JOURNAL OF SPORT & EXERCISE PSYCHOLOGY, 1999, 21, 205-229

Measuring State Anxiety in the Context of Acute Exercise Using the State Anxiety Inventory: An Attempt to Resolve the Brouhaha

Panteleimon Ekkekakis, Eric E. Hall, and Steven J. Petruzzello
University of Illinois at Urbana-Champaign

Two studies were conducted to examine the internal consistency and validity of the state anxiety subscale of the State-Trait Anxiety Inventory (SAI) in the context of acute exercise. SAI responses typically found in the exercise literature were replicated. Analysis at the item level revealed divergent response patterns, confounding the total SAI score. During moderate and immediately after vigorous exercise, scores on items referring to cognitive antecedents of anxiety decreased, whereas scores on items assessing perceived activation increased. Indices of internal showed exercise-associated decreases. A principal-components analysis of responses immediately postexercise revealed a multidimensional structure, distinguishing "cognitive" and "activation" items. By failing to discern exercise-induced and anxiety-related increases in activation from anxiety-antecedent appraisals, the SAI exhibits compromised internal consistency and validity in the context of acute exercise.

Key words: State-Trait Anxiety Inventory, acute exercise, internal consistency, validity, activation

The examination of the effects of physical activity on anxiety is one of the primary research directions in exercise psychology. The importance of this research effort from a public health standpoint is underscored by the fact that between 13 and 17% of American adults suffer from anxiety (U.S. Department of Health and Human Services, 1996). The main tool used to assess anxiety in physical activity studies has been the State-Trait Anxiety Inventory (STAI; Spielberger, 1983; Spielberger, Gorsuch, & Lushene, 1970). In fact, the STAI is perhaps the most extensively used and highly regarded instrument for the assessment of state and trait anxiety in any area of psychological investigation (Levitt, 1980). The state-anxiety subscale of the STAI (SAI), in particular, has been the measure of choice for the assessment of changes in state anxiety associated with acute exercise since shortly after its conception (e.g., Morgan, 1973) up until today (e.g., Bartholomew & Linder, 1998; Breus & O'Connor, 1998; Focht & Koltyn, 1999; Youngstedt, O'Connor, Crabbe, & Dishman, 1998). Almost half (94 out of 207, or

---

The authors are with the Department of Kinesiology at the University of Illinois at Urbana-Champaign, Urbana, IL 61801. E-mail regarding this article may be sent to the first author at <ekkekaki@uiuc.edu>.

45%) of the effect sizes reported in a meta-analysis of the effects of exercise on state anxiety (covering the literature until January 1989) were based on the SAI (Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991).

Despite its popularity, however, the SAI has never been formally validated in the context of exercise. This is an important omission, because some of the items of the SAI tap perceived activation, and it is known that both state anxiety and exercise can independently influence the activity of the autonomic nervous system. Consequently, the activation-related items of the SAI might reflect exercise-induced, not anxiety-induced, activation, thus effectively becoming invalid as indices of state anxiety. This problem has received critical attention in recent years (Gauvin & Spence, 1998; McAuley, Mihalko, & Bane, 1996; Rejeski, Hardy, & Shaw, 1991). These criticisms have, in turn, elicited arguments in favor of the continued use of the scale in exercise research (Raglin, 1997). The purpose of the studies described herein was to reproduce typical patterns of findings commonly identified in exercise studies that used the SAI and then to subject them to a critical conceptual and psychometric analysis in order to help shed light on the controversy.

A Quarter-Century of Exercise Research With the SAI: Basic Conclusions

A number of conclusions have been drawn from the numerous exercise studies that have employed the SAI (see Kerr & Vlaswinkel, 1990; Landers & Petruzzello, 1994; Morgan, 1979, 1982, 1984, 1987; Morgan, Horstman, Cymerman, & Stokes, 1980; Petruzzello et al., 1991; Raglin, 1997; Raglin & Morgan, 1985, for reviews). Overall, it appears that the intensity of the exercise stimulus and the time of assessment (i.e., the stage of the exercise bout or recovery) influence the SAI scores. Specifically, it has been reported that "exercise of *light to moderate* intensities was not found to decrease anxiety" (Morgan, 1984, p. 140). On the other hand, in a bout of *vigorous* exercise lasting approximately 45 min, "anxiety was found to increase slightly in the immediate postexercise setting, but a substantial and significant ($p < .001$) decrease below the baseline level was observed at 20 to 30 min post-exercise" (Morgan, 1979, p. 144). Likewise, bouts of walking or running at 80 or 100% of maximal aerobic power, performed until volitional exhaustion, were shown to lead to increases in SAI scores immediately postexercise and subsequent decreases a few minutes into recovery (Morgan et al., 1980). Responses on the SAI have also been recorded *during* bouts of walking and running at 80% VO_2max: "State anxiety increased in a fairly linear fashion throughout the first half of both the walk and run, reached a plateau and remained stable for the second half of the exercise" (Morgan et al., 1980, p. 55).

Although these change patterns are fairly reliably documented, it must be noted that "it is not clear why state anxiety decreases following acute vigorous physical activity" (Morgan, 1984, p. 140). Various hypotheses, running the gamut from biological to cognitive, have not led to any clear answers (Hatfield, 1991; Morgan, 1997; Petruzzello et al., 1991).

The mechanisms underlying the phenomenon of increased anxiety during and immediately after vigorous exercise are equally elusive. Some authors dismiss it as a transient "eustress rather than stress" reaction, emphasizing that it is "followed by a sudden decrease in state anxiety during the post-exercise recovery period" (Morgan & Ellickson, 1989, p. 172). Others have proposed that it is linked to lactate production during exercise (Pitts & McClure, 1967), only to be contradicted by empirical evidence (Garvin, Koltyn, & Morgan, 1997; Martinsen, Raglin, Hoffart, & Friis, 1998). Still others have proposed that it reflects an apprehensive response to unfamiliar respiratory sensations accompanying the transition to anaerobic metabolism (Raglin & Wilson, 1996). This possibility is also rendered unlikely in light of the fact that, in similar populations and in response to exercise of similar intensity, increases in SAI scores have been found to co-occur with increased feelings of energy but not feelings of tension (Tate & Petruzzello, 1995). Moreover, even during exercise that induced increases in tension, ratings on a visual analogue scale with anchors referring directly to anxiety (i.e., from *not at all anxious* to *the most anxious I have ever felt*) remained unchanged (Steptoe & Bolton, 1988). This failure to account for the observed findings in a conceptually persuasive manner cannot but raise skepticism over the validity of the findings.

Conceptual and Related Psychometric Problems With the SAI in Exercise Research

Researchers have, in fact, identified some serious conceptual problems and associated confounding psychometric elements that emerge when the SAI is used in conjunction with bouts of vigorous exercise. In the first demonstration of such confounding effects, Rejeski et al. (1991) examined the responses to individual SAI items during and after a treadmill run at 75% of age-predicted maximum heart rate reserve. In their analysis, items related to perceived activation (e.g., "calm," "relaxed") showed increases (i.e., during exercise, participants felt less "calm" and less "relaxed," which are scored and interpreted as increases in state anxiety) and items referring to cognitive antecedents of state anxiety (e.g., "worried") showed decreases, whereas a third cluster of items remained unresponsive. Concealing the divergent changes among individual items, the total SAI score remained unchanged from pre- to during-exercise conditions. Also, consistent with the pattern of individual item responses, the coefficient α of internal consistency was dramatically reduced during exercise (.33 from .61 preexercise and .66 during recovery). Subsequent studies using a 10-item version of the SAI failed to replicate the extremely low α values reported by Rejeski et al. during exercise (McAuley et al., 1996; Tate & Petruzzello, 1995). Specifically, the values reported by McAuley et al. ranged during exercise from .81 to .91, and those reported by Tate and Petruzzello ranged from .71 to .92. However, McAuley et al., as well as Bartholomew and Linder (1998), essentially replicated the pattern of divergent individual item responses reported by Rejeski et al.

The presence of divergent response patterns among individual items raises serious concerns for the interpretability and validity of the total SAI score. This is because it appears that changes in items that connote perceived activation do not reflect changes in state anxiety but, rather, the perception of physiologic activation elicited in response to the metabolic demands of exercise.

Examining the Counterarguments: Does the SAI "Possess Construct Validity"?

Discussing the issues raised by Rejeski et al. (1991), Raglin (1997) asserted that

> This research (Rejeski et al., 1991) is not compelling, and until a sound theoretical rationale and empirical evidence can be presented, it is proposed that anxiety continue to be measured during physical activity by means of existing measures such as the STAI . . . that are known to possess construct validity. (p. 111)

This position was based on a series of arguments that we now examine.

First, Raglin (1997) noted that "anxiety responses were not contrasted with actual measures of physiological activity, but rather were limited to self-reports of perceived physiological activity" (pp. 110–111). It is not plainly obvious what is being perceived as a "limitation." One could assume that the alleged limitation lies in the assumption that the inclusion of actual measures of physiologic activity would have substantiated the claim that the increases in activation-laden items in the SAI were, in fact, linked to increases in physiologic activity. However, it should be emphasized that in the context of cognitive theories of emotion, such as Spielberger's theory of anxiety, it is the perception of physiologic activity that is relevant, not physiologic activity per se.

The second issue raised by Raglin (1997) was that "the measurement of state anxiety during the exercise session used only 8 of the 20 STAI-Y1 items" (p. 111). In fact, Rejeski et al. reported a correlation of .97 between the 8-item version and the complete 20-item version of the SAI. This argument again, however, seems to miss the main point. Both the complete 20-item version and the shortened 8-item version of the SAI include items that tap perceived activation, which can be influenced by exercise independently of changes in anxiety. Consequently, in the context of exercise, these items might be rendered invalid indicators of state anxiety as the construct was originally conceptualized by Spielberger (i.e., the experiential-cognitive, behavioral, and autonomic response that follows an appraisal of threat).

A third objection presented by Raglin (1997) was that "there was no indication that issues such as item content (i.e., anxiety-absent or anxiety-present) and item intensity specificity were considered" (p. 111). The issue of item intensity specificity could potentially be important in the context of the criticism presented by Rejeski et al. (1991), given the fact that the items that connote perceived activation (i.e., "calm," "relaxed") were also the only "anxiety-absent" items in the short version of the SAI that they used. However, what the notion of item intensity specificity refers to is varying degrees of *sensitivity* in response to a given stimulus between anxiety-present and anxiety-absent items. Instead, what Rejeski et al., as well as others (Bartholomew & Linder, 1998; McAuley et al., 1996), observed was that in response to vigorous exercise different items in the SAI respond in completely opposite directions! These are two quite different phenomena and should not be confused.

Raglin's (1997) fourth point was that "state anxiety was measured following the 15 min exercise period during a 2 min active cool-down rather than during a more intensive phase of the exercise session" (p. 111). Rejeski et al. (1991) reported that the stages of the exercise protocol were the following: (a) a 1-min warm-up walk, (b) a 3-min gradual increase of treadmill speed, (c) a 15-min run at 75% of maximum heart rate reserve, and (d) a 2-min cool-down. The during-exercise assessment of state anxiety took place "at the end of the 18th min" (p. 68), that is, near the completion of the main exercise phase. In any case, however, Raglin's contention that the SAI should have been administered "during a more intensive phase of the exercise session" (p. 111) is hard to comprehend, because, had the intensity of exercise been higher, the problem identified by Rejeski et al. would presumably have been even more accentuated; that is, participants would probably have felt even less calm and less relaxed.

Given the problems with the aforementioned arguments, the proposition that the SAI is known to possess construct validity, when examined in the context of exercise, remains unsubstantiated. In actuality, the SAI has never been formally validated in the context of exercise. Extensive use does not constitute validation, and there is no reason to believe that the SAI's demonstrated validity in other contexts necessarily transfers to the context of exercise.

Beyond these methodological and psychometric objections, Raglin's (1997) attempt to refute Rejeski et al.'s (1991) critique of the SAI was based on an attack of the conceptual premise of the critique. Specifically, Raglin claimed that the inflation of the SAI score by items responsive to exercise-associated activation does not constitute a confound, because, presumably, this is "not at odds with commonly accepted definitions of anxiety that include physiological activity as a *contributing* factor" (p. 110, emphasis added). In essence, the assumption here is that physiologic activation, regardless of origin, induces or even partly constitutes state anxiety. Because of its fundamental relevance to the issue at hand, a closer scrutiny of this assumption is warranted.

Going to the Source: Activation in Spielberger's Theory of Anxiety

The STAI was developed as the direct outgrowth of Spielberger's extensive state-trait theory of anxiety. Therefore, to better comprehend the origin of the problems encountered in the context of exercise and the veracity of Raglin's (1997) counterarguments, one must examine the role of activation in Spielberger's original conceptualization of state anxiety. In that theoretical framework, autonomic responses were assumed to be anxiety induced or anxiety related. According to Spielberger, Lushene, and McAdoo (1977), state anxiety is defined as

> The emotional reaction or response that is evoked when a person perceives a particular situation as personally dangerous or frightening for him, irrespective of the presence or absence of a real (objective) danger. If an individual appraises a specific situation as threatening, it is assumed that he will respond to it with an elevation in [state anxiety]; i.e., he will experience an immediate increase in the intensity of an unpleasant emotional state characterized by consciously experienced feelings of tension, apprehension, and heightened autonomic system activity (e.g., increased heart rate, blood pressure, and galvanic skin response). The intensity and duration of this transitory anxiety reaction will be determined by the amount of threat that is perceived, and by the persistence of the individual's appraisal of the situation as dangerous. (p. 242)

As is evident from this excerpt, the central element in the process of generating a state anxiety response is one's cognitive appraisal of the situation. In the absence of such an appraisal, no state anxiety response is induced, and when the appraisal ceases, so does the anxiety response. Autonomic activation is considered a consequence of the appraisal of threat and an integral part of the state anxiety experience, but it is not considered an antecedent condition, and certainly not a sufficient antecedent condition. Perceived autonomic activation is fed back to the process via sensory loops to bestow on state anxiety its distinctive experiential quality, but it does not, in itself (i.e., without an appraisal of threat), generate or constitute a state anxiety response: "In situations that are appraised by an individual as threatening, a [state anxiety] reaction will be evoked. Through sensory and cognitive feedback mechanisms, high levels of [state anxiety] will be experienced as unpleasant" (Spielberger, 1972, p. 44). Therefore, Spielberger's model proceeds from a stimulus to an anxiety-related appraisal and, ultimately, to a triune response consisting of behavioral, cognitive-experiential, and autonomic components. Within reasonable individual variation, the different links in this causal chain are theorized to function in a coordinated fashion. Consequently, the items of the SAI refer to the various parts of this process, with no distinction being made between the initial appraisal and subsequent responses or between the different aspects of the triune state anxiety response in the way that the scale is scored and interpreted.

It is noteworthy that, although Spielberger had acknowledged the multidimensional nature of anxiety (distinguishing between "worry" and "emotionality" elements) even before the 1983 revision of the STAI, and, accordingly, developed the Test Anxiety Inventory as a multidimensional measure (Spielberger, Golzalez, Taylor, Algaze, & Anton, 1978), the STAI was never revised to reflect this multidimensionality (cf. Spielberger, 1985). Nevertheless, testament to its exceptional popularity, the SAI seems to work well in the research paradigms in which it is typically used; that is, the internal consistency of the scale remains high and all items respond in a more or less unitary fashion when the experimental manipulation involves stimuli that induce perceptions of threat and no other stimuli are present that are capable of independently inducing changes in activation.

Acute vigorous exercise, however, presents a special case. In contrast to situations in which autonomic activation follows the appraisal of a situation as threatening, during and after vigorous exercise, autonomic activation increases in response to the metabolic demands of the exercise stimulus. It is very important to note that Spielberger himself was aware that activation can fluctuate independently of anxiety, and, in fact, he hoped that the SAI would be able to "facilitate distinguishing the physiological concomitants of anxiety as an emotional state from arousal due to physical exertion" (Spielberger, 1985, p. 14). Indeed, because the source of the increased activation during exercise is so evident, it is highly unlikely that exercisers will misattribute it to an emotional response (Sinclair, Hoffman, Mark, Martin, & Pickering, 1994). According to activation-emotion theories, it is only when the source of activation is unknown or the nature of the somatosensory percepts is ambiguous that a cognitive search for explanatory environmental cues is initiated (Cacioppo, Berntson, & Klein, 1992; Schachter & Singer, 1962).

In summary, from a critical theoretical standpoint, based on Spielberger's model, feeling less "calm" or less "relaxed" during or immediately after a session of vigorous exercise does not necessarily mean that one is more anxious, particularly when the increased activation occurs in the absence of any anxiety-associated cognitions. Similarly, following the termination of the exercise stimulus, certain perceptually salient physiologic indices such as blood pressure (e.g., Raglin & Morgan, 1987) and muscle tension (e.g., DeVries, 1987) have been shown to drop to levels below preexercise values. Again, it is theoretically inappropriate to equate the perception of such changes with decreases in anxiety.

Purpose of the Present Studies

The study of the relationship between exercise and affect is currently at a critical juncture. Exercise psychology researchers are now venturing into systematic theory testing and are taking on the important and timely topic of the dose–response relationship between physical activity and affective responses. Clearly, the way we conceptualize and operationally define the dependent variables of interest is a fundamental factor in determining the scientific quality of future research endeavors. In this context, the purpose of the present studies was to reproduce some of the findings commonly reported in exercise research using the SAI and then to dissect them from a conceptual and psychometric standpoint in an effort to help shed light on the controversy.

Study I

The purpose of this study was to replicate the pattern of individual SAI item responses reported by Rejeski et al. (1991) and McAuley et al. (1996) and to examine the internal consistency of the scale in response to exercise. Furthermore, activation and affective valence responses were independently assessed and contrasted with SAI-based findings.

Methods

Participants. Forty-five women undergraduate students volunteered to participate. They were recruited from fitness programs in which they were regular participants. They first read and signed an informed consent form approved by the Institutional Review Board.

Measures. The eight-item version of the SAI (Spielberger, 1979a) was used in order to allow comparisons with the results obtained by Rejeski et al. (1991). As in the original 20-item version, the response scale has four points, with anchors ranging from *not at all* to *very much so*. The total score of the scale ranges from 8 to 32.

Two pairs of single-item measures of affective valence and activation were used to assess the basic dimensions of the circumplex model of affect, as described by Russell (1978, 1980, 1989). In one pair, the Feeling Scale (FS; Hardy & Rejeski, 1989) was used as a measure of affective valence, and the Felt Arousal Scale (FAS) of the Telic State Measure (Svebak & Murgatroyd, 1985) was used as a measure of activation. The FS is an 11-point bipolar measure of pleasure–displeasure, which is being used extensively for the assessment of affective responses during exercise. The scale ranges from –5 to +5. Verbal anchors are provided at the 0 point (*neutral*) and at all odd integers, ranging from *very good* to *very bad*. The FAS is a six-point scale of perceived activation ranging from 1 (*low arousal*) to 6 (*high* *arousal*). The FAS has been used extensively in the context of reversal theory research, including exercise-related studies (e.g., Kerr & Vlaswinkel, 1993).

The second pair of valence/activation scales was formed using the Valence and Arousal scales of the paper-and-pencil version of the Self-Assessment Manikin (SAM; Bradley & Lang, 1994; Hodes, Cook, & Lang, 1985; Lang, 1980). The Valence scale (SAM-V) includes a strip of five cartoons showing a character with facial expressions that range from very happy to very unhappy. The Arousal scale (SAM-A) includes a strip of five cartoons of a character showing physical signs ranging from extreme activation (heart pounding) to sleepiness (closed eyes). No verbal anchors are provided. The SAM has been used extensively in psychophysiologic research, and formal evidence of its construct validity, as evidenced by correlations with the Semantic Differential Scales, is satisfactory (Bradley & Lang). All scales were administered with the standard instructions recommended by their developers.

Procedure. The exercise stimulus consisted of a typical aerobics class lasting 50 min. The session included a 10-min warm-up, a main aerobic phase lasting approximately 20 min, a strength and conditioning phase lasting approximately 10 min, and a cool-down phase lasting approximately 10 min. The self-report measures were administered three times during the procedure: (a) immediately before, (b) 20 min later (during a 2-min break), and (c) immediately after the exercise session. At those times, to check the intensity of the exercise stimulus, the participants also measured their heart rates by palpation of the radial artery (at 15-s intervals) and responded to the Rating of Perceived Exertion Scale (RPE; Borg, 1970).

Analysis. Data analysis was conducted in two stages. First, a set of "traditional" analyses was performed to examine changes in the total SAI score. This entailed an initial repeated-measures analysis of variance (ANOVA), followed by Fisher-Hayter tests (Kirk, 1995) for a posteriori pairwise comparisons and calculations of effect sizes: $d = (M_i - M_j)/SD_{pooled}$. The second stage of analysis involved a critical, conceptually driven dissection of the findings from the first stage. Initially, individual item responses were examined to determine whether there were divergent response patterns. Second, various indices of internal consistency were calculated for each of the three administrations of the SAI. Finally, activation and valence ratings from the same time points were examined to further substantiate the findings from the analysis of individual SAI item responses.

Results and Discussion

The intensity of the exercise was approximately 59% of the participants' age-predicted maximum heart rate reserve. Average heart rates across the three assessments were 72, 147, and 119 beats/min, respectively. At the same times, RPEs were 10, 15 ("hard"), and 13, respectively.

The repeated-measures ANOVA on the total SAI scores from the three administrations (preexercise, during exercise, postexercise) revealed a significant main effect of time, $F(2, 80) = 6.63$, $p < .01$. Follow-up Fisher-Hayter tests (see Table 1) showed that the total SAI score remained unchanged from pre- to during exercise but was significantly reduced thereafter: $d = -0.46$. This also made the pre-to-post-exercise comparison significant: $d = -0.46$.

Traditional statistical analysis involving the SAI would probably stop at this point, so studies would report that although no statistically significant reduction in

Table 1 Means and Standard Deviations of Individual Item and Total SAI Scores, Study I

	Preexercise		During exercise		Postexercise	
	M	*SD*	*M*	*SD*	*M*	*SD*
1. Calm[a]	2.36	0.86	2.95[b]	0.78	2.23[c]	1.02
2. Tense	2.18	1.06	1.86[b]	0.82	1.63[d]	0.82
3. Upset	1.35	0.69	1.20	0.55	1.12[d]	0.39
4. Frightened	1.11	0.44	1.04	0.30	1.02	0.15
5. Nervous	1.45	0.87	1.23	0.56	1.21	0.56
6. Relaxed[a]	2.36	0.99	2.61	0.87	2.30	0.94
7. Worried	1.89	0.97	1.29[b]	0.55	1.26[d]	0.58
8. Confused	1.39	0.69	1.27	0.62	1.16[d]	0.53
Total score	14.05	4.94	13.48	3.03	11.95[c,d]	3.54

Note. Items are shown in abbreviated format. Follow-up Fisher-Hayter tests were conducted only for items with significant repeated-measures ANOVAs.
[a]Item was reverse-scored. [b]Significant change from pre- to during exercise. [c]Significant change from during to postexercise. [d]Significant change from pre- to postexercise.

state anxiety was observed 20 min into a session of aerobics, a significant decrease was found at the end of the 50-min session. Given that this finding is consistent with the literature on SAI responses to acute exercise (Petruzzello et al., 1991), it is unlikely that the results would raise any skepticism. Instead, on the basis of these findings, researchers might conclude that exercising for 20 min is not sufficient to elicit a significant reduction in state anxiety, and they would probably recommend that people exercise for longer periods of time to reap the benefits (e.g., Dishman, 1986; Raglin & Morgan, 1985). To test the validity of such conclusions, we examined the findings more closely.

First, we examined the changes in individual SAI items. The SAI was developed as a unidimensional measure of state anxiety, and scoring instructions reflect this conception. Thus, all items included in the scale should, theoretically, tap a common latent variable—namely, state anxiety—and respond to relevant stimuli in a unitary direction. A significant initial multivariate ANOVA (MANOVA) for all eight items (Wilks's $\lambda = .227$, $p < .001$) was followed by univariate ANOVAs. Significant time effects were found for five of the eight individual items: calm, $p < .001$; tense, $p < .01$; upset, $p < .05$; worried, $p < .001$; and confused, $p < .05$. Among them, follow-up Fisher-Hayter tests showed that "tense," "upset," "worried," and "confused" exhibited statistically significant decreases compared with preexercise levels at either 20 or 50 min (see Table 1).

On the other hand, consistent with previous research (McAuley et al., 1996; Rejeski et al., 1991), the items "calm" and "relaxed" showed a divergent change pattern, increasing from pre- to during exercise (note that decreases in reported calmness and relaxation are scored as increases in state anxiety, according to SAI's scoring procedures) and decreasing thereafter (although the changes in the "relaxed" item were not statistically significant); that is, participants reported feeling less calm and relaxed during exercise than pre- (d = 0.72 and d = 0.28, respectively) and postexercise (d = 0.80 and d = 0.35, respectively). Thus, the lack of a significant change in the total SAI score from pre- to during exercise was in fact the result of counteracting (i.e., increasing vs. decreasing) trends among individual items. "Calm" and "relaxed" accounted for a combined increase of .85 units, whereas the remaining six items accounted for a combined decrease of 1.44 units. Conversely, the statistically significant reduction in total SAI score from during to postexercise came about as a result of a unified decreasing trend among all items. This pattern of findings runs counter to the assumptions of unidimensionality and cross-situational structural invariance of the SAI. Apparently, during exercise, and presumably *because* of the stimulus properties of exercise, some items begin to reflect latent variables other than state anxiety per se.

To examine the internal consistency of the scale, we calculated Cronbach's α, mean interitem correlations, and mean corrected item-total correlations for each administration. The results are presented in Table 2. All three indices show patterns of exercise-associated decrease. An item analysis was conducted in order to identify the causes of this phenomenon. It was found that the mean item variances before, during, and after exercise were .72, .43, and .47, respectively. This exercise-associated decrease is likely to reflect the strong impact of floor effects on some items. For example, the variance of the item "frightened" was reduced by a factor of 10 (pre-, .20; during, .09; post-, .02). Moreover, the items "calm" and "relaxed," although related to each other (pre-, .82; during, .59; post-, .58), had diminished squared multiple correlations to other items (pre-, .71 and .77; during, .39 and .49; post-, .43 and .39 for calm and relaxed, respectively) and corrected item-total correlations (pre-, .71 and .76; during, .40 and .33; post-, .51 and .46, for calm and relaxed, respectively). Thus, the decline in internal consistency during and after exercise could be attributed to reduced item variances resulting from floor effects and the possible emergence of a separate factor comprising the items "calm" and "relaxed."

The next analytic step involved examining the dynamics of affective valence and activation using the FS, FAS, SAM-V, and SAM-A. Using these scales in pairs (one pair consisting of FS and FAS and the other of the two scales of the SAM), we obtained two independent operationalizations of the affect circumplex, as described by Russell (1978, 1980, 1989; also see Larsen & Diener, 1992, for a review).

The responses to the FS and FAS are shown in Figure 1. The results obtained from the SAM were similar and are not shown here. Repeated-measures ANOVAs

Table 2 Indices of Internal Consistency of the 8-Item SAI, Study I

	Preexercise	During exercise	Postexercise
Cronbach's alpha	.87	.71	.80
Mean interitem correlation	.46	.23	.42
Mean corrected item-total correlation	.64	.40	.57

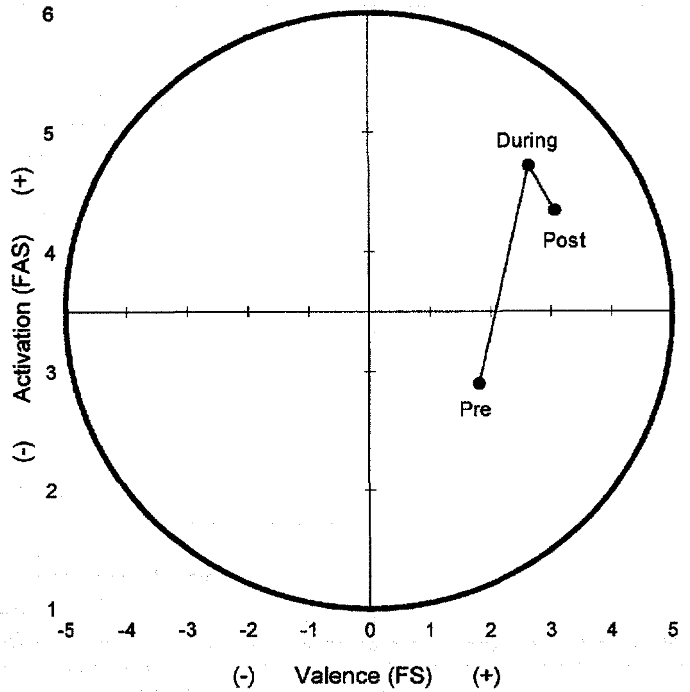

Figure 1 — Responses to the FS (affective valence) and FAS (perceived activation) in Study I plotted in circumplex space.

indicated significant main effects of time for both the FS, $F(2, 80) = 15.57, p < .001$, and the FAS, $F(2, 80) = 53.14, p < .001$. Follow-up Fisher-Hayter tests showed that participants experienced a substantial shift toward higher activation, $d = 1.72$, and more pleasant affect, $d = 0.40$, from pre- to during exercise, followed by a small but significant reduction in activation, $d = -0.33$, coupled with a further, nonsignificant improvement in affective valence, $d = 0.13$, from during to postexercise. These results indicate that overall, activation plays a major role in affective responses to exercise; changes along the activation dimension might, in fact, supersede changes along the valence dimension in determining the exerciser's affective state.

These findings provide some insight into the response patterns of individual SAI items. It is reasonable to suggest that the decreased calmness and relaxation noted during the first part of the exercise bout reflect the increase in activation shown in the circumplex analysis. As the circumplex analysis clearly indicates, however, this increased activation was in fact associated with positive affective valence. The confound in the SAI is a result of the fact that the SAI does not allow for positively laden activation (or negatively laden deactivation, for that matter); that is, all increases in perceived activation are considered anxiety related or anxiety induced and are therefore tied to negative affectivity (conversely, all decreases in perceived activation are considered indices of reduced anxiety and are therefore presumed to be tied to reduced negative affectivity).

Conclusions

These findings indicate that, in response to a session of aerobics, the total SAI score confounds changes in activation with changes in other components of state anxiety. Specifically, in the first part of the exercise session individual items exhibited divergent response patterns, indicating increased activation coupled with reduced tension and apprehension. Examining affective responses from a circumplex framework provided additional evidence that during that period, increased activation was coupled with improved affective valence. Because of the assumptions on which its development was based, however (i.e., that perceived activation is anxiety related), the SAI does not allow for positively laden activation, hence the confound. Furthermore, consistent with the notion of violated factorial invariance of the SAI across nonexercise versus exercise situations, various indices of internal consistency showed patterns of exercise-related deterioration.

Study II

The purpose of this study was to reproduce the phenomenon of increased SAI scores commonly found immediately after strenuous exercise and to dissect this finding in a manner similar to that applied in Study I. To illustrate that the problems in the SAI are not a function of the different versions of the scale, but rather a function of item content in conjunction with the unique properties of the exercise stimulus, a different version of the scale was used (10-item; Spielberger, 1979a). Furthermore, to substantiate the confounding effect of activation on SAI scores, a circumplex analysis similar to the one in Study I was employed. In order to demonstrate that the pattern of exercise-associated affective changes shown in Study I was independent of the measurement instruments, we employed a different operationalization of the affect circumplex, using the Activation–Deactivation Adjective Checklist (AD ACL; Thayer, 1989).

Methods

Participants. A total of 69 undergraduate students volunteered to participate. The sample included 31 women (mean age = 20.84, *SD* = 2.11 years; mean $\dot{V}O_2max = 50.64$, $SD = 5.91$ ml · kg^{-1} · min^{-1}) and 38 men (mean age = 21.97, *SD* = 3.43 years; mean $\dot{V}O_2max = 57.64$, $SD = 8.57$ ml · kg^{-1} · min^{-1}). Before their involvement in the study, participants read and signed an informed consent form approved by the Institutional Review Board. They were each paid $10 for participating.

Measures. A 10-item short version of the SAI and the AD ACL were used in this study. The 10 items of the SAI and the 20 items of the AD ACL were interspersed in random order on the same sheet, using a four-point scale ranging from *not at all* to *very much so*.

The 10-item version of the SAI (Spielberger, 1979a) has been recommended by Spielberger for repeated administrations over a short period of time. It includes six of the items of the eight-item version used in Study I (compare the list of items in Tables 1 and 3). Reported α coefficients from samples of men and women navy recruits and college students ranged from .84 to .92 (Spielberger, 1979a). The total score of the scale ranges from 10 to 40.

The AD ACL (Thayer, 1989) is a 20-item inventory that offers standardized operationalizations of Thayer's theoretical bipolar dimensions of energetic arousal (EA) and tense arousal (TA). EA ranges from energy to tiredness, and TA ranges from tension to calmness. Each of the four poles is assessed by five items (scores ranging from 5 to 20). Extensive psychometric information has been provided by Thayer (1978, 1986). The AD ACL has been used in conjunction with various exercise stimuli (e.g., Tate & Petruzzello, 1995; Thayer, 1987), and the findings seem to support Thayer's (1989) multidimensional activation theory.

The AD ACL was employed within a circumplex framework. The dimensions of EA and TA were used to define the circumplex affective space. Following Thayer's (1989) conception, the orthogonal system defined by EA and TA was used as a 45° rotational variant of the activation-valence system used in Study I. That is, "energy" was placed in the high activation–pleasantness quadrant of the circumplex, and its bipolar opposite, "tiredness," was placed in the low activation–unpleasantness quadrant. Conversely, "tension" was placed in the high activation–unpleasantness quadrant, and "calmness" was placed in the low activation–pleasantness quadrant.

Procedures. In a preliminary session conducted several days before the experimental session, the maximal aerobic capacity ($\dot{V}O_2max$) of the participants was determined through an incremental exercise test on a treadmill. Expired gases were analyzed on-line using a metabolic cart. The point of $\dot{V}O_2max$ was determined by the following criteria: volitional exhaustion, a respiratory exchange ratio higher than 1.1, or a prolonged plateau in oxygen consumption.

The exercise intensity used in the experimental session was 75% of each subject's $\dot{V}O_2max$ recorded during the maximal exercise test. Following a 3-min warm-up at 5 m/hr, the speed of the treadmill was increased until the exerciser's heart rate reached the level that corresponded to 75% of $\dot{V}O_2max$. During the main phase of the exercise session, the intensity was maintained by telemetrically monitoring the exerciser's heart rate and adjusting the speed of the treadmill as needed. This phase lasted for 22 min and was followed by a 5-min cool-down at 5 m/hr. Participants recorded their responses to the SAI and the AD ACL three times: immediately before, immediately after, and 10 min after the exercise bout.

Analysis. As in Study I, the analysis was conducted in two stages, the first consisting of "traditional" analyses on the total SAI score and the second consisting of (a) analysis of change at the item level, (b) calculations of indices of internal consistency, and (c) a circumplex analysis using the AD ACL. Furthermore, given the better item-to-participant ratio achieved in this study, a principal-components analysis of the SAI data collected immediately postexercise was conducted to determine whether the structure of the scale at that point conformed to the unidimensional structure postulated by its developers.

Results and Discussion

The initial repeated-measures ANOVA on the total SAI score was significant, $F(2, 136) = 9.72, p < .001$. Follow-up Fisher-Hayer tests (see Table 3) indicated that there was a significant increase in the total SAI score from pre- to immediately postexercise, $d = 0.43$, followed by a significant decrease within the next 10 min, $d = -0.28$. The difference in SAI scores from pre- to 10 min postexercise was not statistically significant.

Table 3 Means and Standard Deviations of Individual Item and Total SAI Scores, Study II

	Preexercise		During exercise		Postexercise	
	M	*SD*	*M*	*SD*	*M*	*SD*
1. At ease[a]	1.65	0.70	2.14[b]	0.88	1.91[c,d]	0.87
2. Jittery	1.23	0.49	1.43[b]	0.63	1.26[c]	0.50
3. Frightened	1.01	0.12	1.03	0.17	1.01	0.12
4. Worried	1.20	0.47	1.16	0.41	1.25	0.50
5. Calm[a]	1.75	0.81	2.20[b]	0.87	1.91[c]	0.80
6. Nervous	1.29	0.49	1.14[b]	0.35	1.13[d]	0.34
7. Relaxed[a]	1.83	0.80	2.23[b]	0.94	1.90[c]	0.77
8. Steady[a]	2.04	0.85	2.41[b]	0.81	2.45[d]	0.68
9. Tense	1.32	0.56	1.42	0.60	1.28	0.51
10. Worrying	1.51	0.80	1.35[b]	0.70	1.35[d]	0.66
Total score	14.84	3.86	16.52[b]	3.92	15.45[c]	3.64

Note. Items are shown in abbreviated format. Follow-up Fisher-Hayter tests were conducted only for items with significant repeated-measures ANOVAs.
[a]Item was reverse-scored. [b]Significant change from pre- to immediately postexercise. [c]Significant change from immediately post- to 10 min postexercise. [d]Significant change from pre- to 10 min postexercise.

The finding of an increase in SAI scores after acute exercise of intensity similar to that employed in the present study (e.g., Raglin & Wilson, 1996) or greater (e.g., O'Connor, Petruzzello, Kubitz, & Robinson, 1995) is not uncommon in the literature. Therefore, once more, it is unlikely that such a finding would elicit any skepticism. Instead, it is more likely that researchers would treat the phenomenon as a substantive finding and engage in a search for likely reasons that exercise would cause an increase in state anxiety.

As in Study I, we proceeded to examine these findings more closely, starting with an analysis of change patterns at the item level. The initial MANOVA was significant, Wilks's $\lambda = .315$, $p < .001$. Subsequent repeated-measures ANOVAs showed significant variation across time for 7 of the 10 items: at ease, $p < .001$; jittery, $p < .01$; calm, $p < .001$; nervous, $p < .001$; relaxed, $p < .001$; steady, $p < .001$; worrying over possible misfortunes, $p < .01$. An inspection of change patterns among these items by means of Fisher-Hayter tests (see Table 3) indicated that exercise brought about significant increases in some items (less at ease, $d = 0.62$; more jittery, $d = 0.40$; less calm, $d = 0.53$; less relaxed, $d = 0.46$; less steady, $d = 0.44$) but decreases in others (less nervous, $d = -0.34$; less worrying, $d = -0.21$). With the sole exception of "steady," all the items showing increases immediately postexercise had regressed significantly toward baseline 10 min into recovery.

Consistent with the findings from Study I, it appears that the postexercise increase in total SAI score was driven by items pertaining to activation and effort-related tension. On the other hand, items assessing cognitive apprehension, including "worrying" and "nervous," decreased. Because of the small number of such items, however, their impact on the total SAI score was offset by the increases in the activation-related items. This analysis is important because it provides evidence that the significant increase in the total SAI score is in fact unrelated to changes in what Spielberger considered the core of the state anxiety response process, namely, the cognitive appraisal of threat. Contrary to what the total score suggests, participants actually reported significantly reduced worry and nervousness after exercise.

The internal consistency of the scale at each of the three administrations was examined next. The results are shown in Table 4. Indices that are independent of the number of items, such as the mean interitem correlations and mean corrected item-total correlations (Nunnally & Bernstein, 1994), revealed that, overall, the 10-item version of the SAI was less internally consistent than the 8-item version used in Study I. Almost one third (13 of 45) of the interitem correlations obtained immediately postexercise were lower than .10 (five of them being negative), and almost half (20 of 45) were not statistically significant. Nevertheless, by virtue of its 10 items, the α coefficient was .77, a value that would probably be considered adequate by most.

This brings up a very important point. Since Rejeski et al.'s (1991) critique of the SAI, some researchers have been reporting values of the α coefficient in the "acceptable" range as evidence of the psychometric integrity of the SAI in the exercise context. However, the problems identified by Rejeski et al. bear directly on issues of item homogeneity and dimensionality, not only internal consistency. As many authors have emphasized, using the α coefficient as an index of item homogeneity constitutes one of the most serious abuses of this coefficient (Cortina, 1993; Green, Lissitz, & Mulaik, 1977; Schmitt, 1996). This is because the α coefficient is a function of the *average* interitem correlation, which certainly does not exclude the possibility of a nonhomogeneous (i.e., multidimensional) structure. This is precisely the case with the interitem correlation matrix obtained immediately after exercise in this study. As discussed in the preceding paragraph, some items were correlated, but other interitem correlations were near zero.

To examine the structure of this matrix, a principal components analysis was conducted, followed by a varimax rotation (an oblique rotation was also examined, with similar results). By all criteria used (eigenvalues >1.0, scree plot, variance accounted for, and interpretability), a three-component solution accounting for 69.4% of the variance was deemed most appropriate (see Table 5). The components were well defined, had minimal cross-loadings, and were easily identifiable.

Table 4 Indices of Internal Consistency of the 10-Item SAI Pre-, Immediately Post-, and 10 Min Postexercise, Study II

	Preexercise	0 min postexercise	10 min postexercise
Cronbach's alpha	.80	.77	.79
Mean interitem correlation	.29	.26	.28
Mean corrected item-total correlation	.48	.45	.47

Table 5 Results of Principal Components Analysis of the SAI Immediately Postexercise, Study II

	Principal Components			
	I	II	III	h^2
Calm	.87			.77
Relaxed	.82			.73
Steady	.82			.67
At ease	.81			.70
Tense	.60	.40		.54
Worrying		.90		.82
Worried		.88		.84
Nervous		.41	.75	.73
Jittery			.71	.64
Frightened			.61	.49
Eigenvalues	3.55	2.36	1.02	
Cum. % variance	35.5	59.2	69.4	

Note. Items are shown in abbreviated format. Loadings <.40 are omitted.

The first component was labeled effortful tension and consisted of all the anxiety-absent items and the item "tense." The inclusion of the item "tense" in this component is important because it indicates that the formation of the component was not the product of item intensity specificity or item method variance. The second component comprised the two items directly referring to worry. The third component consisted of other apprehension items. Although the extraction of three components from 10 items might be considered overfactoring, the clarity and meaningfulness of the emergent structure points to a substantive finding. That is, immediately after a bout of vigorous exercise, the cognitive elements of anxiety and the activation component that normally accompanies them are dissociated.

It is important to note that similar principal components analyses of the interitem correlation matrices obtained before and 10 min after exercise (not reported here but available from the first author) produced results that were consistent with those of previous factor-analytic studies of the STAI, distinguishing between anxiety-present and anxiety-absent items (Brown & Duren, 1988; Sherwood & Westerback, 1983; Spielberger, 1983; Spielberger, Vagg, Barker, Donham, & Westberry, 1980; Vagg, Spielberger, & O'Hearn, 1980). A test of the factorial invariance of the scale by means of confirmatory factor analysis is needed to formally examine this proposition (Byrne, Shavelson, & Muthen, 1989), but the change in the structure of principal components might indicate a violation of the assumption of factorial invariance across nonexercise versus exercise conditions.

As in Study I, to further document the confounding effects of activation observed in the response patterns of individual SAI items, we examined the data collected with the AD ACL. The main effect of time was significant for all four of the AD ACL scales: energy, $F(2, 136) = 73.49, p < .001$; tiredness, $F(2, 134) = 39.62, p < .001$; tension, $F(2, 136) = 13.95, p < .001$; calmness, $F(2, 134) = 45.03$,

$p < .001$. The mean for each scale across time, plotted in the affect circumplex, is shown in Figure 2. Follow-up Fisher-Hayter tests showed that from pre- to postexercise, energy increased, $p < .01$, $d = 1.33$, whereas tiredness (its bipolar opposite) decreased, $p < .01$, $d = -1.02$. Likewise, tension increased, $p < .01$, $d = 0.52$, whereas calmness (its bipolar opposite) decreased, $p < .01$, $d = -1.14$. Conversely, during exercise recovery, energy decreased, $p < .01$, $d = -0.74$, whereas tiredness increased, $p < .01$, $d = 0.47$, and tension decreased, $p < .01$, $d = -0.49$, whereas calmness increased, $p < .01$, $d = 0.68$. It should be noted that this pattern of changes is consistent with the predictions of Thayer's (1989) model, whereby changes in the dimensions of EA and TA are positively correlated at moderate levels of energy expenditure; that is, increases in tension co-occur with increases in energy, and shifts toward tiredness co-occur with shifts toward calmness.

The implications of these findings for interpreting the responses of individual SAI items is that, even when the exercise stimulus is as intense as it was in this case and capable of inducing increases in perceived tension, there is no basis for assuming that increased activation is linked to anxiety. In fact, as it became evident from the analysis of AD ACL, tension can co-occur with feelings of energy. It is important to note that because the AD ACL allows for variants of affective experience that the SAI does not (such as pleasant high activation and unpleasant low activation), it is more likely to remain internally consistent in response to

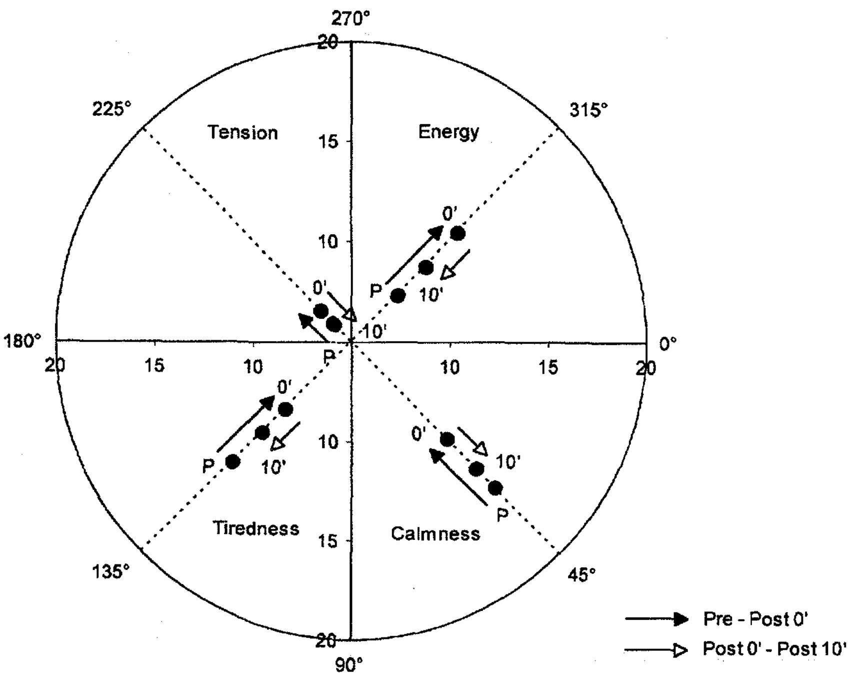

Figure 2 — Responses to the AD ACL scales (energy, tiredness, tension, calmness) in Study II plotted in circumplex space. The scales were rotated 45° for plotting using trigonometric procedures.

various stimuli including exercise. To demonstrate this, indices of internal consistency of the AD ACL scales, including extrapolations to 10 items using the Spearman-Brown prophecy formula (Nunnally & Bernstein, 1994) for the purposes of allowing comparisons to the 10-item SAI, are shown in Table 6. Overall, the internal consistency of the scales ranged from satisfactory to excellent (.65 to .92). It is noteworthy that the scale that exhibited the lowest levels of internal consistency was the tension scale. Our analysis indicated that this was caused by the floor effects (i.e., extremely low means, variances, and covariances) associated with the item "fearful," a finding that underscores the fact that items referring to appraisals of threat might be irrelevant (and, thus, psychometrically weak) in the absence of threat-conducive conditions.

Conclusions

In summary, the confounding effect of activation identified in Study I was replicated here. Exercise performed at 75% $\dot{V}O_2$max produced an increase in SAI scores above baseline. Resting on the assumption that the SAI remains a valid measure of state anxiety in the context of exercise, one would have reached the conclusion that vigorous exercise is anxiety inducing. However, an examination of changes at the item level indicates that the increase in the total score was a function of increases in items associated with activation and effort-related tension

Table 6 Indices of Internal Consistency of the Scales of the AD ACL, Study II

	Preexercise	0 min postexercise	10 min postexercise
Energy			
Cronbach's alpha	.92 (.96)	.88 (.94)	.88 (.94)
mean interitem correlation	.69	.61	.60
mean corrected item-total correlation	.79	.73	.72
Tiredness			
Cronbach's alpha	.92 (.96)	.85 (.92)	.90 (.95)
mean interitem correlation	.71	.53	.65
mean corrected item-total correlation	.81	.66	.76
Tension			
Cronbach's alpha	.67 (.80)	.65 (.79)	.73 (.84)
mean interitem correlation	.28	.27	.37
mean corrected item-total correlation	.43	.41	.51
Calmness			
Cronbach's alpha	.75 (.86)	.82 (.90)	.82 (.90)
mean interitem correlation	.38	.48	.48
mean corrected item-total correlation	.53	.61	.62

Note. Values in parentheses are extrapolated estimates from 5- to 10-point scales, based on the Spearman-Brown prophecy formula.

rather than state anxiety per se. In fact, items referring to anxiety-related cognitions showed significant decreases. The emergence of distinct components in the item structure was supported by internal consistency and principal-components analyses. As in Study I, examining affective changes from a circumplex framework helped elucidate the nature and dynamics of these changes while avoiding confounds.

General Discussion

The studies presented here examined the information derived from SAI-based assessments of state anxiety from a critical psychometric perspective. We were able to reproduce some SAI-based findings commonly reported in the literature, such as the absence of a significant change after 20 min of moderate exercise and an increase in SAI scores immediately after a bout of vigorous running. Our analyses provide evidence that the validity of these findings is undermined by conceptual and psychometric problems associated with the use of the SAI in conjunction with exercise stimuli. Given that the SAI has never undergone a formal psychometric evaluation in the context of exercise, this demonstrates in the most illustrative manner the dependence of the knowledge-development process on the measurement technology used. As emphasized in the introduction to this article, SAI-based findings have been used as a basis for deriving widely echoed conclusions regarding dose–response relationships (e.g., Dishman, 1986; Raglin & Morgan, 1985), as well as a basis for testing theoretical predictions (e.g., Petruzzello, Landers, & Salazar, 1993; Youngstedt, Dishman, Cureton, & Peacock, 1993).

The analyses reported here call the validity, internal consistency, and factorial invariance of the SAI in the context of acute exercise into question. According to Spielberger's theory of anxiety, autonomic activation (and, presumably, perceived activation) is a direct consequence of the perception of threat. Therefore, assuming that (a) a threatening stimulus is present, (b) the stimulus is appraised as threatening, and (c) no stimulus capable of inducing changes in activation is present, other than the perception of threat itself, increased perceived activation can be considered a valid index of state anxiety. This is probably a safe set of assumptions in the majority of situations in which no extraneous factors are present that might interfere with this causal chain. However, exercise clearly presents a special case, in which profound increases in activation are induced that are not linked to anxiety. In fact, increased activation in most cases appears to be linked to positive affect. In the case of highly demanding exercise stimuli, shifts toward increased activation might be coupled with unpleasantness, but this combination is characteristic of effort-related tension rather than anxiety, because it occurs in the absence of anxiety-related cognitions such as worry and apprehension.

In the studies presented here, the dissociation of items that indicate perceived activation from items that indicate other components of state anxiety was demonstrated in several ways. First, in analyses of change at the item level, activation items exhibited change patterns that opposed those of cognitive items. Second, in analyses of internal consistency at the scale and item levels, symptoms of exercise-related decreases were found. Third, a principal-components analysis indicated that immediately after a bout of vigorous exercise the SAI assumed a multidimensional structure, with distinct activation/tension and worry/apprehension components. Fourth, parallel analyses of affective responses using a circumplex framework showed that increases in perceived activation during and immediately after exercise were primarily coupled with positive affective valence. Even in Study II, in which the vigorous nature of the exercise stimulus brought about an increase in tension and a decrease in calmness, these changes were accompanied by an increase in energy and a decrease in tiredness.

Calling into question the validity and overall psychometric integrity of the SAI in the context of exercise entails calling into question the validity of what has been heretofore regarded as an extensive body of knowledge. As daunting and perhaps embarrassing a task as it might be, one should begin to place many of the conclusions from exercise studies involving the SAI under a critical light (cf. Petruzzello et al., 1991; Raglin, 1997). Two considerations are important. First, one should keep in mind that, despite the clarity and consistency of the data reported herein, it would be imprudent to attempt generalizations of the findings to different populations and exercise stimuli without direct empirical evidence. Second, these findings should not be taken to imply that exercise does not modify state anxiety. The failure of the measure should be distinguished from the effectiveness of the method. In fact, if the analyses of individual SAI items reported here are any indication, exercise was consistently shown to reduce the elements that are theorized to form the core of the state anxiety response process, namely, the cognitive antecedents of anxiety, such as worry and apprehension.

Given the problems associated with the SAI, what, then, is the solution for researchers interested in studying anxiety in the context of exercise? First, researchers must contemplate whether it is, in fact, anxiety per se (i.e., the emotional reaction that follows the perception of a situation as threatening) that they are interested in. This is a fundamental consideration, which becomes even more critical in light of the fact that a compelling case has yet to be made for examining state anxiety in exercise studies involving nonanxious samples and in the absence of anxiety-inducing treatments. In general (but with possible exceptions), state anxiety depends on the presence of potentially threatening stimuli in the environment, the presence of an anxiety-conducive disposition, and, primarily, the presence of an anxiety-congruent pattern of appraisals. In the absence of such conditions, either naturally occurring or experimentally induced, studying exercise effects on state anxiety does not appear to make much sense.

On the other hand, there are certainly situations in which there is a theoretical basis for studying state anxiety in conjunction with acute exercise, for example, when examining trait-anxious (e.g., Breus & O'Connor, 1998) or clinically anxious subjects (e.g., Cameron & Hudson, 1986) or when state anxiety is experimentally induced before, during, or after the exercise intervention (e.g., Acevedo, Dzewaltowski, Kubitz, & Kraemer, in press; Crocker & Grozelle, 1991; Kleine, 1994). In these cases, the operationalization of state anxiety presents a considerable challenge. The selection of a psychometric instrument should be based on the researcher's theoretical approach. If one accepts the prevailing cognitive conceptualization of anxiety (which is presumably what exercise psychology researchers have been doing by accepting Spielberger's appraisal-based model), then a reasonable choice would be to focus on the cognitive antecedents of state anxiety, that is, to distinguish the cognitive antecedents—which are theorized to be the initiating, necessary, and sufficient factor—from concomitants and consequences (e.g., see Rost & Schermer, 1989, and Schwarzer & Quast, 1985, for examples in anxiety and Barnett & Gotlib, 1988, for an example in depression).

A substantial literature has evolved from Lazarus' (1991a, 1991b, 1999) cognitive relational theory of emotion, which is now being applied to specific emotions including anxiety (Ellsworth & Smith, 1988; Reisenzein & Hofmann, 1993; Reisenzein & Spielhofer, 1994; Smith & Lazarus, 1993). This research seeks to identify the patterns of cognition that underlie each emotion. According to Lazarus (1991a), the core relational theme underlying anxiety is "uncertain, existential threat" (p. 235), and the key differentiating appraisal is the "protection of personal meaning or ego-identity against existential threats" (p. 237). Thus, the use of measurement instruments that focus on or provide separate scales for assessing the cognitive antecedents of anxiety, with emphasis on the perception of ego-related threats, would be recommended.

In conclusion, we echo the concern expressed by Rejeski et al. (1991) regarding the use of the SAI in the context of acute exercise. Researchers who are still not convinced are urged to reexamine some of their existing data at the item level and perform tests of the structural invariance of the SAI's proposed unidimensional structure across different phases of an exercise bout and across exercise stimuli of different dose characteristics. Researchers now venturing into studies of the exercise–affect relationship are urged to consider whether they are interested in state anxiety per se; if so, they should devise experimental protocols and measurement approaches that specifically target the cognitive antecedents of anxiety.

References

Acevedo, E.O., Dzewaltowski, D.A., Kubitz, K.A., & Kraemer, R.R. (in press). Effects of a proposed challenge on effort sense and cardiorespiratory responses during exercise. *Medicine and Science in Sports and Exercise*.

Barnett, P.A., & Gotlib, I.H. (1988). Psychosocial functioning and depression: Distinguishing among antecedents, concomitants, and consequences. *Psychological Bulletin*, **104**, 97-126.

Bartholomew, J.B., & Linder, D.E. (1998). State anxiety following resistance exercise: The role of gender and exercise intensity. *Journal of Behavioral Medicine*, **21**, 205-219.

Borg, G.A.V. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*, **2**, 92-98.

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.

Breus, M.J., & O'Connor, P.J. (1998). Exercise-induced anxiolysis: A test of the "time-out" hypothesis in high anxious females. *Medicine and Science in Sports and Exercise*, **30**, 1107- 1112.

Brown, M.T., & Duren, P.S. (1988). Construct validity for Blacks of the State-Trait Anxiety Inventory. *Measurement and Evaluation in Counseling and Development*, **21**, 25-33.

Byrne, B.M., Shavelson, R.J., & Muthen, B. (1989). Testing for the equivalence of factor covariance and mean structures: The issue of partial measurement invariance. *Psychological Bulletin*, **105**, 456-466.

Cacioppo, J.T., Berntson, G.G., & Klein, D.J. (1992). What is an emotion? The role of somatovisceral afference, with special emphasis on somatovisceral "illusions." In M.S. Clark (Ed.), *Review of personality and social psychology: Vol. 14. Emotion and social behavior* (pp. 63-98). Newbury Park, CA: Sage.

Cameron, O.G., & Hudson, C.J. (1986). Influence of exercise on anxiety level in patients with anxiety disorders. *Psychosomatics,* **27,** 720-723.

Cortina, J.M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology,* **78,** 98-104.

Crocker, P.R.E., & Grozelle, C. (1991). Reducing induced state anxiety: Effects of acute aerobic exercise and autogenic relaxation. *Journal of Sports Medicine and Physical Fitness,* **31,** 277-282.

DeVries, H.A. (1987). Tension reduction with exercise. In W.P. Morgan & S.E. Goldston (Eds.), *Exercise and mental health* (pp. 99-104). Washington, DC: Hemisphere.

Dishman, R.K. (1986). Mental health. In V. Seefeldt (Ed.), *Physical activity and well-being* (pp. 303-341). Reston, VA: AAHPERD.

Ellsworth, P.C., & Smith, C.A. (1988). From appraisal to emotion: Differences among unpleasant feelings. *Motivation and Emotion,* **12,** 271-302.

Focht, B.C., & Koltyn, K.F. (1999). Influence of resistance exercise of different intensities on state anxiety and blood pressure. *Medicine and Science in Sports and Exercise,* **31,** 456-463.

Garvin, A.W., Koltyn, K.F., & Morgan, W.P. (1997). Influence of acute physical activity and relaxation on state anxiety and blood lactate in untrained college males. *International Journal of Sports Medicine,* **18,** 470-476.

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.

Green, S.B., Lissitz, R.W., & Mulaik, S.A. (1977). Limitations of coefficient alpha as an index of test unidimensionality. *Educational and Psychological Measurement,* **37,** 827-838.

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

Hatfield, B.D. (1991). Exercise and mental health: The mechanisms of exercise-induced psychological states. In L. Diamant (Ed.), *Psychology of sports, exercise, and fitness: Social and personal issues* (pp. 17-49). New York: Hemisphere.

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.

Kerr, J.H., & Vlaswinkel, E.H. (1990). Effects of exercise on anxiety: A review. *Anxiety Research,* **2,** 309-321.

Kerr, J.H., & Vlaswinkel, E.H. (1993). Self-reported mood and running under natural conditions. *Work and Stress,* **7,** 161-177.

Kirk, R.E. (1995). *Experimental design: Procedures for the behavioral sciences* (3rd ed.). Pacific Grove, CA: Brooks/Cole.

Kleine, D. (1994). Sports activity as a means of reducing school stress. *International Journal of Sport Psychology,* **22,** 366-380.

Landers, D.M., & Petruzzello, S.J. (1994). Physical activity, fitness, and anxiety. In C. Bouchard, R.J. Shephard, & T. Stephens (Eds.), *Physical activity, fitness, and health: International proceedings and consensus statement* (pp. 868-882). Champaign, IL: Human Kinetics.

Lang, P.J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J.B. Sodowski, J.H. Johnson, & T.A. Williams (Eds.), *Technology in mental health care delivery systems* (pp. 119-137). Norwood, NJ: Ablex.

Larsen, R.J., & Diener, E. (1992). Promises and problems with the circumplex model of emotion. In M.S. Clark (Ed.), *Review of personality and social psychology: Vol. 13. Emotion* (pp. 25-59). Newbury Park, CA: Sage.

Lazarus, R.S. (1991a). *Emotion and adaptation*. New York: Oxford University Press.
Lazarus, R.S. (1991b). Progress on a cognitive-motivational-relational theory of emotion. *American Psychologist,* **46**, 819-834.
Lazarus, R.S. (1999). *Stress and emotion: A new synthesis*. New York: Springer.
Levitt, E.E. (1980). *The psychology of anxiety* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.
Martinsen, E.W., Raglin, J.S., Hoffart, A., & Friis, S. (1998). Tolerance to intensive exercise and high levels of lactate in panic disorder. *Journal of Anxiety Disorders,* **12**, 333-342.
McAuley, E., Mihalko, S.L., & Bane, S.M. (1996). Acute exercise and anxiety reduction: Does the environment matter? *Journal of Sport & Exercise Psychology,* **18,** 408-419.
Morgan, W.P. (1973). Influence of acute physical activity on state anxiety. In *Proceedings of the National College Physical Education Association for Men* (pp. 113-121). Pittsburgh, PA.
Morgan, W.P. (1979). Anxiety reduction following acute physical activity. *Psychiatric Annals,* **9,** 141-147.
Morgan, W.P. (1982). Psychological effects of exercise. *Behavioral Medicine Update,* **4,** 25-30.
Morgan, W.P. (1984). Physical activity and mental health. In H.M. Eckert & H.J. Montoye (Eds.), *Exercise and health* (pp. 132-145). Champaign, IL: Human Kinetics.
Morgan, W.P. (1987). Reduction of state anxiety following acute physical activity. In W.P. Morgan & S.E. Goldston (Eds.), *Exercise and mental health* (pp. 105-109). Washington, DC: Hemisphere.
Morgan, W.P. (Ed.). (1997). *Physical activity and mental health.* Washington, DC: Taylor & Francis.
Morgan, W.P., & Ellickson, K.A. (1989). Health, anxiety, and physical exercise. In D. Hackfort & C.D. Spielberger (Eds.), *Anxiety in sports: An international perspective* (pp. 165-182). New York: Hemisphere.
Morgan, W.P., Horstman, D.H., Cymerman, A., & Stokes, J. (1980). Exercise as a relaxation technique. *Primary Cardiology,* **6,** 48-57.
Nunnally, J.C., & Bernstein, I.H. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.
O'Connor, P.J., Petruzzello, S.J., Kubitz, K.A., & Robinson, T.L. (1995). Anxiety responses to maximal exercise testing. *British Journal of Sports Medicine,* **29,** 97-102.
Petruzzello, S.J., Landers, D.M., Hatfield, B.D., Kubitz, K.A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise: Outcomes and mechanisms. *Sports Medicine,* **11,** 143-182.
Petruzzello, S.J., Landers, D.M., & Salazar, W. (1993). Exercise and anxiety reduction: Examination of temperature as an explanation for affective change. *Journal of Sport & Exercise Psychology,* **15,** 63-76.
Pitts, F.N., & McClure, J.N. (1967). Lactate metabolism in anxiety neurosis. *New England Journal of Medicine,* **277,** 1329-1336.
Raglin, J.S. (1997). Anxiolytic effects of physical activity. In W.P. Morgan (Ed.), *Physical activity and mental health* (pp. 107-126). Washington, DC: Taylor & Francis.
Raglin, J.S., & Morgan, W.P. (1985). Influence of vigorous exercise on mood state. *The Behavior Therapist,* **8,** 179-183.
Raglin, J.S., & Morgan, W.P. (1987). Influence of exercise and quiet rest on state anxiety and blood pressure. *Medicine and Science in Sports and Exercise,* **19,** 456-463.
Raglin, J.S., & Wilson, M. (1996). State anxiety following 20 minutes of bicycle ergometer exercise at selected intensities. *International Journal of Sports Medicine,* **17,** 467-471.

Reisenzein, R., & Hofmann, T. (1993). Discriminating emotions from appraisal-relevant situational information: Baseline data for structural models of cognitive appraisals. *Cognition and Emotion,* **7,** 271-293.

Reisenzein, R., & Spielhofer, C. (1994). Subjectively salient dimensions of emotional appraisal. *Motivation and Emotion,* **18,** 31-77.

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 & Exercise Psychology,* **13,** 65-74.

Rost, D.H., & Schermer, F.J. (1989). The various facets of test anxiety: A subcomponent model of test anxiety measurement. In R. Schwarzer, H.M. van der Ploeg, & C.D. Spielberger (Eds.), *Advances in test anxiety research* (Vol. 6, pp. 37-52). Amsterdam: Swets & Zeitlinger.

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. (1989). Measures of emotion. In R. Plutchik & H. Kellerman (Eds.), *Emotion: Theory, research, and experience: Vol. 4. The measurement of emotions* (pp. 83-111). San Diego, CA: Academic.

Schachter, S., & Singer, J.E. (1962). Cognitive, social and physiological determinants of emotional state. *Psychological Review,* **69,** 379-399.

Schmitt, N. (1996). Uses and abuses of coefficient alpha. *Psychological Assessment,* **8,** 350-353.

Schwarzer, R., & Quast, H.H. (1985). Multidimensionality of the anxiety experience: Evidence for additional components. In H.M. van der Ploeg, R. Schwarzer, & C.D. Spielberger (Eds.), *Advances in test anxiety research* (Vol. 4, pp. 3-14). Lisse, The Netherlands: Swets & Zeitlinger.

Sherwood, R.D., & Westerback, M.E. (1983). A factor analytic study of the State-Trait Anxiety Inventory utilized with preservice elementary teachers. *Journal of Research in Science Teaching,* **20,** 225-229.

Sinclair, R.C., Hoffman, C., Mark, M.M., Martin, L.L., & Pickering, T.L. (1994). Construct accessibility and the misattribution of arousal: Schachter and Singer revisited. *Psychological Science,* **5,** 15-19.

Smith, C.A., & Lazarus, R.S. (1993). Appraisal components, core relational themes, and the emotions. *Cognition and Emotion,* **7,** 233-269.

Spielberger, C.D. (1972). Anxiety as an emotional state. In C.D. Spielberger (Ed.), *Anxiety: Current trends in theory and research* (Vol. 1, pp. 23-49). New York: Academic.

Spielberger, C.D. (1979a). *Preliminary manual for the State-Trait Personality Inventory.* Tampa, FL: Author.

Spielberger, C.D. (1979b). *Understanding stress and anxiety.* New York: Harper & Row.

Spielberger, C.D. (1983). *Manual for the State-Trait Anxiety Inventory (Form Y).* Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C.D. (1985). Assessment of state and trait anxiety: Conceptual and methodological issues. *The Southern Psychologist,* **2,** 6-16.

Spielberger, C.D., Golzalez, H.P., Taylor, C.J., Algaze, B., & Anton, W.D. (1978). Examination stress and test anxiety. In C.D. Spielberger & I.G. Sarason (Eds.), *Stress and anxiety* (Vol. 5, pp. 167-191). Washington, DC: Hemisphere.

Spielberger, C.D., Gorsuch, R.L., & Lushene, R.E. (1970). *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C.D., Lushene, R.E., & McAdoo, W.G. (1977). Theory and measurement of anxiety states. In R.B. Cattell & R.M. Dreger (Eds.), *Handbook of modern personality theory* (pp. 239-253). New York: John Wiley & Sons.

Spielberger, C.D., Vagg, P.R., Barker, L.R., Donham, G.W., & Westberry, L.G. (1980). The factor structure of the State-Trait Anxiety Inventory. In I.G. Sarason & C.D. Spielberger (Eds.), *Stress and anxiety* (Vol. 7, pp. 95-109). Washington, DC: Hemisphere.

Steptoe, A., & Bolton, J. (1988). The short-term influence of high and low intensity physical exercise on mood. *Psychology and Health,* **2,** 91-106.

Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personality and Social Psychology,* **48,** 107-116.

Tate, A.K., & Petruzzello, S.J. (1995). Varying the intensity of acute exercise: Implications for changes in affect. *Journal of Sports Medicine and Physical Fitness,* **35,** 295-302.

Thayer, R.E. (1978). Factor analytic and reliability studies on the Activation-Deactivation Adjective Check List. *Psychological Reports,* **42,** 747-756.

Thayer, R.E. (1986). Activation-Deactivation Adjective Check List: Current overview and structural analysis. *Psychological Reports,* **58,** 607-614.

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

Thayer, R.E. (1989). *The biopsychology of mood and arousal.* New York: Oxford University Press.

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

Vagg, P.R., Spielberger, C.D., & O'Hearn, T.P., Jr. (1980). Is the State-Trait Anxiety Inventory multidimensional? *Personality and Individual Differences,* **1,** 207-214.

Youngstedt, S.D., Dishman, R.K., Cureton, K.J., & Peacock, L.J. (1993). Does body temperature mediate anxiolytic effects of acute exercise? *Journal of Applied Physiology,* **74,** 825- 831.

Youngstedt, S.D., O'Connor, P.J., Crabbe, J.B., & Dishman, R.K. (1998). Acute exercise reduces caffeine-induced anxiogenesis. *Medicine and Science in Sports and Exercise,* **30,** 740-745.

Acknowledgment

This research was supported in part by a grant from the National Institute of Mental Health (RO3 MH55513-01) to Steven J. Petruzzello.

Date submitted: March 4, 1998
Revision accepted: April 25, 1999