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Published in *Psychology of Running*, Michael H. Sacks, M.D., Editor, Michael L. Sachs, Ph.D., Associate Editor. Human Kinetics Publishers, Inc., Champaign, IL, 1981. Pages 192–210.

CHAPTER 18

Exercise and Stress Tolerance

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Presented in this paper is research designed in part to show that although moderate running by well-trained runners plays a significant role in *reducing* stress response to subsequently introduced stressors, running at the level of marathon competition alters psychological and physiological dispositions in a manner not conducive to reduced stress responses. In these demonstrations, the choice of our psychological and physiological dependent measures was guided by a larger theoretical framework concerning the relationship of exercise to temperament. We will discuss this larger view first because it provides a theoretical perspective that is useful in considering our specific hypotheses.

We believe that regular aerobic exercise, with its requirements for sympathetic nervous system (SNS) activation and associated endocrine activity, leads to chronic reduction in the individual's experienced stress responses to psychological stressors. As long as two decades ago, Michael (1957) suggested that regular exercise would allow greater steroid reserves—reserves available

to counter stress. Other similar views include that advanced by Edington and Edgerton (1976), who posit that extending the capacity of the adrenal medulla to generate the catecholamines through exercise may help to reduce the experience of stress. Moorehouse and Miller (1971) have suggested that exercise may "increase the size and lower the threshold of stimulation of the adrenal glands," resulting in greater reserves of antistress steroids and shorter response times to stressors.

For reasons related to the limits of permissible research with human subjects, those ideas concerning the possible relationship of exercise to stress tolerance remain speculative. We do, however, have access to other empirically based knowledge which will allow reasonable inferences about this relationship. We know that physiological responses to exercise and to physiological or psychological stressors are very much alike in broad outline, with both exercise and stress responses calling for activation of the SNS and the generation of steroids and catecholamines. Adaptation to cold requires a similar physiological response pattern. Logically, then, if we can establish a reasonable case that regular exposure to (manageable) psychological or physiological stressors or to cold leads to increased stress tolerance, we could infer a similar result for regular exercise.

The most convincing evidence that regular activation of the stress response leads to chronic changes in temperament is found in animal research, where it has been demonstrated that the gentle stress of daily handling or even the daily shocking of young rodents leads to an enlarged adrenal capacity *and* a calmer or less emotional temperament in adulthood (e.g., Denenberg, 1967). With humans, several lines of modern evidence suggest a relationship between increased hormonal and/or SNS response capacity and a more calm and stress-tolerant human temperament. Several years ago, Dienstbier investigated the relationship of cold tolerance to temperament. Students who indicated that they could tolerate cold temperatures with minimal discomfort (indicating a high ability to generate and sustain SNS arousal) indicated less fearfulness, more emotional control, and a greater preference for emotional and suspenseful forms of entertainment. Recently, Frankenhaeuser (1979) has demonstrated that school children rated as more emotionally stable and competent than their classmates indicate *greater* catecholamine responses to classroom challenges than do their less emotionally stable classmates.

In summary, several lines of evidence suggest that greater SNS and hormonal capacities are associated with more positive responses to stressful situations, and with temperaments generally characterized by less anxiety and emotional upheaval. Considering that most researchers concerned with stress responses in the psychological and medical areas organize much of their thinking on the principles of the General Adaptation Syndrome developed by Selye (1976), these findings should constitute no surprise. That is, it follows from Selye's approach that if an individual is able to develop a more intensive physiological reaction during the stage of alarm or a more prolonged response during the stage of resistance, then the stage of exhaustion is postponed or even avoided (if the stressor is eliminated during those early stages of the stress response sequence). A major block in our recognizing the positive features of an ability to develop and sustain larger SNS and hormonal stress responses was probably the recognition of those responses as a sign of stress, and hence, as a sign that "something is going wrong." That previous conclusion may be most applicable in situations in which the stressor is largely psychological *and* where activity to combat the stressor is not available or not undertaken. In support of this idea, Gal and Lazarus (1975) have recently suggested that stress reactions as indicated by hormonal indices are experienced as more uncomfortable and are associated with more somatic symptoms only when activity is not undertaken; they suggest that the positive benefits of activity may exist even when the activity is not directly related to the stressor.

To return to our major point, if running changes the capacity of our hormonal system and our SNS response through the regular use or "exercise" of those systems, then one should anticipate long-term positive changes in temperament from running. Although we would like to be able to state that our research has demonstrated that such long-term personality benefits do follow from regular running, the best we are able to do is to demonstrate the interrelationship of exercise to short-term stress tolerance *and* to changes on psychological dimensions relevant to personality or temperament. Then we may infer the relationship of exercise to personality, but our inferential leap will be substantial.

We did not look for long-term personality changes mainly because we did not have the resources to overcome the very difficult control group problems which must be addressed to adequately confront this issue. Others, such as Ismail (Young & Ismail, 1976), who has shown an exercise program to influence personality or temperament, have not used control groups with expectancies for change which would be similar to those held by their exercising subjects. It is therefore difficult to know if the personality shift indicated over time is due to the exercise per se or to changes in expectation. As Morgan recently suggested (Morgan & Pollock, Note 1), another major difficulty with such studies is that subjects involved in exercise programs often "get religion," changing their intake of drugs and stimulants, and modifying eating, sleeping, and other living habits. In addition, it is extremely difficult to abstract those personality changes which might be due to our physiological response to a rigorous exercise program from those personality changes related to the sense of accomplishment, improved body image, and other psychological factors. Indeed, the difficulties of such an analysis are such that I know of no serious attempts to control such factors. These criticisms are not meant to denigrate previous research attempts but to suggest that doing conclusive research in this area is a most complex and difficult undertaking; as will be shown, our own research does not overcome all possible interpretive difficulties. Although we have avoided the pitfalls of the before-after research designs detailed earlier, we have not avoided the need for significant inferential leaps from our data to our theoretical perspectives.

To make our inferential leap, we will attempt to develop two types of empirical evidence. First, we will demonstrate that in the short term, running has a complex influence on our tolerance for psychological (loud noises) and physiological (cold) stressors introduced after the exercise; our measures of stress tolerance will also be both psychological and physiological. Success in such a short-term demonstration will lend weight to our overriding theory that long-term exercise may have comparable long-term effects by demonstrating in a convincing fashion that exercise does have an impact on the relevant variables. Secondly, when we refer to long-term differences in stress tolerance and other chronic dimensions of emotional functioning, the term temperament is relevant and appropriate. Using a standard psychometric instrument for measuring temperament, we will attempt to demonstrate that short-term differences in subjects' responses to that instrument follow from different prior exercise levels. This demonstration, too, will add weight to our inferences about chronic personality changes from a long-term exercise program by showing that in the short run the relevant exercise variables do have impact on the relevant temperament dimensions. Finally, using the same temperament inventory, we will attempt to demonstrate that our running subjects' expectations about the impact of short-term exercise do *not* match perfectly the real changes in temperament. This will allow us to conclude that the changes we do observe are probably due to more than the operation of mere subject expectancies.

The basis for our short-term hypotheses concerning the positive impact of moderate exercise on stress tolerance is that running provides an activity outlet for possible physiological imbalances caused by past stress, preventing a large cumulative stress response to a subsequent moderate stressor. In addition, it is possible that a "priming" function is realized by the prior exercise in the form of prestimulation of hormones and steroids and other energy-mobilization factors necessary to combat stress. In this latter regard, Edington and Edgerton (1976) have suggested that "pretreatment with mild stressing agents protects and aids the body in responding to the second independent stress." Past research addressing this issue using psychological measures has usually assessed anxiety on a standardized inventory or checklist following a prior short-term exercise session of usually up to ½ hour of treadmill walking or bicycle ergometer work. (For a recent review of exercise and anxiety studies, see Morgan, 1976). Other research on this hypothesis has employed physiological measures. For example, using the anticipation of a test as a stressor, Sime (Note 2) has demonstrated that 12 minutes of treadmill exercise leads to reduced muscle tension and blood pressure during the later stress. Our research attempted to go beyond those previous approaches by looking at changes on a wider variety of physiological and psychological dimensions following three different exercise conditions which range from no exercise to marathon competition. As suggested earlier, psychological dimensions were chosen to allow us a conceptual bridge back from our findings of acute differences to inferences about chronic or personality changes following a sustained exercise program.

We hypothesized that following marathon competition the exhaustion of the SNS and of hormonal capacity would lead to reduced capacity to tolerate subsequent stressors, exaggerating psychological and physiological stress responses. In formulating this hypothesis we were aware of "contradictory" data such as those developed by Morgan (1976) suggesting that even exercise "to exhaustion" is followed by anxiety reduction as indicated by performance on anxiety questionnaires. Our assumption that our runners would not perform similarly was based upon the belief that no laboratory exercise could ethically impose effort or exhaustion which would be comparable to that which our runners would drive themselves to in the course of marathon competition.

Mood and Temperament Hypotheses

Our hypotheses about mood were that although those moods relevant to anxiety would be exaggerated by not running (NoR) and by marathon (MarR) competition relative to a short run (ShR), those moods related to vigor would be reduced by NoR and MarR conditions, relative to ShR. Unlike the more global activation concept which has dominated psychological thinking until recently, our theory therefore implies a multifactor concept of activation. The mood measure used was the Mood Adjective Check List (MACL) (Nowlis & Green, Note 3).

To measure temperament, we employed a psychological measure devised by Buss and Plomin (1975) which contains items designed to assess the temperament factors of Emotionality, Activity, Sociability, and Impulsivity (EASI). In his work with this instrument, Buss concluded that all four of those dimensions were highly influenced by hereditary factors. It was our assumption that the high heritability of temperament dimensions such as Emotionality and Activity existed because those psychological dimensions depend, in part, upon physiological predispositions such as those associated with the SNS and related hormonal capacities. We noted earlier that both the work of Frankenhaeuser (1979) with children and that of Denenberg (1967) with rodents supported this link between physiological characteristics and the temperament dimension of emotionality. Relevant to our change-through-exercise hypothesis is that Denenberg's work also suggested some plasticity or "training effect" of the emotionality dimension following systematic subjection of animals to regular doses of tolerable stress. We therefore hypothesized that temperament factors might be influenced by the temporary physiological states induced by running. Of the temperament dimensions of the Buss inventory, we predicted that ShR would decrease Emotionality and increase Activity relative to NoR and MarR. Although many of the Buss items are worded in "chronic" terms, subjects were asked to interpret each item as if it were asking about how they felt "right now."

Subjects and Procedure

Our research was conducted in spring 1978 with a class of students who were training, under our direction, to run a marathon. Members of the class were recruited via various informal communications networks of students and runners.

Although the majority of our participants were students from the University of Nebraska, several nonuniversity members of the Lincoln running community enrolled for the course. Of the 30 runners who participated in the course, 23 completed their training and five were women.

Research Scheduling

At the beginning of the semester, all participants filled out a series of questionnaires including one concerning the centrality of running to their self-concept. Near the semester's end, all subjects were to participate either in a marathon or in a criterion run of over 20 miles (hereafter referred to as the marathon). Most of the data reported in this paper were gathered from three sessions scheduled for each subject. The sessions were separated by approximately 2 weeks, with each subject reporting at the same time in the afternoon (or within ½ hour) as his/her other sessions. One of the sessions followed the marathon run (MarR), one followed a day in which the subject did not run prior to the research (NoR), and one followed a "short" run (ShR). On ShR days, subjects ran approximately 6 miles at an easy pace. The order of MarR, NoR, and ShR conditions was determined randomly for subjects, with the restriction that condition and order were counterbalanced across subjects.

Research Tasks and Physiological Measures

Upon arrival at the laboratory, subjects were seated in an overstuffed chair which was isolated by a curtain from the physiograph used to monitor their physiological responses to a "stress" tape. The tape presented various loud (92db) sounds separated by approximately 30 seconds. The sounds included glass crashing, automobile crashes, a loud electric drill, and a circular saw cutting wood; the tape ended with a balloon being blown up until it burst.

Capillary constriction in the finger in response to the sounds on the tape (indicating SNS activity) was measured by a pulse transducer attached to the middle finger of the left hand. Galvanic skin response (GSR) was measured with electrodes attached to the wrist of the left hand as a further check of SNS activity.

After the sound-tape session ended, each subject went to another room where he/she rated the subjective stressfulness of the sound tape, filled out a Mood Adjective Check List (MACL) (Nowlis & Green, 1957), filled out the Buss and Plomin (1975) temperament inventory, and sat for 5 minutes in a 60 degree (F) room prior to rating the subjective discomfort of that cool temperature. Because acute cold adaptation is accomplished through SNS activation with the accompanying catecholamines of noradrenalin and adrenalin, it was anticipated that subjective comfort in the cold would be greatest following ShR, with NoR and MarR being characterized by relative discomfort.

The procedure of physiological monitoring and psychological testing described above was repeated on each of the three sessions for each subject. At the end of the third session, subjects were asked to fill out the Buss temperament inventory three additional times reflecting the way they *typically* feel after conditions of NoR, ShR, or MarR. This procedure was undertaken to study the degree to which actual differences between feelings on those days corresponded with the subject's expectations of differences following different running conditions. It was predicted that, in general, subjects' expectations would reflect an exaggeration of those between-condition differences found on the three experimental days. Scores from GSR and capillary constriction monitoring in response to each of the 17 discrete sound events on the sound tape were derived from the print-out of the continuously recording physiograph as discussed above. Single GSR scores and capillary constriction scores were created for each subject by combining the scores obtained in response to all the taped sounds. In order to statistically control for possible adaptation effects between sessions, physiological scores were standardized between the three sessions.[1]

Results

After a preliminary examination of the data, it became apparent that the subjects' degree of commitment to running was an important moderator variable influencing how they responded to our dependent measures. Therefore, for the analyses subsequently presented, subjects were divided into approximately equal halves, based upon how central running was to each person's self-concept. Those individuals in the high running self-concept (Hi RSC) group had indicated that running was "very central to my self-concept . . . one of the first things I think of when I think about defining who I am"; or that running was "moderately central . . . important, but not one of the two or three most important aspects of self-definition." Those indicating that running was "important but not central . . . not one of the dimensions I usually think of in defining myself"; and those indicating running was "not very important . . . while I take some pride in running, it's no big thing," were classified as low in running self-concept (LoRSC). (Other options indicating even less commitment were available, but none of our subjects chose those less-involved-with-running self-definitions). The data were mainly examined through two by three factorial analyses of variance with two levels of running self-concept as a between-subjects variable and the three running conditions of NoR, ShR, and MarR as a within-subjects variable.

[1]Scores were standardized around a mean of zero and a standard deviation of 100. For example, the GSR measures for all subjects reporting for their first physiological monitoring session (approximately 1/3 of those in each of the three running conditions) were equated with the mean and standard deviation for the data from the remaining two sessions. This standardization was permitted by the almost perfect counterbalancing of running conditions within order. Effects due to the factor of running condition could therefore by analyzed as a main effect in analyses of variance without the intrusion of the theoretically meaningless dimension of adaptation to the sound tape across the three sessions. More importantly, with the introduction of the running self-concept dimensions as a moderator variable, this normalization of physiological scores allowed the selection of two subgroups for which perfect counterbalancing of running condition within session did not exist. Because session effects had been previously removed statistically, they could not confound comparisons between such imperfectly matched groups. (Actually, the counterbalancing within the two running self-concept subgroups was reasonably similar between the groups.)

Overview of Negative Mood Factors

We predicted that the mood and temperament factors usually characterized as negative would be reduced (or improved) in the ShR condition as compared with NoR; additionally, it was predicted that indicators of stress reactions such as GSR and capillary constriction would also change in a positive direction, indicating reduced stress in the ShR condition as contrasted with NoR. We predicted that many of those negative mood and stress indicators would be higher following MarR than following the ShR condition. Negative mood factors were Anxiety, Skepticism, Aggression, Fatigue, and Sadness; in addition to those multiple-item factors, we included the single-item mood terms of Disgust, Guilt, and Sick. Negative EASI temperament factors were Impulsivity and Emotionality; we were, however, particularly interested in the part of the Emotionality score consisting of fear-related items, (contrasted with the anger items). (Although each of the four temperament factors except Sociability were composed of several subfactors, only emotionality was examined at the subfactor level.) Negative scaled items consisted of the rating of the discomfort experienced from the 5-minute stay in the 60 degree room, and ratings of the stressfulness of the sound tape played during the physiological monitoring. Those negative dimensions of major theoretical interest and/or indicating large between-condition differences are presented in Table 1, along with statistical analyses. Those dimensions are also illustrated in Figures 1 and 2, along with these positive dimensions indicating large between-condition changes.

Every negative dimension of mood, temperament, physiological change, or scaled item, except the rating of cold discomfort, changed in the predicted direction of reduction from NoR to ShR conditions. Although the degrees of change for the measures not reported in Table 1 were often not statistically significant or substantial, this almost perfect directional support across a variety of different types of measures suggests a remarkable improvement in well being for our running subjects after a moderate run.

The pattern of results following MarR is somewhat less clear, for some of the negative dimensions of interest did not differ between ShR and MarR con-

Table 1

Means[a] and F-Ratios for Dependent Measures by Running Condition (with Running Self-concept for Some Measures)

Measure	Run Self-concept	N	Means by Running Condition: NoR	ShR	MarR	ANOVA F-Ratios: Running Condition	Running Self-concept	Interaction (RC × RSC)
Anxiety	All	21	11.75	9.39	9.42	3.28*	<1	<1
	Low	11	11.91	10.18	9.64			
	High	10	11.60	8.60	9.20			
Fatigue	All	21	7.76	6.69	9.36	5.04*	1.77	<1
Vigor	All	21	6.07	7.41	4.70	9.50**	<1	1.09
Elation	All	21	8.04	9.17	11.10	8.41**	<1	<1
Social affection	All	21	6.85	7.51	7.65	1.23	<1	<1
Temperament Factors								
Emotionality	All	23	17.16	16.70	15.69	<1	<1	1.17
	Low	12	16.82	19.00	17.18			
	High	11	17.50	14.40	14.20			
Emotion-Fear	All	23	5.68	5.30	4.47	<1	4.49*	4.61*
	Low	12	5.37	7.00	6.09			
	High	11	6.00	3.60	3.40			
Activity	All	23	17.66	18.03	13.65	5.20*	<1	<1
Sociability	All	23	3.80	4.77	4.06	1.40	2.47	<1
Physiological Measures								
GSR	All	20	72	-277	115	2.15	<1	<1
	Low	11	-130	-270	29			
	High	9	274	-285	201			
Capillary constriction	All	19	332	-104	-67	2.81	<1	6.75**
	Low	11	-43	-65	306			
	High	8	708	-143	-440			
Scaled Items								
Temperature discomfort	All	20	2.40	2.40	2.45	<1	<1	2.56
	Low	10	2.10	2.20	2.80			
	High	10	2.70	2.60	2.10			
Sound tape rating	All	18	3.89	3.28	3.50	1.60	2.26	<1
	Low	9	3.67	3.00	3.22			
	High	9	4.11	3.56	3.78			

*Significant at $p < .05$
**Significant at $p < .01$
[a]All negative dimensions (e.g., anxiety, emotionality, sound tape rating of stress, and the physiological indicators) are scored so that a larger mean indicates more negative or greater indicators of stress; with positive factors, a higher score indicates more of that positive dimension or less stress.

ditions (i.e., moods of Anxiety, Skepticism, Aggression, and Disgust; Capillary Constriction, and temperature discomfort), whereas others indicated less negative feeling or stress following MarR compared with ShR (i.e., temperament factors of Impulsivity and Emotionality and its component, Fear). Most dimensions, however, did indicate more negativity following MarR contrasted with ShR (i.e., moods of Fatigue, Sadness, Guilt and Sick—the latter at a statistically significant level, the physiological measure of GSR, and the stressfulness of the sound tape). As discussed below, this somewhat unclear picture is improved with the division of subjects into those high and those low in RSC.

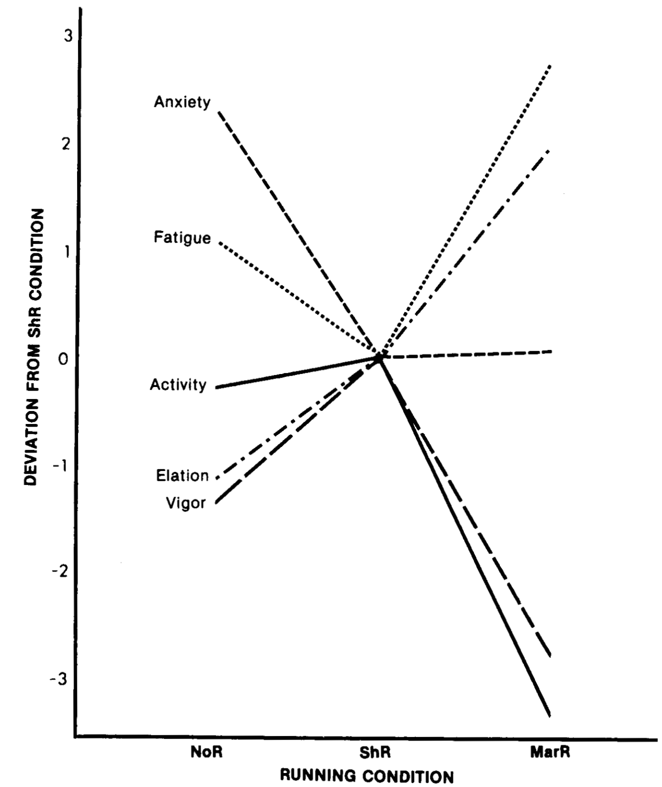

Figure 1. Mood and temperament scores by running condition. To clearly illustrate differences of NoR and MarR from ShR conditions, the dependent measure scales are arranged so that they overlap at ShR.

Overview of Positive Factors

The prediction that positive dimensions would be found to be higher following ShR compared with NoR was upheld with every dimension studied (i.e., mood factors of Social Affection, Elation, Vigor, Surgency, and Elation; temperament factors of Sociability and Activity).

Differences between ShR and MarR for the positive dimensions were less definitive, as was the case with the negative dimensions. Although the mood of Elation went up dramatically following MarR, the mood of Vigor declined, as did the temperament scores on Sociability and Activity. Moods of Surgen-

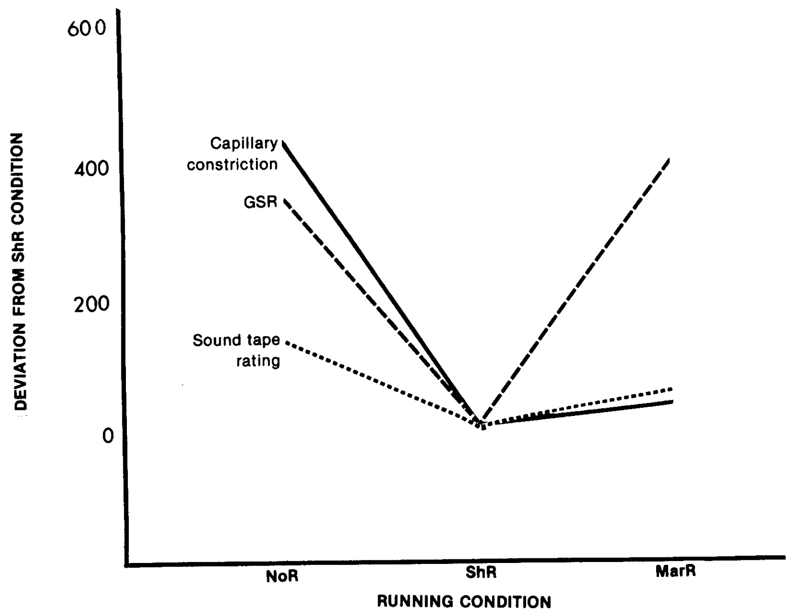

Figure 2. Physiological scores and sound tape rating by running condition. As in Figure 1, the dependent measures are arranged so that they overlap at ShR.

cy and Social Affection indicated no change. Because the reasons for these changes are, in most cases, quite apparent, and because RSC did not appear to be a major moderator variable for these dimensions, the remainder of this paper will be devoted largely to the negative dimensions. Those positive dimensions of relatively major interest and/or those indicating the greatest change are included in Table 1 and shown in Figures 1 and 2.

Specific Issues and Consistencies

Attention to the temperament factor of Emotionality was given because it is a central concept in our approach to the impact of exercise on personality. Two important subfactors in Emotionality are Fear and Anger. Although Anger did not vary between conditions for all subjects or when subjects were divided by RSC, the subfactor of Fear yielded a statistically significant interaction on the running condition and RSC dimensions with LoRSC runners, indicating a slight increase in fear in ShR and MarR conditions (over NoR), but with HiRSC runners indicating a fear reduction with ShR or MarR (see Table 1). Because it is to be expected that the mood factor of Anxiety should resemble the Fear factor, even without the justification of a comparable statistically significant interaction for Anxiety, both factors are shown in Figure 3 for comparison. As illustrated in the figure, HiRSC subjects indicated a large drop in anxiety and fear from NoR to ShR, with no further changes of any magnitude

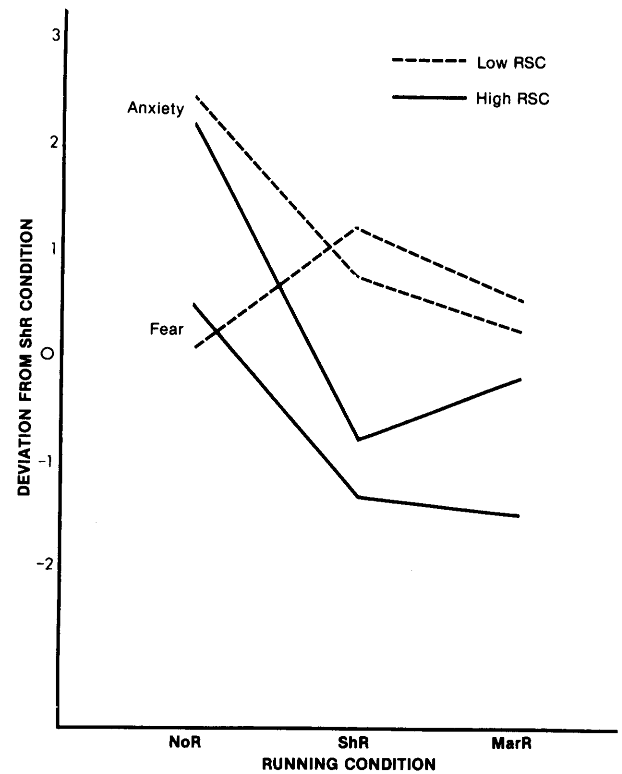

Figure 3. Anxiety (MACL) and Fear (EASI) scores by running condition and by running self-concept.

from ShR to MarR. With a far less consistent pattern, LoRSC individuals, who indicate similar NoR baserates of anxiety and fear to HiRSC individuals, evidence far less positive change following either ShR or MarR. In general, where interactions of the RSC and Running Condition factors exist on the various dependent measure dimensions, this pattern of greater change from NoR to ShR or MarR with HiRSC subjects is repeated.

The two physiological measures yield a somewhat similar picture to that formed by the dimensions of Anxiety and Fear. That is, as demonstrated in Figure 4, while the HiRSC subjects evidence a dramatic decline in physiological responses to the stressful sound tape between NoR and ShR conditions, comparable differences for the LoRSC group do not exist, with practically no NoR to ShR physiological differences. (Although the differences between RSC groups across running conditions are reflected in a statistically significant interaction for capillary constriction, as indicated in Table 1, comparable differences for GSR are far from statistically significant;

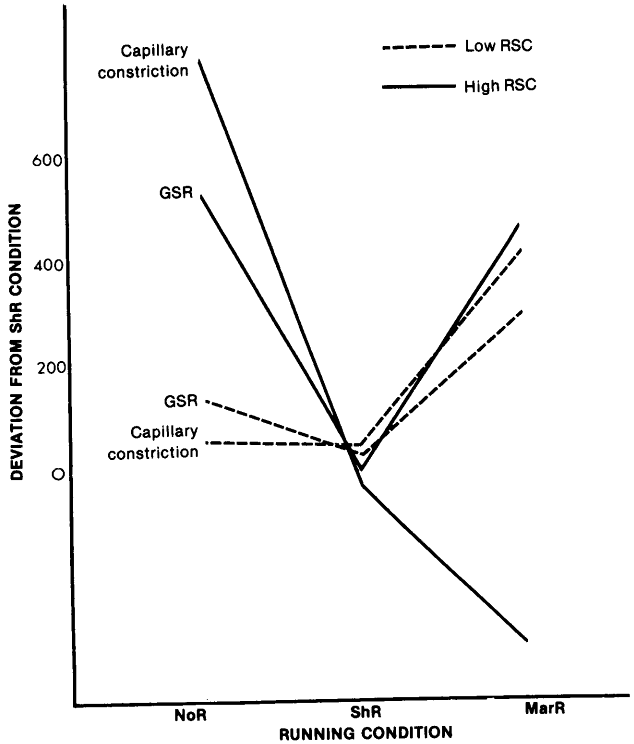

Figure 4. GSR and capillary constriction scores by running condition and by running self-concept.

these discussed similarities between the two measures are therefore only moderately supported by statistical analyses.)

Differences in the physiological measures from ShR to MarR between RSC conditions also exist, with GSR and capillary constriction both indicating increased stress responses for the LoRSC group following the marathon, whereas only GSR indicates such increased stress responses following MarR for the HiRSC group. No significant assistance is given to the interpretive problem suggested by these data from the sound tape rating or temperature discomfort as indicated in Figure 5. On the one hand, the temperature discomfort scale suggests that the HiRSC subjects are more stress-tolerant following the marathon than at any other time (contrasted with the opposite pattern for LoRSC subjects, as indicated by an interaction approaching statistical significance). Yet ratings of stressfulness of the sound tape are almost identical for the two RSC groups, giving no illumination to the problem of blood flow differences between the two RSC groups (but giving weak support to the hypothesis of lowest stress response following ShR).

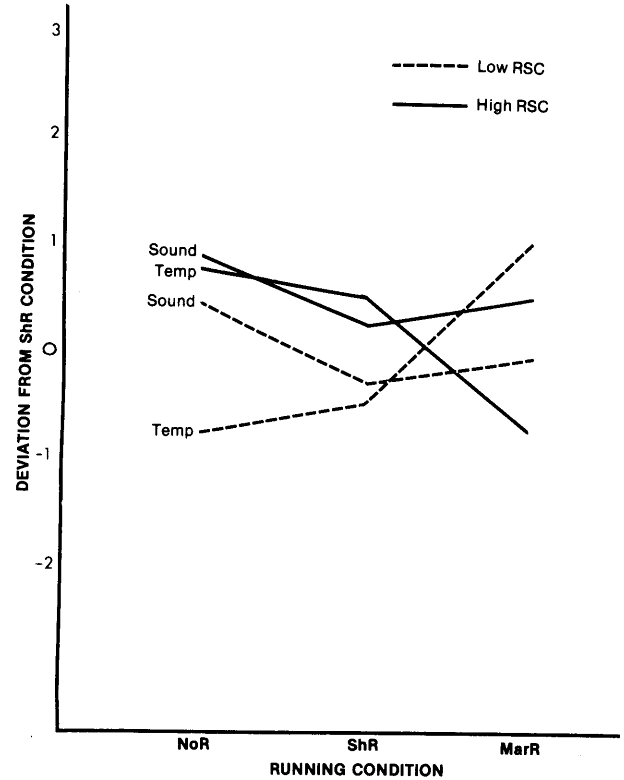

Figure 5. Sound tape rating and temperature discomfort scores by running condition and by running self-concept.

The array of data illustrated in Figures 3, 4, and 5 leads to the conclusion that although runners in both RSC groups experienced reductions in psychological and physiological indicators of stress from NoR to ShR, HiRSC runners indicate a stronger and more consistent improvement following moderate running. Less certainly, it appears that for the HiRSC runners running in a competitive marathon does not entirely eliminate the psychological and physiological benefits accrued after a moderate run, possibly even reducing stress responses to some stimuli on some measurement dimensions. For the LoRSC runners, not only are their benefits from ShR less certain, but there is no strong evidence that they retained any significant psychological or physiological stress response benefits at all when they extend their running to a competitive marathon level.

Runners' Expectations

Keeping in mind the pattern of results described previously about the real psychological and physiological benefits derived from running, the temperament data gathered in each runner's last experimental session allows some comparison with the benefits runners believed they achieve from their running. As indicated above, on that final day runners were asked to fill out the EASI temperament inventory three additional times, *as if* they had just completed NoR, ShR, or MarR. Table 2 indicates results from the four EASI factors plus the subfactors of Anger and Fear comprising the Emotionality factor.

The Imaginary means of Table 2 reveal that the HiRSC participants expected their Emotionality to decrease dramatically when they ran longer distances, whereas LoRSC subjects anticipated only a slight drop (with the differences between the groups across conditions statistically significant, as indicated by the interaction F-ratio). Comparably large expectations for Fear and Anger reductions by the HiRSC subjects also exceeded expectations for Fear and Anger reductions by the LoRSC subjects. The low expectations for change by the LoRSC subjects were reasonably accurate, for their feelings on Anger and Fear did not change appreciably across running conditions. However, although the positive expectation of change by HiRSC subjects was reasonably accurate for Fear, their considerable expectations for Anger reduction reflected no similar trend in the real between-running condition mean changes. The relative accuracy of both RSC groups with prediction and realization of greater changes across running conditions is also reflected on the Activity and Impulsivity dimensions.

The relatively small predicted change on the Sociability dimensions is reflected in the real scores on that dimension. In conclusion, it appears that highly committed runners expect and achieve more positive benefits from their running than expected and achieved by LoRSC runners. Furthermore, with the possible exception of the unfulfilled anticipation of anger reduction following running, runners' expectations of the benefits they achieve from their running generally reflect reality.

Of course, it could be objected that the responses given on NoR, ShR, and MarR days reflect nothing more than the expectations which, in more salient form, account for the between-running condition scores obtained under imaginary conditions. First, however, the very real physiological differences noted between running conditions in response to the sound tape suggest basic stress-tolerance differences resulting from running. It seems quite likely that those differences would have an impact upon both mood and temperament scale responses (when the latter are framed in terms of immediate rather than chronic feelings). Secondly, the directional similarity between imagined and real scores is not perfect. If real between-running condition differences reflected only expectations of change, we should not expect any situations such as demonstrated by the HiRSC subjects anticipating dramatic drops in Anger with running, while indicating no comparable trend in data gathered after real NoR, ShR, and MarR condition. Similarly, the dramatic drop expected by LoRSC subjects in Impulsivity across running conditions is not reflected in the real data generated by those subjects.

Table 2

Means and F-Ratios for Real and Projected Temperament Scores Following Real and Imagined NoR, ShR, and MarR

		Imaginary						Real						Imag. vs. Real F-Ratio
		Means by Running Condition			F-Ratios			Means by Running Condition			F-Ratios			
Measure	Run Self-concept	NoR	ShR	MarR	Run Cond	Run Self-conc	RC × RSC	NoR	ShR	MarR	Run Cond	Run Self-conc	RC × RSC	Interaction Real vs. Imag. by RC
Emotionality	All	20.08	15.96	13.61	9.98**	<1	3.92*	17.16	16.70	15.69	<1	<1	1.17	2.27
	Low	17.17	15.92	14.67				16.82	19.00	17.18				
	High	23.00	16.00	12.54				17.50	14.40	14.20				
E-Fear	All	5.81	4.60	4.12	8.34**	<1	3.32*	5.68	5.30	4.74	<1	4.49*	4.61*	<1
	Low	5.08	4.83	4.33				5.36	7.00	6.09				
	High	6.54	4.36	3.91				6.00	3.60	3.60				
E-Anger	All	6.47	5.07	4.36	5.62**	<1	3.46*	4.66	4.76	4.85	<1	<1	<1	2.63
	Low	5.58	5.42	5.08				4.82	5.00	4.91				
	High	7.36	4.73	3.64				4.50	4.50	4.80				
Activity	All	19.42	19.24	14.08	7.76**	<1	<1	17.66	18.03	13.65	5.20*	<1	<1	<1
	Low	19.67	19.75	15.33				16.73	17.36	14.00				
	High	19.18	18.28	12.82				18.60	18.70	13.30				
Sociability	All	4.96	5.24	5.04	<1	<1	1.26	3.80	4.77	4.06	1.40	2.47	<1	<1
Impulsivity	All	7.11	3.95	1.47	17.60**	<1	<1	4.88	4.22	3.70	<1	<1	<1	3.45*
	Low	5.50	3.17	0.75				5.36	5.64	4.91				
	High	8.73	4.73	2.18				4.40	2.80	2.50				

*Significant at $p < .05$
**Significant at $p < .01$

Conclusions

Our major hypothesis, that moderate running would positively influence tolerance for subsequently introduced stress, was confirmed by these data in a consistent manner across physiological and psychological dependent measure dimensions. Although it has been suggested by Morgan (Bahrke & Morgan, 1978) that the positive impact of running on feelings of well being and improved stress tolerance may result from nothing more than the run being a "time-out" period from the stresses of daily living, several aspects of our data do not support that explanation. First, although most laboratory studies using controlled exercise periods test subjects within a brief period following that exercise, we usually tested our subjects several hours following their ShR and an average of 5 hours following MarR. Intuitively, it does not seem that the impact of a brief time away from the usual activities of life would retain its impact so well after several hours of return to usual activities. Secondly, the differences between our running self-concept groups, with greater impact for the HiRSC subjects (from ShR relative to NoR), would not seem to support a time-out hypothesis, for there is no logical reason why "time out" should have a more significant impact on individuals for whom running is an important part of self-concept than for less committed runners. Finally, we might argue that the "time out" encountered on a marathon day is the ultimate "time out," for irrespective of the stressfulness of the marathon itself, runners are unlikely to engage in stress-producing activities following that long Sunday run. Yet marathon running did not seem as effective as more moderate running in consistently indicating positive changes on our dependent measure dimensions.

The second part of our major hypothesis, that MarR conditions would lead to increased indications of stress and an elimination of positive benefits predicted and found for ShR, was not consistently confirmed. That hypothesis had been based upon the assumption that the SNS and associated catecholamines, steroids, and other body chemicals which are activated by moderate exercise would be depleted by MarR, so that they would not be available for later stress resistance. Prior to our research, however, we were not aware of Appenzeller's remarkable data suggesting that well-trained marathoners sustain no apparent exhaustion of the SNS and related hormones during or following such competition. Appenzeller (Note 4) has demonstrated that total catecholamines increase by a factor of three (over baseline) during the early miles of a marathon, and increase after 20 miles to a level of six-fold over baseline. Had we been aware of those data, our initial hypothesis would have been presented in a more articulated manner, with distinctions made concerning the predicted impact of MarR on stress tolerance for different levels of runners. In fact, the data from this study do support such an articulated hypothesis, especially the capillary constriction differences on MarR between the LoRSC and HiRSC groups, indicating better physiological stress tolerance for the HiRSC subjects following MarR.

Our theoretical interest concerning the potential impact of running on long-term personality dispositions of stress tolerance and temperament was supported as well as possible, given the large inferential leap we had to make from our data to that conclusion. The relevant data show a remarkably consistent impact on psychological and physiological indicators of stress tolerance following moderate running, suggesting that those physiological dispositions underlying stress tolerance are indeed influenced by exercise. The data following MarR (and the data from other work such as that of Appenzeller) suggest that extensive endurance exercise may sufficiently tax SNS and hormonal systems that some adaptation or "training" responses in the form of gradually increasing capacity and/or efficiency may result. Given the documented role such physiological systems play in temperament (particularly the dimension of Emotionality) the inference of long-term personality changes following long-term endurance training seems warranted.

It may well be, however, that significant individual differences exist between individuals in the ability of their SNS and related hormonal systems to adapt and adjust to such an endurance program. Indeed, the early identification of potential world-class athletes in East Germany is accomplished in part by monitoring and correctly predicting individual differences in the ability of physiological systems to adapt and respond to training. The psychological and physiological benefits from our running program were obviously not realized equally by all of our runners. It seems likely that the truly committed or addicted runners (see Sachs & Pargman, Note 5) become so committed because they are more able to derive benefits, such as those studied in our research, from their running.

Acknowledgement

Our thanks to Dwight Heil and Brian Plank for their assistance with the data gathering.

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