- Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39, 1161–1178.
- Russell, J. A. (1983). Pancultural aspects of the human conceptual organization of emotions. *Journal of Personality and Social Psychology*, 45, 1281–1288.
- Russell, J. A. (1989). Measures of emotion. In R. Plutchik, & H. Kellerman (Eds.), (pp. 83–111). *Emotion: Theory, research, and experience. The measurement of emotions*, 4. San Diego, CA: Academic Press.
- Russell, J. A. (1997). How shall an emotion be called? In R. Plutchik, & H. R. Conte (Eds.), *Circumplex models of personality and emotions* (pp. 205–222). Washington, DC: American Psychological Association.
- Russell, J. A., & Bullock, M. (1985). Multidimensional scaling of emotional facial expressions: Similarity from preschoolers to adults. *Journal of Personality and Social Psychology*, 48, 1290–1298.
- Russell, J. A., & Bullock, M. (1986). On the dimensions preschoolers use to interpret facial expressions of emotion. *Developmental Psychology*, 22, 97–102.
- Russell, J. A., & Carroll, J. M. (1999a). On the bipolarity of positive and negative affect. *Psychological Bulletin*, 125, 3–30.
- Russell, J. A., & Carroll, J. M. (1999b). The phoenix of bipolarity: Reply to Watson and Tellegen (1999). *Psychological Bulletin*, 125, 611–617.
- Russell, J. A., & Feldman-Barrett, L. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology*, 76, 805–819.
- Russell, J. A., & Mehrabian, A. (1974). Distinguishing anger and anxiety in terms of emotional response factors. *Journal of Consulting and Clinical Psychology*, 42, 79–83.
- Russell, J. A., & Mehrabian, A. (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality*, 11, 273–294.
- Russell, J. A., & Steiger, J. H. (1982). The structure in persons' implicit taxonomy of emotions. *Journal of Research in Personality*, 16, 447–469.
- Russell, J. A., Ward, L. M., & Pratt, G. (1981). Affective quality attributed to environments: A factor analytic study. *Environment and Behavior*, 13, 259–288.
- Russell, J. A., Lewicka, M., & Niit, T. (1989). A cross-cultural study of a circumplex model of affect. *Journal of Personality and Social Psychology*, 57, 848–856.

- Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect Grid: A single item scale of pleasure and arousal. *Journal of Personality and Social Psychology*, *57*, 493–502.
- Schlosberg, H. (1952). The description of facial expression in terms of two dimensions. *Journal of Experimental Psychology*, *44*, 229–237.
- Schlosberg, H. (1954). Three dimensions of emotion. *Psychological Review*, *61*, 81–88.
- Selye, H. (1983). The stress concept: Past, present, and future. In C. L. Cooper (Ed.), *Stress research: Issues for the eighties* (pp. 1–20). New York: John Wiley and Sons.
- Sevastos, P., Smith, L., & Cordery, J. L. (1992). Evidence on the reliability and construct validity of Warr's (1990) well-being and mental health measures. *Journal of Occupational and Organizational Psychology*, *65*, 33–49.
- Sjoberg, L., Svensson, E., & Persson, L. O. (1979). The measurement of mood. *Scandinavian Journal of Psychology*, *20*, 1–18.
- Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.
- Steiger, J. H. (1979). MULTICORR: A computer program for fast, accurate, small-sample testing of correlational pattern hypotheses. *Educational and Psychological Measurement*, *39*, 677–680.
- Steiger, J. H. (1980). Testing pattern hypotheses on correlation matrices: Alternative statistics and some empirical results. *Multivariate Behavioral Research*, *15*, 335–352.
- Steptoe, A. (1992). Physical activity and psychological well-being. In N. G. Norgan (Ed.), *Physical activity and health* (pp. 207–229). Cambridge, UK: Cambridge University Press.
- Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personality and Social Psychology*, *48*, 107–116.
- Tellegen, A. (1985). Structures of mood and personality and their relevance to assessing anxiety, with an emphasis on self-report. In A. H. Tuma, & J. D. Maser (Eds.), *Anxiety and anxiety disorders* (pp. 681–706). Hillsdale, NJ: Lawrence Erlbaum.
- Thayer, R. E. (1967). Measurement of activation through self-report. *Psychological Reports*, *20*, 663–678.
- Thayer, R. E. (1978). Factor analytic and reliability studies on the Activation-Deactivation Adjective Check List. *Psychological Reports*, *42*, 747–756.
- Thayer, R. E. (1985). Activation (arousal): The shift from a single to a multidimensional perspective. In J. H. Strelau, F. H. Farley, & A. Gale (Eds.), (pp. 115–127). *The biological bases of personality and behavior, 1*. Washington: Hemisphere.
- Thayer, R. E. (1986). Activation-Deactivation Adjective Check List: Current overview and structural analysis. *Psychological Reports*, *58*, 607–614.
- Thayer, R. E. (1989). *The biopsychology of mood and arousal*. New York: Oxford University Press.
- Tracey, T. J. G. (2000). Analysis of circumplex models. In H. E. A. Tinsley, & S. D. Brown (Eds.), *Handbook of applied multivariate statistics and mathematical modeling* (pp. 641–664). San Diego, CA: Academic Press.
- Triandis, H. C., & Lambert, W. H. (1958). A restatement and test of Schlosberg's theory of emotion with two kinds of subjects from Greece. *Journal of Abnormal and Social Psychology*, *56*, 321–328.
- Tuson, K. M., & Sinyor, D. (1993). On the affective benefits of acute aerobic exercise: Taking stock after twenty years of research. In P. Seraganian (Ed.), *Exercise psychology: The influence of physical exercise on psychological processes* (pp. 80–121). New York: John Wiley and Sons.
- Van Katwyk, P. T., Fox, S., Spector, P. E., & Kelloway, E. K. (2000). Using the Job-related Affective Well-being Scale (JAWS) to investigate affective responses to work stressors. *Journal of Occupational Health Psychology*, *5*, 219–230.
- Van Landuyt, L. M., Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2000). Throwing the mountains into the lakes: On the perils of nomothetic conceptions of the exercise–affect relationship. *Journal of Sport and Exercise Psychology*, *22*, 208–234.
- van Schuur, W. H., & Kiers, H. A. L. (1994). Why factor analysis often is the incorrect model for analyzing bipolar concepts, and what model to use instead. *Applied Psychological Measurement*, *18*, 97–110.
- van Schuur, W. H., & Kruijtbosch, M. (1995). Measuring subjective well-being: Unfolding the Bradburn Affect Balance Scale. *Social Indicators Research*, *36*, 49–74.
- Warr, P. (1990). The measurement of well-being and other aspects of mental health. *Journal of Occupational Psychology*, *63*, 193–210.

- Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin*, 98, 219–235.
- Watson, D., & Tellegen, A. (1999). Issues in dimensional structure of affect — Effects of descriptors, measurement error, and response formats: Comment on Russell and Carroll (1999). *Psychological Bulletin*, 125, 601–610.
- Watson, D., & Clark, L. A. (1997). Measurement and mismeasurement of mood: Recurrent and emergent issues. *Journal of Personality Assessment*, 68, 267–296.
- Watson, D., Clark, L. A., & Tellegen, A. (1984). Cross-cultural convergence in the structure of mood: A Japanese replication and a comparison with US findings. *Journal of Personality and Social Psychology*, 47, 127–144.
- Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, 54, 1063–1070.
- Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology*, 76, 820–838.
- Wundt, W. (1912). *An introduction to psychology*. New York: Macmillan.
- Yik, M. S. M., Russell, J. A., & Feldman-Barrett, L. (1999). Structure of self-reported current affect: Integration and beyond. *Journal of Personality and Social Psychology*, 77, 600–619.
- Zevon, M. A., & Tellegen, A. (1982). The structure of mood change: An idiographic/nomothetic analysis. *Journal of Personality and Social Psychology*, 43, 111–122.