

Problem Perception, Optimism, and Related States as a Function of Time of Day (Diurnal Rhythm) and Moderate Exercise: Two Arousal Systems in Interaction

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Two experiments are described in which perceptions of personal problems, optimism, and associated feelings were studied as a function of time of day and moderate exercise (walking). Over multiweek periods, participants completed self-ratings at fixed times of day representing high and low periods of energetic arousal. While ratings on individual days varied, means across all rating days indicated that problems were perceived as more serious at mid-to late afternoon, a period of low energetic arousal, than they were at late morning and after the walk, periods of high energetic arousal. Separate analyses of rated high energy and low tension states, compared to their opposites, indicated that problems were perceived as least serious in the former states. Ratings of optimism and associated feelings were consistent with the problem ratings. Also discussed are theoretical implications regarding moods as predispositional variables, state-dependent memory, and research involving naturalistic settings and aggregated measurements.

A casual perusal of the popular literature on psychology reveals a common assumption that everyday moods strongly influence mind and behavior. And yet, experimental demonstrations of these effects have not appeared in great numbers. This disparity exists, I believe, because the effects of mood are extremely ephemeral. Mood is a predispositional variable (e.g., Ryle, 1949), and its effects may be apparent or not, depending upon a larger number of other immediate motivational and cognitive influences.

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Elsewhere, I have argued that subtle mood effects cannot be easily studied with the traditional nomothetic laboratory design, in which measures are taken on a single occasion (Thayer, 1985, 1987; also note Epstein, 1980; Rushton, Brainerd, & Pressley, 1983). For the usual research participant, just being in an experiment, with its attendant manipulations and measurements, probably is sufficiently activating to mask any subtle mood effects that might be under study. What is necessary to capture these effects, in my view, is a more naturalistic setting, in which mood measurements are taken on multiple occasions, and thus the effects can be assessed as they might occur in natural life circumstances. The present research design, which will be described below, was based on these important considerations.

The influence of mood on cognition could be viewed as an example of state dependency (cf. Bower, 1981). State-dependent learning (see review in Overton, 1978), and state-specific consciousness (Tart, 1975) are similar theoretical concepts, which imply that perceptions and memories are often partially associated with moodlike states. As these states change, the cognitive elements are more or less available to conscious awareness. For instance, a person experiencing depression might perceive life circumstances in a particular way, but when the depression lifts, the same circumstances could appear quite different.

In the research presented below, several kinds of state-dependent consciousness are described, but rather than the usual drug-induced states, these are assumed to be created by time of day (diurnal rhythm) and moderate exercise. There is some empirical precedent for the association of time of day and state-dependent learning with infrahuman animals (Holloway, 1978), and related work exists with humans (cf. Colquhoun, 1971). There is other research concerning learning during exercise-produced arousal and recall in a similar state (Clark, Milberg, & Ross, 1983).

Two anecdotal examples, as described to the author, will illustrate the commonplace occurrences on which this research is partially based. These are experiences that are probably common to many people.

Late one evening (11:00 p.m.), a young man worries about a personal problem that has been bothering him recently. As in the case of other late night ruminations, the more he thinks about it, the more bleak the problem outlook appears. It seems as if it will be very difficult to solve, and he becomes increasingly agitated. The scene now shifts to the next morning about 11:00. The young man, who finally fell asleep, has now been up and active for several hours, and he pauses briefly to consider the problem of the night before. He is amazed at how much less serious and more soluble the same problem appears at this time. The facts of the problem have not changed, only the time of day and the young man's reactions to the problem.

And a second example: At 4:00 in the afternoon, as a young woman describes the specifics of her situation, she becomes more and more upset. Her friend suggests that they go for a walk and then talk further. After walking briskly for about 10 minutes, the woman again begins to talk about the problem. She now notices that her previous anxiety is considerably reduced, and she becomes more optimistic. As in the above example, the problem has not changed, but after the brisk walk, it appears different.

These two common examples involved states of consciousness within which personal problems appeared serious and other states in which the same problems appeared less serious. The personal problems had not changed, but, as shall become apparent below, the arousal states underlying the pessimism and optimism were quite different. For one who repeatedly experiences the same negative perceptions at certain times or optimistic views at other times, it is as though there is a kind of cognitive dependency associated with the existent states, one in which the arousal states themselves seem to call forth given sets of memories and perceptions.

In the anecdotal examples, one could interpret the changing levels of problem perception and optimism with reference only to the somewhat familiar experimental variables of time of day and moderate exercise. However, a much more complete and heuristically valuable understanding of the underlying arousal states may be possible on the basis of a recently proposed model of multidimensional activation (Thayer, 1978b, 1985, 1986). This model has a historical basis in general activation or arousal theories (Duffy, 1962; Malmö, 1959), but, unlike those, it proposes that two or more activation dimensions underlie behavior.

The two dimensions that make up the multidimensional model are called energetic arousal and tense arousal (also labeled Activation Dimensions A and B, respectively, in Thayer, 1978b). Tense arousal is assumed to be determined by danger, broadly interpreted, and to be largely cognitively mediated. But variations in energetic arousal are believed to occur naturally, as a function of such factors as time of day, exercise, and nutrition. These two dimensions are assumed to form a curvilinear relationship; that is, they are positively correlated at low to moderate levels, and negatively correlated at moderate to high levels. Since levels of each dimension are relative to the other, this theoretical assumption accounts for the phenomenon of danger having a greater psychological impact (greater tense arousal) when energy is low, and a lesser impact when energetic arousal is high.

In one of the anecdotal examples described above, the late-night ruminations and the late-morning considerations of the problem would be associated with low and high points, respectively, on an endogenous diurnal rhythm of energetic arousal (Thayer, 1967, 1978b; Thayer, Takahashi, Pauli, &

Solheim, 1985). In the second anecdotal example, the late-afternoon agitation would also be associated with a naturally occurring low point on the same diurnal rhythm. And the brisk 10-minute walk would be assumed to produce increased energetic arousal (Thayer, 1978b, 1987).

Following the multidimensional activation model, the changes in agitation or anxiety experienced by the two persons could be seen as occurring because of variations in energetic arousal. That is, the personal problems that these persons were experiencing would be expected to create a potential for tense arousal. And, because the two arousal dimensions are negatively correlated at higher levels, the low energetic arousal of late evening and afternoon would be associated with greater tense arousal, and the increased energetic arousal of late morning and following the rapid walk would be associated with reduced tense arousal. To say this in another way, if there were a pressing problem, these persons could be expected to be more tense in the late evening than in the morning, and less tense following the brisk walk than without exercise in the late afternoon.

A variety of kinds of historical and current evidence about the existence and interaction of the two arousal dimensions has been discussed and reported elsewhere (Thayer, 1967, 1978a, 1978b, 1985, 1986, 1987), but evidence concerning the association of these kinds of arousal with the perception of personal problems and related perceptions concerning optimism and happiness have not been reported. That is, in part, the purpose of the present research.

The two experiments reported below were designed to utilize the subtle arousal changes that occur with circadian rhythms and with exercise. The first dealt with perception of chronic personal problems, and the second concentrated on optimism, happiness, and good physical feelings. Both experiments employed various arousal states as conceptual independent variables. Time of day and moderate physical exercise were quasi-experimentally manipulated so as to sample the highest and lowest arousal states of the day. Self-reports of energy and tension were employed as classificatory variables.

Consistent with the beginning personal examples and the theoretical assumptions underlying the arousal model described above, it was hypothesized that, over multiday periods, particular times of day associated with low levels of energetic arousal and high levels of tense arousal would be correlated with greater apparent seriousness of personal problems, and a generally pessimistic outlook. It was further hypothesized that, over an extended period, moderate exercise and other times of day associated with the opposite arousal configuration (high energetic and low tense arousal) would be correlated with a relatively positive view about personal problems, and with optimism and related states.

EXPERIMENT I

Method

Subjects. Six female and two male college students between 20 and 33 years of age were employed in this research. These individuals were referred from the University Counseling Center or they came from a class taught by the author (students were unfamiliar with the author's empirical and theoretical work). They were selected because they had a bothersome personal problem of somewhat long-standing duration (e.g., a painful marital separation, an unyielding weight problem, severe parental discord) and on the basis of their willingness to participate in a time-consuming experiment. The students were motivated by the promise that they would be fully informed of all the research purposes and results at the experiment's termination, and that they might well learn important things about themselves. Furthermore, they were each paid \$25. This payment was made once they agreed to cooperate, and with the understanding that if for any reason they decided not to complete the experiment the money would still be theirs, and no pressure would be applied for completion.

Measures. The Short Form Activation-Deactivation Adjective Check List (AD ACL) was used to assess energetic and tense arousal (Thayer, 1967, 1978a, 1986). This is a self-report test that provides information about the respondent's present feeling state from ratings of energy and tension-related adjectives. It has been validated in a variety of ways, including correlations with psychophysiological variables (Thayer, 1967, 1970), diurnal cycles (Thayer, 1967, 1978b; Thayer et al., 1985), and various kinds of performance measures (see Thayer, 1978b, for a review). This test takes about 30 seconds to complete; it provides four subscales: G Act (energy), Deac-S1 (tiredness), H Act (tension), and G Deac (calmness). There are five adjectives on each subscale, and each adjective is self-rated on a 4-point continuum. The two subscales most relevant to the present hypotheses (energy and tension) were employed in this experiment. Specifically, the adjectives included in these two subscales were *energetic, lively, active, vigorous, and full of pep*, and *tense, clutched-up, fearful, jittery, and intense*.

Ratings of perceptions of personal problems were accomplished with three 20-point Likert-type scales. On the first scale, the problem was rated on the basis of how serious it appeared, with a rating of 20 representing "extremely serious" and 1 representing "not serious at all." On the second scale, the same problem was rated on the basis of its apparent difficulty of solution (20 = extremely difficult, 1 = not difficult at all). On the third scale, the problem was rated according to its likelihood of solution (1 = very like-

ly, 20 = not likely at all). Scores for problem perception were derived from means of the three ratings.

Procedure. The experimenter first met individually with each participant, in part to determine exactly what problem would be focused upon. Once the problem was pinpointed, participants were instructed that prior to each rating they were to first complete the AD ACL and then think about the agreed-upon problem for 1 or 2 minutes, considering its full implications. Finally, they were to make their ratings. Participants were also explicitly warned that all their self-ratings must be made on the basis of their feelings and perceptions at the moment the ratings were made. They were also told that if they made any ratings on the basis of self-generated hypotheses, or if they considered other ratings before making the present ratings, the experiment could be invalidated.

The experiment was carried out by each individual in whatever daily setting was natural for that person. Participants were instructed to choose 10 experimental days over 3 or 4 weeks. The days were to be as much alike as possible, particularly with regard to previous night's sleep, morning awakening, and anticipated daily activities.

On each test day, participants were to keep rating materials at hand so ratings could be made promptly at the appointed time. Consistent with known high and low levels of energetic arousal (Thayer, 1978b), ratings were to be made five times on each day: immediately after awakening, in late morning (approximately 11:00 a.m.), in mid- to late afternoon (approximately 4:00 p.m.), and just before night sleep. In addition, prior to beginning the experiment, participants also chose one time of day, at least 1.5 hours from any other rating, to take a 10-minute rapid walk. The time of day of the walk varied across participants, but it was always the same for each individual participant. The fifth rating was made immediately after this walk.

Results

The conditions of the experiment, and in particular the requirement to remember to make self-ratings five times a day for 10 days, proved more difficult than initially anticipated. Therefore, consistent with the agreement that experimental participants could terminate their participation whenever they no longer could carefully complete the conditions of the experiment, only three of the experimental participants completed all 10 days of measurements. Two completed 9 days, one 8, one 7, and one 5 days. Since means across days were employed for most statistical analyses, the ratings of all eight participants were included in the analyses.

With days averaged, means and standard deviations of self-reported energy, tension, and perception of personal problems are presented in Table

Table I. Means and Standard Deviations of Energy, Tension, and Perception of Problems for Time of Day and Exercise Conditions

Self-ratings		Conditions				
		Waking	Morning	Afternoon	Walking	Before sleep
Energy	<i>M</i>	7.7	13.9	9.2	15.1	6.0
	<i>SD</i>	2.87	2.21	3.38	2.86	2.11
Tension	<i>M</i>	7.8	9.0	9.5	8.8	8.2
	<i>SD</i>	2.46	2.72	3.07	2.86	2.24
Problem perception	<i>M</i>	11.9	11.5	12.8	11.5	12.3
	<i>SD</i>	3.63	3.07	3.17	3.62	3.86

1. As can be seen, energy was rated as highest after the walk and in late morning, and it was rated as lowest before sleep, just after waking, and in mid- to late afternoon. A single-factor, repeated-measures ANOVA indicated that these variations were statistically significant ($F(4, 28) = 19.89, p < .001$).

Ratings of perception of personal problems were generally opposite those of energy, with the most negative perceptions in mid- to late afternoon, before sleep, and just after awakening. Problems were viewed least negatively after the walk and in late morning. These variations only approached statistical significance, however ($F(4, 28) = 2.00, p < .1$). Ratings of tension were highest in mid- to late afternoon, the same time period that problems were viewed most negatively, but variations of tension ratings across time periods were not significant ($F(4, 28) = .84$).

In planned comparisons, analyses of ratings of problem perception during conditions of high energy and low tension, as opposed to conditions of low energy and high tension, yielded two statistically significant differences. In mid- to late afternoon, the conditions of highest tension and relatively low energy, problem perception ratings were significantly higher than after the walk and in late morning, the conditions of highest energy and relatively low tension ($t(7) = 2.85, \omega^2 = 31\%$ (late morning) and $2.59, \omega^2 = 26\%$ (after walk), $p < .05$ and $< .01$, respectively). Problem perception ratings before sleep and upon awakening did not differ significantly from ratings after the walk or in late morning.

In comparing states of high energy and low tension with those of low energy and high tension, the perception data could also be viewed another way. For each participant, it was possible to choose average problem ratings from whatever condition represented one mood extreme and compare them with ratings from the condition representing the other extreme. For example, for six persons the walk condition included ratings of the highest energy and lowest tension, but for one person it was the awakening condition, and for another it was the afternoon condition. Thus, the problem perception ratings at these periods of mood extremes were compared with the problem

Table II. Means and Standard Deviations of Problem Perceptions as a Function of Relative Energy and Tension Levels Across Conditions

Statistics	Relative energy (E) and tension (T)			
	Highest E, lowest T	Mod. high E, mod. low T	Mod. low E, mod. high T	Lowest E, highest T
Means	10.9	11.6	12.6	12.8
Standard deviations	3.85	3.09	3.27	3.45

ratings during whatever conditions included the lowest energy and highest tension for the same persons (awakening condition for three subjects, mid- to late afternoon for two, and before sleep for three).

Means and standard deviations of energy, tension, and problem ratings for these various mood extremes and midpoints of mood are presented in Table II. As can be seen, the relationship of energy and tension predicted problem ratings. From a repeated-measures analysis, it is clear that problem perception ratings during periods of highest energy and lowest tension were different from those during lowest energy and highest tension ($t(7) = 3.08$, $\omega^2 = 35\%$, $p < .001$).

Discussion

The experimental results clearly suggest that energy and tension states in interaction are associated with the perception of personal problems. In mid- to late afternoon over a multiday period the same chronic personal problems appeared more serious and less likely to be solved to the experimental participants than they did in late morning or after a brisk walk. Moreover, self-ratings of energy and tension at various times of day confirmed that a mood pattern of high energy and low tension predicts more positive problem perception than a pattern of low energy and high tension.

One of the major issues in this research concerns causality. Did the mood states influence problem perception or were they merely correlates of the changes in problem perception that were due to other causes? On the face of it, the likelihood is that the arousal states were in some sense primary causal factors. There was no apparent reason other than these changing states why the same problems appeared more negative at one time of day than another. But the reports of energy changes with time of day and moderate physical exercise corresponded exactly with previous empirical observations (Thayer, 1967, 1978b, Thayer et al., 1985). The quasi-experimental manipulations of energy states by time of day and moderate exercise do not guarantee causality, but, taken together with previous research on time of day and moderate exercise, at least directionality is strongly suggested.

The significant shift in perception of personal problems with time of day and moderate exercise may appear unlikely to some. The normative view is probably that such perceptions are controlled by outside circumstances, not naturally occurring internal changes (cf. McArthur, 1972). Indeed, in the present data, observing these relationships on any one day could have shown little or no relationship since many other factors may influence perception to a greater degree than background arousal states. In my experience, these naturally occurring moods are very subtle in their effects. As predispositional variables, they may not be very influential at any one time, and yet, in a longer time frame, their influence can be substantial. As in the present research, it may require natural settings combined with aggregation of stabilities and changes over time to observe their real effect.

One alternative explanation for these results, however unlikely, is subject expectation effects. It is, of course, possible that experimental participants guessed the hypotheses and cooperated in providing confirmatory results. This is unlikely for several reasons. First, the hypotheses are not at all obvious without knowledge of previous research on variations in energetic arousal. While it is possible that participants could have guessed the relationship between walking and problem perception, particularly if the walk were eventually perceived as exercise, the relationship between time of day and problem perception would appear to be very difficult to guess.

Additionally, experimental participants were warned specifically that failure to make ratings only on the basis of current feelings could invalidate the experiment, and, if any cooperation occurred, it would have been most likely on this point. Furthermore, in the author's experience with previous research involving multiple measurements with the AD ACL, the testings seem to become quite automatic, with subjects exhibiting little concern for the significance of each measurement.

A last point regarding possible expectations effects is that an analysis of changing effects by day of measurement indicated no systematic effect. (The analysis was completed on the first 5 days, the period on which complete data for all eight subjects were available.) If expectation influences had been present, it is likely that this analysis would have shown at least marginal significance since experimental participants could be expected to have guessed the purposes of the experiment only over time.

EXPERIMENT II

The above experiment provided strong evidence of the relationship between arousal states and perception of chronic personal problems. Although, by modern research standards, the numbers of separate measurements taken

in this experiment were quite substantial, and the resultant reliability of the dependent measures very high, the actual number of experimental participants was small. Moreover, these individuals may have been unrepresentative of the wider population in that they were all selected because they were experiencing a continuing personal problem. Therefore, it seemed advisable to attempt a replication of the above findings with more research participants of a different kind and with related but different self-perceptions.

Thus, a second experiment was planned in which typical college students were engaged without consideration of any chronic personal problems. And, rather than focusing on problem perception, optimism and associated feelings were studied in relation to the two kinds of arousal. In order to make the requirements for participation a bit less arduous in this second experiment, only the conditions of Experiment I that provided the greatest effect were included (mid- to late afternoon, late morning, and walking).

It was hypothesized that optimism, happiness, and physical good feelings would be lowest in mid- to late afternoon, the condition of least energetic and highest tense arousal, and that these self-perceptions would be highest in late morning and after a walk, the conditions of relatively higher energetic and lower tense arousal. It was further hypothesized that during the 3 weeks of data collection, optimism and related states would be greatest on days of highest energy and lowest tension and lowest on days of the opposite arousal configuration.

Method

Subjects. Experimental participants were students recruited from classes taught by the author, but at the point of this experiment, participants were not knowledgeable about the author's theories or research. Participants included nine females and three males between the ages of 19 and 41 years. They were recruited on the basis that they would learn something about themselves through the complete results provided at the termination of the research. They were also told that the study would be time-consuming, and that any time they believed they could not carefully complete the research they could turn in the remaining materials and no questions or problems would occur.

Measures. The Short Form AD ACL (Thayer, 1967, 1978a, 1986) was once again used to measure energy and tension states. Optimism, happiness, and physical good feelings were assessed with three 20-point Likert-type scales. The positive poles (20) were anchored with the term *extremely* and the negative poles (1) with the term *not at all*.

Procedure. In a similar way to Experiment I, the experimenter met with each participant to explain the ratings, the times when the ratings were to

occur, including the required similarity of the 6 days on which the ratings were to occur, and the fact that each rating must be independent of all others.

As in Experiment I, each rating was conducted in the participant's natural daily setting. Morning ratings were at approximately 10:00 or 11:00 a.m., afternoon ratings were at 3:00 or 4:00 p.m., and the rapid walk was taken at any time of the day that was at least 1.5 hours from the other two ratings (different times for different persons, but the same time each day for each individual).

At the appointed time on each experimental day, the participant was to complete the AD ACL and then spend a minute or two considering his or her general life circumstances before making the global ratings of optimism, happiness, and physical well-being. As with the AD ACL, these global ratings were to be made on the basis of feelings at the moment of consideration.

Results and Discussion

As in Experiment I, experimental participants were allowed to terminate their participation any time that they felt they could not carefully complete the conditions of the experiment. Nine persons completed all 6 days, two completed 5 days, and one completed 4 days. Since means across days were employed for most analyses, the data of all 12 participants were included in subsequent analyses.

With days averaged, means and standard deviations for the two mood states and for optimism, happiness, and good physical feelings are presented in Table III. As expected, self-reported energy was greatest at late morning and after the walk; it was lowest in mid- to late afternoon. Reported tension was greatest in mid- to late afternoon. Repeated-measures analyses indicated that energy differences were reliable (morning vs. afternoon, $t(11) = 7.41$,

Table III. Means and Standard Deviations of Energy, Tension, Optimism, Happiness, and Good Physical Feelings for Time of Day and Exercise Conditions

Self-ratings	Conditions					
	Morning		Afternoon		Walking	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Energy	16.0	2.32	9.8	3.13	15.9	2.73
Tension	7.8	1.97	8.4	2.63	7.3	1.48
Optimism	15.2	2.74	13.8	3.06	16.0	2.69
Happiness	14.4	2.61	13.7	2.46	15.5	2.48
Good physical feelings	14.5	2.45	13.4	2.63	15.8	2.42

$p < .001$; walk vs. afternoon, $t(11) = 5.90$, $p < .001$). Reported tension differences across conditions were not statistically significant.

Also as expected, optimism, happiness, and good physical feelings were all rated as lower in mid- to late afternoon than they were in late morning and after the walk. Planned repeated-measures analyses revealed that all but one of these differences were statistically significant. (Results for morning vs. afternoon and walk vs. afternoon, respectively, were as follows: optimism, $t's(11) = 2.69$, $p < .05$, and 2.82 , $p < .02$; happiness, $t's(11) = 1.63$, n.s., and 2.48 , $p < .05$; good physical feelings, $t's(11) = 2.43$, $p < .05$, and 4.63 , $p < .001$).

In general these results indicate that, of the various self-ratings, time of day and walking had the strongest effects on energy ($\omega^2 = 69\%$, 58% , respectively), the next strongest effect occurred for walking on good physical feeling ($\omega^2 = 46\%$), followed by the effect for optimism in the two condition comparisons (22% for morning and 21% for walk vs. afternoon). The weakest effect occurred for the nonsignificant happiness difference (7% for morning vs. afternoon). These differential effects suggest that the underlying processes associated with the two independent variables are most closely related to self-rated energy and less strongly related to optimism. The differential effects also indicate that the experimental participants were not uniformly rating all scales in the same way.

In Experiment I, meaningful results were obtained from within-subject comparisons for conditions of highest energy and lowest tension as against conditions of lowest energy and highest tension. In this experiment, there was not sufficient variance within each condition for that same analysis. But it was possible to compare ratings of optimism, happiness, and physical good feelings for each participant on the 1 day of the 6 when he or she felt the highest energy and lowest tension and the single day when the lowest energy and highest tension were experienced. When relative ratings of energy and tension were tied for 2 or more days, means for all tied days were taken for the various other self-ratings. These ratings are presented in Table IV.

As can be seen, the two mood configurations predict very substantial differences in ratings of optimism, happiness, and physical well-being. Repeated-measures analyses indicated that these differences were all statistically highly significant (optimism, $t(11) = 3.87$, $p < .01$, $\omega^2 = 39\%$; happiness, $t(11) = 4.76$, $p < .001$, $\omega^2 = 50\%$; good physical feelings, $t(11) = 4.83$, $p < .001$, $\omega^2 = 50\%$).

In a similar way to Experiment I, the possibility of subject expectation effects was evaluated as an alternative explanation for the above results. Once again, the hypotheses in the present experiment are not obvious without knowledge of the underlying theory. As in Experiment I, an analysis of effects by day of measurement would probably have indicated reliable changes

Table IV. Means and Standard Deviations for Optimism, Happiness, and Good Physical Feelings on High-Energy, Low-Tension Days versus Low-Energy, High-Tension Days

Classifications	Self-ratings					
	Optimism		Happiness		Good physical feelings	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Highest energy, lowest tension day	16.9	2.28	16.6	2.37	16.6	2.43
Lowest energy, highest tension day	12.1	4.47	11.3	3.93	11.5	3.75

if expectation effects were present. The same analysis on the present data, for the 4 days that were completed by all participants, indicated no significant differences.

The results of this second experiment, involving similar but different dependent measurements, represent an excellent replication for the results of the first experiment. And, since the participants in Experiment II were not selected for chronic personal problems, a wider generalization of the obtained effects can be assumed.

GENERAL DISCUSSION

Although causation cannot be firmly established, the results of Experiments I and II, taken together, clearly suggest that hour of the day and moderate physical exercise produce changes in perception of personal problems, optimism, and related states. With aggregated measurements, in late morning or after a rapid 10-minute walk, the resultant energetic and calm state is associated with relatively positive perceptions of personal problems, optimism, good physical feelings, and happiness. On the other hand, in mid-to late afternoon, during the associated state of low energy and high tension, personal problems are likely to be interpreted as more serious and less soluble. Less optimism, happiness, and good physical feelings are also likely.

These effects could well be due to the diurnal rhythm of energetic arousal and the influence of exercise on the two kinds of arousal. However, even without the assumption of causation involving the present independent variables or possible underlying arousal states, there are important implications of these results. Few would question the fact that problem perception and optimism are significant elements of personality, with associations involving both pathology and psychological health.

Just to consider one immediate and practical matter, the apparent effects of the two independent variables suggest that individuals concerned about personal problems and optimism should pay careful attention to what time of day positive and negative thoughts about the future usually occur, and the proximity of exercise to the pertinent thinking. The obtained results suggest that interventions affecting arousal states, such as exercise, or merely waiting for a more propitious time of day, could advantageously affect problem perceptions and optimism.

Establishing causation between arousal states and the cognitive processes studied in the present research would be scientifically valuable, but this is a difficult task. Directionality is strongly implied from the quasi-experimental manipulations of time of day and exercise. But, given the present evidence, causation can only be inferred theoretically.

A theoretical analysis of causation would move from the observation that a diurnal cycle can be established for energetic arousal, in the shape assumed as part of the present independent variable (in addition to the present results, see Thayer, 1967, 1978b; Thayer et al., 1985). Moderate exercise apparently affects the same arousal process, or at least the same measured variables (Thayer, 1978b, 1987). In turn, the perceptions of personal problems, optimism, happiness, and good physical feelings also seem to be affected by time of day and moderate exercise, but to a lesser degree. The fact that energetic feelings are most strongly associated with time of day and exercise suggests a primary role for this arousal variable. Further evidence of primacy is suggested because extremes of energetic and tense arousal have the strongest associations with problem perceptions, optimism, and related perceptions.

A plausible explanation for how the interaction of energetic and tense arousal produces the various self-perceptions would be a clear aid in this theoretical analysis, of course. And such a possible explanation emerged from informal interviews with some of the participants in the present research. The explanation incorporates certain principles of cybernetics (cf. Carver & Scheier, 1982).

To illustrate this explanation, let us go back to one of the anecdotal examples used in the beginning of this article. In that case, late one evening the young man was worrying about a personal problem, and the more he thought about it, the more bleak the problem outlook appeared. He probably considered the difficulties involved in solving the problem, together with the likelihood of ultimate solution. From a problem-solving perspective, this young man probably considered the various requirements associated with the problem as well as his available resources for meeting those requirements.

The cybernetics analysis to be proposed here would maintain that as he thought ahead about these matters, a kind of rapid and low awareness

feedback loop was involved. That is, as he thought about whether or not he could meet the necessary demands, the question arose, "Could I meet those demands *now*?" And since his present resources were low, the natural answer was "No." Thus, on the basis of an inappropriate projection of present resources into the future, his perception would have been that the problem was serious and not likely to be solved. On the other hand, the next morning, when resources were high, the same self-question would have resulted in an affirmative answer and, therefore, a problem outlook of less seriousness and greater likelihood of solution.

These inappropriate projections of current energy states into the future would work both ways, of course. While unrealistic pessimism is likely to result from such improper projections, decisions about the future at higher energy times might be unrealistically optimistic. For example, if plans are always made in late morning or after moderate exercise, the elevated energy state present then may not be a good indication of how the individual is likely to feel when the planned activities must be carried out. Given the validity of this underlying explanatory mechanism, the most realistic decisions about the future would likely be made when energy states are most similar to the times when the future activities must be carried out.

Admittedly, there are a number of untested assumptions in this analysis. But these assumptions about subtle cognitive errors and improper projections about present energy states into the future are reasonable, and they fit with personal experience.

Natural Reactions to Predispositional States versus Subject Expectation Effects: Design Considerations

Mood effects such as those demonstrated in the above experiments are very subtle. It may not be possible to assess them except with very reliable measurements in naturalistic settings. This kind of mood can be best thought of as a predispositional variable rather than a direct causal agent. In the presence of such predisposing states, certain effects are more probable, but other cognitive or motivational conditions can easily override the mood (e.g., overcoming tiredness to attend to something important).

Such characteristics make these moods particularly difficult to study in controlled experimental conditions because the obtrusiveness of the laboratory and measurement processes could have greater effects upon the dependent measures than the moods under study. Largely for this reason, I have advocated short-term longitudinal designs such as those used in the present research (Thayer, 1985, 1987). Unfortunately, there are disadvantages to this type of design. In particular, subject expectation effects are dif-

difficult to completely control because, with repeated experimental manipulations and measurements, experimental participants have the opportunity to guess the purposes of the research. Thus, the experimenter is left with the dilemma of investigating predispositional states with single-occasion designs that control subject expectation effects but miss the subtle mood variations, or the experimenter may employ repeated-measures designs in naturalistic settings that yield reliable measurements of such subtle states but leave possible subject expectation effects as competing explanations for obtained results.

It is, of course, possible to minimize expectation effects, and to evaluate evidence of their likely influences, as was done in the present research, with less obvious hypotheses and statistical tests of occasions' effects. One may also view expectation effects in a more balanced manner than has usually occurred in psychological research. These competing explanations for results, even if they cannot be entirely ruled out, do not automatically invalidate reasonable findings. In an excellent analysis of demand characteristics, Berkowitz and Donnerstein (1982) have shown that even if subjects are aware of the purpose of an experiment, there is no reason to assume that they would necessarily provide confirmatory results.

State Dependency

State dependency has usually been demonstrated experimentally with the aid of drugs (Overton 1978), but psychological manipulations have also been used (e.g., Bower, 1981). The results of the present research suggest something at least akin to state dependency, but, in this case, the state was produced through diurnal rhythms and exercise. If this is state dependency, there are a number of important possible connections that might be considered.

For example, the natural daily variability of energetic arousal (Thayer, 1967, 1978b; Thayer et al., 1985) suggests that some important elements of cognition could be much more variable than previously recognized. In our daily lives, as days progress and more or less exercise occurs, our perceptions of our inner and outer world could also change in predictable ways. It is likely that the traditional view of these kinds of perceptions concerning personal problems and optimism would be one of stability, with change coming only from variations in external circumstances (McArthur, 1972). But, from the reported experimental results, the picture is one of daily variability, with naturally occurring arousal shifts.

I believe that at least part of the promise of state-dependent consciousness for the psychology of personality is that this neuropsychological phenomenon may enable explanation of some of the puzzling aspects of subjective ex-

perience associated with mood. In particular, case study evidence of strong mood states suggests a pervasive consciousness that, in the case of negative mood states, is maddeningly familiar to the unfortunate person experiencing it (Arieti & Bemporad, 1978). One can view depression as discouraging, for example, because the depressed person is reminded of often considered shortcomings and seemingly hopeless conditions in his or her life.

In this context, the present results may be quite meaningful. The cumulative effect of recurrent problem perceptions, even if subtle, could make these thoughts quite significant in a person's life. This would be particularly true if speeded and stressful lifestyles resulted in a higher frequency of nonenergetic and tense states. The realization that, over and over again in the past, similar thoughts and memories have occurred, and the lack of awareness that these are energy-state-specific, could contribute to an overall sense of hopelessness, despondency, or even panic.

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