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Toward a Psychological Theory of Multidimensional Activation (Arousal)

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The traditional physiologically defined activation or arousal continuum, which ranges from intense emotion and vigorous activity on one extreme to calmness and sleep on the other, is rejected in favor of a psychological model with two activation dimensions and a single continuum of energy expenditure. One activation dimension ranges from subjectively defined feelings of energy and vigor to the opposite feelings of sleepiness and tiredness. Activation states associated with this dimension regularly vary in a circadian rhythm, and this dimension underlies gross physical activity and many aspects of cognition. The second dimension ranges from subjective tension to placidity and quietness, and it probably underlies a variety of emotions (e.g., anxiety) and stress reactions (e.g., effects of loud noise). While the two dimensions are positively correlated at moderate levels of energy expenditure, they are negatively correlated at high levels of expenditure; therefore, tension is lowest when energy-vigor is greatest and vice versa. Vulnerability to tension increases at late night, early morning, and at other times when effort and stress have increased tiredness and reduced vigorousness. Extremely low activation on either dimension de-energizes the whole system. Although only two dimensions are assumed, the possibility of four or more activation dimensions is discussed.

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Why do the same personal problems look different to us at midday from the way they do late at night? What is the relationship between the feeling of vigor that is associated with physical exercise and the feeling of tiredness that comes with sitting around doing nothing? Why, in the same social setting, do we react one way when we are tense and another way when we are calm? This article deals with these questions and other similar ones.

Each of the questions posed has in common an activation or arousal dimension. Historically, such dimensions have been nondirectional in character, and they have been assumed to mediate or energize a broad range of behaviors (cf. Duffy, 1962; Hebb, 1955; Lindsley, 1951; Malmo, 1959). For many theorists, a single activation dimension ranging from maximal excitement to relaxation and sleep was believed to account for behaviors as varied as those represented in the above questions. As shall be demonstrated, however, on a psychological level at least *two* energizing dimensions seem necessary for any complete accounting.

The use of activation constructs, though not necessarily as part of any general activation theory, remains an important part of modern-day psychology even though there have been influential and well-conceived criticisms (e.g., Lacey, 1967). The currency of this usage is particularly apparent in personality and social research (e.g., Geen & O'Neal, 1969; Schachter, 1964; Zajonc, 1965), but it is also apparent in such traditional experimental psychological subject areas as verbal behavior (e.g., Eysenck, 1976b) and information processing (e.g., Broadbent, 1971). It is perhaps a noteworthy development that the latter usages represent something of a shift toward broader behavioral definitions of arousal or activation and away from more traditional physiologically defined concepts.

The extreme complexity of organismic functioning has undoubtedly caused many to avoid the use of general activation constructs. For example, there have been frequent descriptions of low intercorrelations of central and peripheral subsystems in situations that theoretically should be activation-inducing (e.g., Lacey, 1967; Routtenberg, 1968). However, to deny the validity of an intensity continuum that underlies behavior seems to fly in the face of common sense. It can be readily observed that humans and other animals are more active and expend more energy at some times than at others. These activity and energy expenditure differences are quite complex but nevertheless predictable on a gross level in the case of the rhythmic sleep–wakefulness cycle, and only slightly less predictable when considering task activity at varying degrees of cognitive and motoric difficulty. From another perspective, no one would deny that we experience emotions less intensely at some times and more intensely at others. These general observations are tangibly supported by the agreement among psychophysiologists that a variety of intensities and kinds of stimulation lead the resting organism to heightened activity in diverse bodily systems (Sternbach, 1966).

Thus investigators evaluating the utility of general activation constructs are faced, on one hand, with the obvious idea of similarly appearing gross variations in intensity in a variety of kinds of behavior and, on the other hand, with low intercorrelations among bodily systems when simultaneous measurement of intensity variations is attempted. If activation constructs are to be theoretically valuable, what is needed is one or more common measures of intensity or activation that can be used to predict diverse behaviors. This paper will demonstrate that controlled self-report can meet that need.

Although self-report is associated with numerous methodological problems, it usually represents a high level of organismic integration. The relatively sophisticated individual, when asked to describe his momentary activation feelings, potentially may utilize self-derived information about a number of simultaneously functioning bodily systems. It is not known how awareness occurs, but it is at least probable that the summation of information from many of these systems leads to an individual's awareness of any given level of activation (see, Davitz, 1969). Experimental evidence is very difficult to obtain on this matter, but there are some reliable data that suggest that, under certain conditions, self-report provides a better indication of general organismic functioning than does any single psychophysiological measure (Thayer, 1967, 1970). Therefore, if integrated organismic functioning is to be assessed, in theory, self-report would appear to be an excellent practical index.

The model to be presented below is mainly based upon self-report data obtained with the Activation–Deactivation Adjective Check List (AD ACL). In the first research on this instrument (Thayer, 1964), a diverse group of activation descriptive adjectives that sampled all elements of a hypothesized nondirectional activation continuum was gathered from various sources, including the Nowlis Mood Adjective Check List (Nowlis, 1965). Following the Nowlis research paradigm, subjects were asked to rate each adjective on a 4-point scale according to how it described their feelings at the moment the test was taken. On the basis of repeated factor analyses involving numerous groups and activation conditions, the large set of activation descriptive adjectives was culled to 22 relevant adjectives. A subsequent factor analysis with an orthogonal rotation (Thayer, 1967) yielded the following four factors: General Activation (G Act: lively, active, full of pep, energetic, peppy, vigorous, and activated); Deactivation–Sleep (D-Sl: sleepy, tired, drowsy); High Activation (H Act: clutched up, jittery, stirred up, fearful, and intense); and General Deactivation (G Deac: at rest, still, leisurely, quiescent, quiet, calm, and placid). The reliability and construct validity of the obtained measures were then studied in relation to several physiological and behavioral indices associated with a loose theory of activation (Thayer, 1967, 1970, 1971; Thayer & Carey, 1974; Thayer & Cox, 1968; Thayer & Moore, 1972).

SUMMARY OF THE TWO-DIMENSIONAL MODEL

The model developed in this paper incorporates a single continuum of energy expenditure. This is similar to early activation models, and in particular to Duffy's (1962) activation theory. However, the present model differs importantly from earlier conceptualizations in that at least two (and possibly several) separate energizing dimensions are seen as necessary to account for most behavioral variations. These two dimensions, which may be roughly characterized as energy–sleep and tension–placidity, each are thought to vary from high to low energy expenditure. An important part of the present model concerns the conditions under which these two dimensions are positively correlated and under which they are negatively correlated (see Figure 1).

The dimension believed to underlie most behavior will be called Activation Dimension A. It is approximately associated with a range of subjective feelings extending from energetic and vigorous at one extreme to

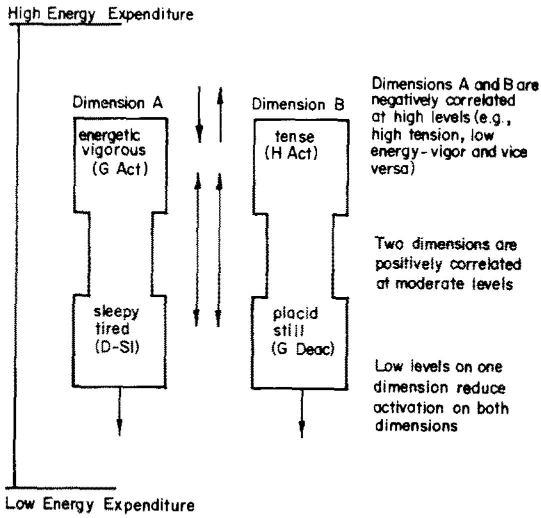

Fig. 1. A two-dimensional activation model.

drowsy and tired at the other. Dimension A activation is presumed to vary diurnally, and probably in a circadian rhythm, with the general sleep–wakefulness cycle. Feelings of energy and vigor are greatest at some point or points during the normal waking hours, and feelings of drowsiness and tiredness are greatest upon awakening and before sleep. This dimension is believed to be integrally tied to variations in ordinary (nonemergency) voluntary motor activity. For example, physical exercise most strongly affects activation on this dimension. Apparently, Dimension A also underlies many aspects of cognitive activity, particularly verbally oriented processes. Finally, high energy expenditure on Dimension A seems to be weakly linked with positive affective tone. Feelings of well-being and happiness are correlated with feelings of energy and vigor.

A second and separate activation dimension is presumed to mediate defensive behavior at one extreme, including emergency energy mobilization, and at the other extreme, reciprocal quiescent bodily reactions. This will be called Activation Dimension B. It is approximately associated on one pole with subjective tension and, on the other, with placidity and stillness. This dimension is believed to underlie a variety of emotions and stress reactions. For example, it is connected with anxiety and the effects of at least one external stressor (i.e., noise). Also, meditation produces the most pronounced changes on the low energy expenditure pole of Dimension B (subjective placidity–stillness). Dimension B may mediate cognition and some voluntary motor activity, but this dimension is not associated with these functions nearly as directly as is Dimension A. Lastly, high Dimension B activation (subjective tension) appears to be weakly correlated with negative affective tone.

Since there is a common continuum of energy expenditure, both Activation Dimensions A and B are believed to covary with autonomic and skeletal muscular arousal. For this reason, commonly employed indices such as skin conductance, heart rate, and muscle action potentials may reflect energy expenditure on either Dimension A or B. A further complication in psychophysiological differentiation occurs because Activation Dimensions A and B are correlated with each other during most ordinary waking activities. At these times Dimension B measures show little variation while Dimension A measures are the best predictors of a variety of behavioral correlates.

The separateness of the two activation dimensions is indicated by certain interaction patterns. During conditions leading to high tension, and also when individuals are experiencing high energy and vigor, Dimensions A and B are believed to be negatively correlated. That is, high tension is associated with reduced energy and vigor, and peaks of energy and vigor are associated with reduced tension. Furthermore, as Dimension A activation varies in its circadian rhythm, tension-inducing conditions have their greatest effect when energy–vigor is low and tiredness is high (e.g., late night and early morning). Conversely, tension-inducing conditions have their least effect when Dimension A activation is high. Prolonged effort and the subsequent reduced energy and increased tiredness will also make an individual vulnerable to increased tension. A last assumption concerning the relationship of the two dimensions is that extreme tiredness results in reduced energy expenditure in the body as a whole. Extreme stillness–placidity may also reduce all bodily energy expenditure.

The present model assumes two bipolar activation dimensions, and most of the evidence is consistent with that conception. However, subjective energy–vigor is not always reciprocal with drowsy–tiredness, nor is tension always reciprocal with placidity–stillness. Therefore, at present it appears that four separate activation factors may be identified, and that these factors generally, but not always, act as two reciprocal pairs. It is assumed that the two dimensions within the present model are inclusive of all general activation states. But, with this conception, certain problems exist in accounting for the diversity of emotions that can be subjectively labeled. Should additional general activation dimensions be identifiable, the present model would not necessarily be invalidated. Rather, other dimensions could complement the model. Activation Dimensions A and B and their correlation patterns stand alone in at least accounting for many important segments of behavior.

In the remainder of this paper, the evidence that supports different aspects of the proposed model will be presented. Some of this evidence is in the form of previously unpublished data on the AD ACL, while other evidence comes from reports on AD ACL research from several different laboratories. Other relevant research evidence not incorporating the AD ACL, as well as important anecdotal observations, will also be reviewed as a basis for the model.

DIMENSIONS OF ACTIVATION

The current factor-analytic model used to describe multidimensional activation states evolved in two stages. As mentioned above, early factor analyses yielded four distinct activation factors that were thought to be independent. However, the four factors usually did not show independent variation in various experimental studies. It seemed more probable that two pairs of somewhat independent factors existed.

To more fully understand the exact relationship among activation factors, two extensive studies were carried out utilizing large numbers of subjects and comparing orthogonal and oblique rotation solutions of the ratings (Thayer, 1978). These studies were performed in conjunction with the development of a short-form AD ACL and the addition of two anxiety-descriptive adjectives (*tense* and *anxious*) to the other 22 activation adjectives.

In both studies the four previously identified activation factors once again appeared, but a new finding cast doubt on earlier exclusive use of orthogonal rotations. A substantial amount of correlation among factors occurred, and the most unambiguous and psychologically meaningful factor structure was obtained with oblique rotations. Consistent with informal observations in various experimental studies, G Act and Deac-S1 were negatively correlated in both new studies (−.58, −.49). Also similarly to findings of previous experimental studies, H Act and G Deac were negatively correlated in the new studies (−.50, −.41). These negative relations among factors were explored more fully with second-order factor analyses, and two general dimensions were indicated. In both studies the two pairs of primary factors showed high bipolar loadings on two distinct second-order factors.

The above factor-analytic studies, particularly the second-order analyses, are obviously inconsistent with a unidimensional activation construct. Instead, at least two separate general dimensions appear to exist (also see Clements, Hafer, & Vermillion, 1976; Bohlin & Kjellberg, 1973). One dimension, designated A, includes G Act and D-S1, and the second dimension, designated B, includes H Act and G Deac. However, the lack of high negative correlations between the polar opposites on the two general dimensions suggests caution in interpretation. Such results could have occurred because there are two loose dimensions made up of pairs of factors that usually but not always act as polar opposites. This possibility will be discussed more fully below.

Although the factor-analytic evidence provides the outlines of Activation Dimensions A and B, and shows strong indications that the two dimensions are separate, the factor analyses do not give a complete picture of activation multidimensionality. The factor model is complemented by demonstrations in experimental settings of the simultaneous existence of activation states representing polar opposites of the traditional one-dimensional activation continuum.

For example, Thayer and Moore (1972) produced three levels of anxiety through experimental manipulation while subjects completed AD ACLs. As predicted, H Act reports were greatest at the highest manipulated anxiety level, but G Act and D-S1 were decreased compared to lower anxiety levels. Thus, in the condition in which subjects reported they were most tense, they did not simultaneously report that they were least tired and most energetic as might be expected in a traditional activation model. Instead, at high tension, subjects were also tired and nonenergetic.

Another example of the same phenomenon comes from an as yet unpublished depression study by Anne Wettler and this author. In this research, eight females monitored their activation states during several days when they felt very depressed, and at the same times of day and under similar conditions, on comparison days when they were not depressed. Very reliable configurations of depression-related activation states emerged. Compared to control days, the subjects were invariably tense (H Act), and at the same time they were tired (D-S1) and low in energy–vigor (G Act). These depression findings are quite similar to other observations of the phenomenology of depression (Becker, 1974), and the observed state of low energy and tiredness with accompanied tension is difficult to encompass in a unidimensional activation model.

Anecdotal evidence is readily available that people may simultaneously experience activation states representing opposite ends of a continuum thought by many to be unidimensional in nature. Athletes, performers, and for that matter, anyone who is very anxious may be tired and tense at the same time. Tension and reduced energy–vigor also apparently exist together, although this is not so obvious without recourse to a parametric study (e.g., Thayer & Moore, 1972). These various examples indicating that traditionally defined activation states do not relate to each other in an ordinal fashion are quite significant since a one-dimensional activation construct has had wide currency in the psychological world.

A Common Continuum of Energy Expenditure

Assuming a continuum from high to low energy expenditure, it appears likely that subjective states of energy–vigor (Dimension A) and tension (Dimension B) are based on greater energy expenditure than are states of tiredness and stillness–placidity (see Figure 1). Consistent with this assertion, several research studies utilizing simultaneous measurements with the AD ACL and a number of psychophysiological measures have demonstrated that reports of increasing G Act or H Act and reports of decreasing D-S1 or G Deac are associated with increasing physiological arousal (Thayer, 1967, 1970). In this research, combinations of physiological measures substantially correlated with different activation factors in different conditions with no apparent consistency except that physiological arousal was positively correlated with G Act or H Act and negatively correlated with D-S1 or G Deac. In the present model, it is assumed that autonomic and skeletal–muscular arousal can be associated with Dimension A or B just as cardiac acceleration, increases in skin conductance, and muscular tension would be associated with mowing a lawn, fear of electric shock, or anticipation of negative evaluation.

The common energy expenditure continuum that includes Activation Dimensions A and B makes peripheral physiological differentiation of the two dimensions a difficult or impossible matter. This common continuum may account for why traditional physiologically based activation theories have failed to note the existence of two dimensions. If distinctions between the activation dimensions are to be made it would appear necessary to utilize self-report (e.g., AD ACL), different stimulus conditions (e.g., required physical exercise, circadian time variations, anxiety-provoking conditions), or central physiological indices that are not, as yet, clearly understood.

ACTIVATION DIMENSION A

The two experiments presented below, together with other published and unpublished research, provide evidence of the characteristics of Activation Dimension A. This evidence covers the presumed circadian rhymicity of activation on this dimension as well as the relationship of Dimension A to physical exercise, cognitive activity, and affective tone.

Study 1

Purpose. An important part of the present model is the assumption that Dimension A activation level varies diurnally, and probably in a circadian rhythm, with the general sleep–wakefulness cycle. In part, this assumption is based on earlier AD ACL research (Thayer, 1967) in which subjects monitored their activation states at four times in a single day. The present study was designed to replicate the earlier research, but with a much more complete sampling of daily activation periods. In this research, subjects monitored their activation states for 2 full days.

Method. Within their naturally occurring daily settings, 25 subjects (8 males and 17 females) from an upper division laboratory psychology class completed short forms of the AD ACL (Thayer, 1978) immediately upon awakening in the morning and retiring at night, and at each 2-hour interval in between for 2 full days. Except for measurements at awakening and retiring, all AD ACLs were taken within 5 minutes of the hour. The second measurement of the day was always taken 2 hours from the closest hour to the measurement upon awakening. This self-reported monitoring task was completed as a cooperative learning experience for the students and experimenter. It was not part of the course requirement, and it was entirely voluntary. Such a research procedure was deemed absolutely necessary in order to ensure that all measurements were completed at the appointed time with care and accuracy.

Considering the difficulty of the task, cooperation was good. However, 41 students began the monitoring project, and the data of 16 students could not be included in the final results. Fourteen of these individuals missed two or more recording periods in sequence, and contrary to instructions, two subjects took drugs during the recording periods. For purposes of statistical analysis and plotting of daily curves, the data of all subjects who were awake less or more than 16 hours were transformed to the 16-hour standard. Transformations were done by expanding or reducing each hourly recording by equal proportions in such a way that the 16-hour standard was achieved.

Results and Discussion. In order to determine the effect of daily cycles on the various activation measures, six treatments-by-subjects analyses of variance (two observations per cell) were completed. In each case, the treatment effect was highly significant (see Table I), thus indicating that the four AD ACL factors and the two physiological measures reliably reflected daily variations. The nonsignificance of the interaction effect for the four AD ACL variables indicated that there were no reliable differences among subjects in daily cycle patterns. However, the interactions for the two physiological measures did reach statistical significance. Although this effect was a small one, it does suggest that there may be stable individual differences among subjects in their daily temperature and heart-rate cycles.

Table I. Summaries of Six Analyses of Variance (Diurnal Variation × Subjects)

Source	*MS*	*df*	*F*	ω^2	Source	*MS*	*df*	*F*	ω^2
G Act					G Deac				
D. Var.	321.05	16	28.85[a]	.31	D. Var.	125.06	16	14.12[a]	.15
Subjects	77.81	24	6.99[a]	.10	Subjects	131.90	24	14.89[a]	.23
A × B	11.13	384	1.03	.01	A × B	8.86	384	.94	.00
Error	10.78	425			Error	9.47	425		
D-S1					Temperature				
D. Var.	537.97	16	62.85[a]	.47	D. Var.	2.45	16	14.41[a]	.11
Subjects	95.36	24	11.14[a]	.12	Subjects	6.78	24	39.88[a]	.50
A × B	8.56	384	.95	.00	A × B	.17	384	1.42[b]	.06
Error	8.99	425			Error	.12	425		
H Act					Heart rate				
D. Var.	53.06	16	11.48[a]	.08	D. Var.	412.53	16	9.61[a]	.06
Subjects	135.82	24	29.40[a]	.34	Subjects	2599.83	24	60.56[a]	.61
A × B	4.62	384	.60	.00	A × B	42.93	384	1.18[b]	.03
Error	7.76	425			Error	36.33	425		

[a] $p < .01$.
[b] $p < .05$.

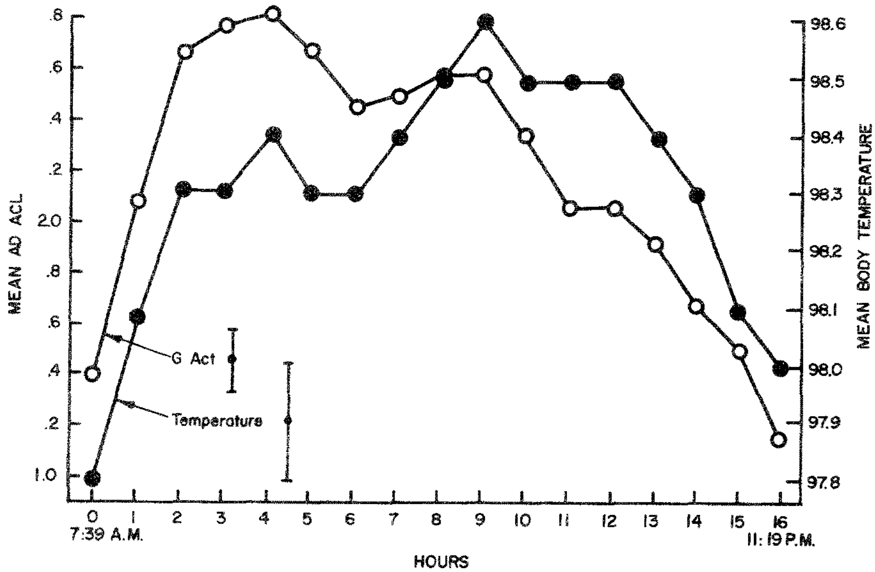

Fig. 2. Mean self-report and body temperature scores for daily periods from awakening to sleep (brackets indicate median variability, $\pm 1\sigma_M$).

Table I also includes omega-squared coefficients (ω^2; Dodd & Shultz, 1973; Hays, 1973) that provide rough indications of the strengths of association between effects due to daily changes and scores on the various activation measures. In general, this index comes from the proportion of treatment variance to total variance. Assuming comparable reliabilities for all six measures, the best reflections of daily variations occurred with AD ACL subtests D-S1 and G Act (Activation Dimension A). For these two indices, 47% and 31%, respectively, of reported activation variance could be accounted for by daily change, but less than half of that amount of correlated variance occurred with any of the other four activation measures. It is interesting to note that body temperature, a physiological measure commonly employed as an index of circadian rhymicity (Kleitman, 1963), showed a much smaller association with daily change (11%) than did two AD ACL subtests.

All six measures showed activation level to be lowest at awakening and retiring times and highest at points during the day. Figure 2 presents the diurnal rhythms of G Act and body temperature. It can be noted that G Act appears to peak early in the day, at around noontime for most subjects. Temperature peaks at early or midevening, and that peak time is consistent with other research employing this physiological variable (Kleitman, 1963). Research on verbal report measures of activationlike states has also shown peaks consistent with body temperature (Dermer & Bersheid, 1972). On the other hand, the relatively early peak time for G Act is consistent with earlier AD ACL research (Thayer, 1967) and with research conducted with the AD ACL and a modified scoring system (Clements et al., 1976).

These differences among activation indices are quite intriguing. The fact that G Act and temperature are out of phase with each other could simply reflect differing underlying determinants between verbally reported activation and temperature. It is well known that within the normally functioning individual, different bodily systems show maximum and minimum points at different times (Mills, 1966). Nevertheless, these differing cycles should be investigated in relation to relevant behavioral correlates. An additional important matter to consider when studying daily activation curves is that existent research indicates there may be stable individual differences in the shape of these curves as a function of moderating personality variables such as introversion–extroversion (Blake, 1967; Broadbent, 1971).

The above results confirm that Dimension A activation varies diurnally to a substantial degree; however, the Dimension B measures (H Act, G Deac) also showed significant diurnal variation with a pattern roughly similar to Dimension A measures. Nevertheless, the relative strength of association figures clearly indicate that the variation of Dimension B activation was considerably less pronounced than that for Dimension A, and the Dimension B variation could well have occurred because of the correlation on Dimensions A and B at moderate levels of energy expenditure.

It is not clear how much diurnal variance in Dimension A self-reports is associated with an endogenous rhythm and how much is associated with socially determined gross activity changes during the day. But there is some evidence of the stability of G Act and D-S1 cycles independent of daily activity. This evidence comes from three experimental procedures: individuals completing AD ACLs during sleep deprivation (Bohlin & Kjellberg, 1973); AD ACLs completed by individuals awakened at various night times while in an isolation unit (Fort & Mills, 1972); and AD ACLs completed by individuals flying across time zones (Conroy, Elliot, Fort, & Mills, 1969; Fort, 1969). In addition to these AD ACL studies, Kleitman (1963) observed numerous subjects during sleep deprivation and found the reports of greatest sleepiness and tiredness between 3:00 and 6:00 a.m. This early morning time period would roughly correspond to the probable nadir of Dimension A activation (particularly D-S1) in its circadian rhythm.

Study 2

Purpose. Another important assumed property of Activation Dimension A is its close ties to variations in gross motor activity. The present ex-

Table II. Summaries of Four Analyses of Variance (Sex × Exercise)

Source	*MS*	*df*	*F*	ω^2	Source	*MS*	*df*	*F*	ω^2
G Act					H Act				
Between					Between				
Sex	169.00	1	5.67[a]	.03	Sex	.81	1	.03	.00
Error	29.79	48			Error	25.18	48		
Within					Within				
Exercise	1713.96	1	103.33[b]	.41	Exercise	1.21	1	.12	.00
A × B	4.84	1	.29	.00	A × B	2.25	1	.23	.00
Error	16.59	48			Error	9.98	48		
D-S1					G Deac				
Between					Between				
Sex	94.09	1	3.95	.04	Sex	62.41	1	3.54	.03
Error	23.80	48			Error	17.64	48		
Within					Within				
Exercise	349.69	1	57.30[b]	.17	Exercise	171.61	1	19.11[b]	.10
A × B	2.89	1	.47	.00	A × B	44.89	1	5.00[a]	.02
Error	6.10	48			Error	8.98	48		

[a] $p < .05$.
[b] $p < .001$.

perimental investigation of the effects of physical exercise on activation level was designed as a test of this assumption, and particularly as a test of the relative influence of exercise on activation states associated with Dimensions A and B.

Method. The revised AD ACL (Thayer, 1978) was completed by 25 female and 25 male introductory psychology students. On one occasion the students were tested after they had sat quietly for 15 minutes, and on the other occasion just after they had engaged in a moderately brisk 10-minute walk around the campus. The males and females were divided equally into two groups that were given sitting and walking conditions in counterbalanced order.

Results and Discussion. Summaries of analyses of variance, means, and standard deviations are presented in Tables II and III. As can be seen,

Table III. Means and Standard Deviations in Sitting and Walking Conditions

AD ACL factors	Conditions: Sitting *M*	Sitting *SD*	Walking *M*	Walking *SD*
G Act	1.82	.70	3.00	.72
D-S1	2.41	.86	1.66	.71
H Act	1.79	.58	1.82	.60
G Deac	2.70	.52	2.32	.56

within-subjects comparisons (sitting vs. walking) were statistically significant for G Act, D-S1, and G Deac; H Act differences were not significant. Although three factors reliably monitored activation changes, it is apparent from the strength of association figures (ω^2; Dodd & Schultz, 1973; Hays, 1973) that the physical exertion manipulation resulted in greatest change on G Act reports (.41), next greatest on D-S1 (.17), and least on G Deac reports (.10). Sex differences were significant for G Act although not for the other three measures. However, in the case of the significant sex difference for G Act, the effect was very small ($\omega^2 = .03$), and the interaction was not significant.

Since it might be argued that the above within-subjects design does not adequately control subject expectation of activation changes, a second set of analyses was completed comparing the reports of the 26 male and female subjects who sat first (and before they experienced the walking condition) with the reports of the 24 subjects who walked first. While such a between-subjects comparison does not eliminate the effects of subject expectations, it should at least reduce them. For G Act, D-S1, H Act, and G Deac the respective F values were $(1, 48) = 37.9$, 10.7, .4, and 3.9. Only G Act and D-S1 were statistically significant ($p < .01$). Strengths of association were quite comparable to the within-subjects analysis with this comparison: G Act (.42), D-S1 (.16), G Deac (.06), H Act (< .01).

There are several pieces of research showing that Dimension A measures (primarily G Act) can be used to predict cognitive activity, particularly a variety of verbal functions. For example, Thayer and Cox (1968) found that Hull–Spence predictions concerning performance on complex and noncomplex verbal learning tasks were verified with the use of Dimension A (G Act) measures, but no reliable predictions could be made with the use of Dimension B measures or Manifest Anxiety Scale scores. Eysenck (1975) has demonstrated that G Act can be used reliably to predict recall and recognition of verbal material. Another study shows that G Act scores are reliably related to production of verbal material, particularly when level of extraversion is assessed as a moderator variable (Eysenck, 1974). Still another study indicates that G Act scores, as opposed to measures related to Dimension B, can predict performance on a college examination (Wittmaier, 1974). One other aspect of cognitive and psychomotor functioning has been found to be related to Dimension A, as opposed to Dimension B. Bohlin and Kjellberg (1973) found that reports obtained from a Swedish translation of G Act and D-S1 subscales predicted reaction time, but H Act did not predict the behavior.

Two kinds of evidence support the obvious assumption that feelings of energy and vigor involve positive affective tone while feelings of tension are mildly negative in tone. First, factor analyses on the long-form AD

ACL, which contains activation and other mood adjectives (Thayer, 1978), yielded positive intercorrelations among G Act self-descriptions and another factor containing adjectives relating to being carefree, warm-hearted, and affectionate. Furthermore, these same general mood adjectives correlated negatively with H Act while factors involving feelings of suspiciousness, sadness, and being blue correlated positively. These patterns of correlations were not repeated with reported tiredness and placidity–stillness, however. For the latter factors much smaller and variable correlations were obtained. Another kind of evidence comes from a recently completed study (Rubadeau & Thayer, 1976) in which college students repeatedly assessed their state of self-concept over a two-month period using a measure that allows subjects to employ whatever descriptive words are appropriate on each testing. At the same time they completed AD ACLs. Substantial positive correlations were found between reported energy and vigor and positive self-conceptual descriptions while negative correlations were obtained with reported tension.

ACTIVATION DIMENSION B

In this section, a number of kinds of research are offered as bases for the claimed characteristics of Activation Dimension B. Considering Dimension B from a wide perspective, it would appear to be a continuum associated with defensive and emergency energy expenditure and quiescence. However, most of the evidence deals with the emotional construct of anxiety or tension and with the stressful effects of intense white noise. That Dimension B underlies other emotions and stress reactions is largely presumptive at this time.

Study 3

Purpose. In previous research concerning Activation Dimension B (Thayer, 1967), AD ACLs were administered to college students on a typical class day and on the day of an examination. Measuring activation states just prior to an important college examination seemed to be an excellent means of assessing anxiety or tension, since exams are commonly known to provoke these adverse states among many of the student participants. The early research indicated that, compared to Dimension A, Dimension B measures showed the greatest change from the typical to the exam days.

Data recently gathered in conjunction with factor analytic studies of the short and revised forms of the AD ACL (Thayer, 1978) offered a good opportunity to replicate earlier findings with a larger sample and the addition of another activation condition. These data included reports of students from several college classes who were tested on exam and nonexamination days (separate students in the two conditions). Also included were self-reports by other students who experienced guided Yogic meditation and deep breathing exercises. Because of the popularly reported anxiety-reducing effects of meditation, (e.g., Bloomfield, Cain, Jaffe, & Kory, 1975), these stimulus conditions seemed ideal for study of the low activation pole of Dimension B.

Method. Short-form and revised long-form AD ACLs (Thayer, 1978) were completed by 90 students during guided Yogic meditation and deep-breathing exercises. The procedure involved counterbalanced administrations of the short form and revised tests at 20 and 40 minutes into the session. Short-form AD ACLs were completed by 237 students just before a college examination, and the same tests were completed by 159 students from other classes on nonexamination days.

Results and Discussion. Evidence of the strong differential effects of the three conditions (typical day, examination, meditation) is provided from the summary statistics in Tables IV and V. Although the order of factor-score differences is the same across sex, data for males and females are presented separately because there were significant differences between sexes in magnitude of factor scores for G Deac in the exam condition, and for G Act and D-S1 in the meditation condition, $F(1,235) = 12.32$, $p < .001$; $F(1,88) = 9.66$, $p < .005$; $F(1,88) = 8.32$, $p < .005$; respectively. The highly significant main effects for conditions led to tests of the simple

Table IV. Summaries of Eight Analyses of Variance (Three Activation Conditions)

Males					Females				
Source	*MS*	*df*	F^a	ω^2	Source	*MS*	*df*	F^a	ω^2
G Act					G Act				
Conditions	16.82	2	25.08	.18	Conditions	38.70	2	59.30	.31
Error	.67	215			Error	.65	265		
D-S1					D-S1				
Conditions	13.56	2	19.26	.15	Conditions	38.76	2	57.77	.30
Error	.70	215			Error	.67	265		
H Act					H Act				
Conditions	26.09	2	50.59	.32	Conditions	53.41	2	90.24	.40
Error	.52	215			Error	.59	265		
G Deac					G Deac				
Conditions	20.30	2	41.11	.27	Conditions	54.12	2	110.96	.45
Error	.49	215			Error	.49	265		

$^a p < .001$ in all cases.

Table V. Means and Standard Deviations in Three Experimental Conditions

AD ACL factors	Typical class *M*	Typical class *SD*	Examination *M*	Examination *SD*	Meditation *M*	Meditation *SD*
Males						
G Act	2.48	.83	2.53	.87	1.54	.70
D-S1	2.05	.80	1.96	.90	2.87	.77
H Act	1.85	.69	2.60	.83	1.36	.47
G Deac	2.49	.74	2.00	.69	3.16	.65
Females						
G Act	2.32	.82	2.67	.89	1.17	.36
D-S1	1.91	.94	1.81	.82	3.28	.56
H Act	1.76	.75	2.79	.86	1.24	.40
G Deac	2.46	.77	1.68	.70	3.38	.56

effects in which each condition was compared with each other condition for all AD ACL factors. All comparisons were statistically significant ($p < .05$, two-tailed tests) except for comparisons of typical vs. exam conditions for males with G Act and D-S1 and females with D-S1.

Consistent with previous research (Thayer, 1967), the exam had its greatest effects on H Act and G Deac (Dimension B) especially in comparison with the typical-day condition. The exam vs. meditation and exam vs. typical-class differences respectively accounted for 42% and 27% of the male plus female H Act variance (ω^2; Hays, 1973). Those same differences accounted for 47% and 19% of G Deac variance. On the other hand, exam vs. typical day differences on G Act and D-S1 were small or nonsignificant (less than 2% of variance). The exam vs. meditation differences on these two factors accounted for 33% and 30% of the respective variances. The meditation effects on the AD ACL should be particularly noted since meditation is currently attracting a great deal of attention in literature concerning both biofeedback and altered states of consciousness. Apparently this condition was very powerful; it affected AD ACL changes on all factors to a substantial degree. It should be noted that G Deac showed the highest mean ratings as a function of meditation, however.

In addition to the demonstrated effects of examinations and meditation on Dimension B factors, other research also indicates that this activation dimension is associated with anxiety-provoking conditions. The experiment referred to above, in which anxiety was manipulated with instructions (Thayer & Moore, 1972), showed that H Act is a good index of anxiety effects. Unlike the other AD ACL factors, this Dimension B factor increased as a linear function of the three levels of manipulated anxiety. Another indication of activation effects related to an anxiety construct comes from a study of apprehension due to social evaluation (Moore, 1973). Dimension B measures showed reliable subjective effects due to audience evaluation of subjects engaged in a learning task, but there were no evaluation effects on Dimension A measures.

The primary effect of intense white noise is increased Dimension B activation. A number of experiments support this assertion. Thayer, Anderson, Spadone, and White (1970) employed 75 dB of continuous white noise for a 20-minute period. They found the expected significant increases in Dimension B activation (more H Act, less G Deac). Consistent with the predicted relationship between the two dimensions (see next section), this moderately intense noise condition also produced some change in Dimension A activation (D-S1 was significantly decreased). Two experiments (Patterson, 1974; Thayer & Carey, 1974) employed a more intense level of 80 dB over approximately 20 minutes, and reliable increases in Dimension B activation were obtained, but no reliable changes in Dimension A activation occurred. Lopes (1971) employed the most intense noise of all (85–88 dB) and found reliable increases in reported tension and sleepy–tiredness. (Consistent with the above results, subjects also reported somewhat less placidity –stillness and less energy–vigor.) This experiment showed the predicted negative correlation between Dimensions A and B during very intense noise. The above studies all demonstrated increased Dimension B activation and, depending upon the intensity of the noise, either increased or decreased Dimension A activation.

Based upon the conceptualization of Dimension B as related to defensive and emergency energy expenditure, and to some extent on the general anxiety literature, one might reasonably expect this dimension to be associated with uneven cognitive functioning and with at least some aspects of gross motor activity. There is, in fact, some evidence that Dimension B (H Act) reports are correlated with the debilitating aspects of verbal performance in people with habitual problems of anxiety-related deterioration (Munz & Costello, 1975). Yet the major weight of existent AD ACL research (Bohlin & Kjellberg, 1973; Eysenck, 1974, 1975, 1976a; Thayer & Cox, 1968; Wittmaier, 1974; Study 2 above) indicates that both cognitive and motor activity are related to Dimension A, not B. Future research may show that activation states on the two dimensions affect different aspects of cognitive and motor activity.

CORRELATION PATTERNS OF DIMENSIONS A AND B

It is clear from the evidence presented above that in many respects Activation Dimensions A and B are associated with qualitatively different aspects of behavior. The exact relationship between these two dimensions is at the same time the most speculative part of this model and of great potential importance from practical and theoretical perspectives. A set of assumed relationships between dimensions will be presented below together with some supporting evidence from research employing the AD ACL, from the general research literature, and from casual observations.

Within an inexactly defined band of functioning, which shall be designated as moderately low to moderately high energy expenditure, increases in feelings of energy–vigor generally lead to some increases in tension and to decreases in sleepy–tiredness. In a similar manner, increases in tension lead to increases in energy–vigor and decreases in placidity–stillness. The same associations in reverse would be expected for individuals who experience moderately strong feelings of sleepy–tiredness or placidity–stillness. These relationships are consistent with the concept of a common continuum of energy expenditure, and evidence for them can be found in a number of studies employing the four factors of the AD ACL (e.g., Thayer, 1967, 1978; Thayer & Moore, 1972; also see Studies 1, 2, and 3 above).

Low Dimension A Activation, High Dimension B Activation

While the two activation dimensions are generally correlated at moderate levels of energy expenditure, high levels of energy expenditure on either dimension are assumed to result in a different pattern. For example, high tension is associated with low energy–vigor and with sleepy–tiredness. This inverse relationship is demonstrated in the manipulated anxiety experiment mentioned previously (Thayer & Moore, 1972). That experiment is particularly relevant because it demonstrates a dynamic relationship among three of the AD ACL factors making up Dimensions A and B. In that research, anxiety was manipulated with instructions and setting while subjects completed standard AD ACLs. As anxiety was manipulated from low to moderate levels, subjects reported increasing tension (H Act). Energy–vigor reports (G Act) showed a correlated increase while sleepy–tiredness reports (D-S1) showed a negatively correlated decrease. But from moderate to high manipulated anxiety, while tension increased as expected, sleepy–tiredness also increased and energy–vigor decreased (see Figure 3).

Earlier a self-reported depression study was discussed in which subjects using AD ACLs described their depression as involving high tension, low energy–vigor, and sleepy–tiredness. Certain characteristics or syndromes of more serious cases of clinical depression offer a possible example of how Dimension B activation shifts in relation to the circadian rhythm of Dimension A activation. One of the symptoms that is often associated with endogenous depression is a worsening of the state in the morning. On the other hand, reactive depression characteristically reaches its

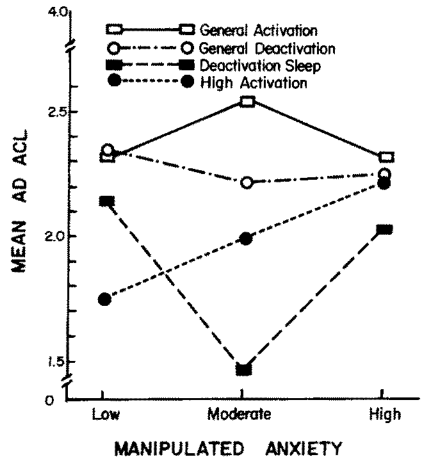

Fig. 3. AD ACL factor scores as a function of manipulated anxiety. (From Thayer & Moore, 1972. Reprinted by permission of Journal Press.)

height in the evening (Mendels, 1970; Winokur, Clayton, & Reich, 1969). In these periods, patients report and have been observed to experience greatest difficulty. What is relevant about this for the present discussion is that peak depression times correspond exactly to the times when energy–vigor is low and sleepy–tiredness is high (see Study 1 above). As a qualification of this evidence, it must be noted that there is some difference of opinion among clinicians about whether true depression is accompanied by anxiety or whether the two clinical categories should be separated. Nevertheless, it is clear that a large number of cases diagnosed as depression also involve anxiety or tension (Becker, 1974).

Chronic anxiety states are frequently connected with sleep disturbances and interrupted sleep (Lader & Marks, 1972; Meares, 1963). Furthermore, intense anxiety is often accompanied by lack of energy and apparent tiredness. Extensive empirical studies of anxiety neurotics indicate that some of their most commonly observed symptoms are: tires easily, feelings of tiredness not related to physical exertion, and fatigued all the time (Miles, Barrabee, & Finesinger, 1951; Wheeler, White, Reed, & Cohen, 1950). On one level, there is a certain intuitive meaningfulness in the conception that anxiety or tension elicits reduced energy–vigor and tiredness. This effect would have the utilitarian function of discouraging the individual from sustaining very high expenditures of energy. Or, to look at it another way, there are only limited energy reserves, and extreme tension depletes those reserves, thus resulting in tiredness.

Tiredness and Tension

In the present model, the relationship between tiredness and tension is somewhat more complex than simple covariation. A curvilinear function would best express the relationship. Low energy–vigor and tiredness leave the individual susceptible to tension or anxiety, but at some point, when extreme tiredness occurs, there is a reduction in energy expenditure for the body as a whole. At that point, tension would be reduced and tension-producing stimuli would have less, rather than more, impact.

Research on sleep deprivation provides some evidence relevant to the assumed complex interaction of sleepy–tiredness and tension. Although it is impossible to find any systematic research on tension or anxiety throughout long-term sleep deprivation, this emotional state was noted tangentially in a number of studies. Murray (1965) reviewed a wide literature on sleep deprivation and found numerous reports of anxiety and irritability together with seemingly inconsistent reports of general apathy. He reconciled these inconsistent reports with the conclusion that long-term sleep deprivation produces the prevailing mood of apathetic depression, suggesting a "de-arousal" reaction. Apathy increases with the amount of sleeplessness. Furthermore, he maintained that anxiety occurs mostly at the beginning of deprivation and is related to the experimental situation and the personality of the subject (p. 245).

One piece of research reviewed by Murray is a study in which 74 subjects were deprived of sleep for 72 to 98 hours while a variety of observations were made (Morris & Singer, 1961). Anxiety was greatest on the first day, then it decreased and dropped off markedly by the last day. Morris and Singer observed that anxiety did not occur without cause. It was seemingly related to treatment by the staff and to the personality of the subjects. This observation is consistent with an important part of the present theory. Tension or anxiety does not inevitably occur when sleepy–tiredness increases to high levels. Rather, the individual becomes more vulnerable in this tired state, and any anxiety-provoking conditions or mental habits will have their greatest effect in this state.

Some interesting experimental findings that have been given prominence in reviews of arousal or activation constructs can be understood with reference to the assumed relationship of extreme tiredness and tension. Wilkenson (1963) found that on a serial reaction task loud noise reduces the adverse effects of sleep deprivation. Corcoran (1962) also obtained results compatible with that finding. Broadbent (1971) interpreted these results as indicating that both noise and sleeplessness operate in antagonistic or opposite ways on the same arousal mechanism (p. 441). However, within the present model, noise and sleeplessness would be seen as operating on two separate activation mechanisms. Sleep deprivation of any length would produce extremely low Dimension A activation and noise would produce an increase in Dimension B activation. Although loud noise alone would normally increase Dimension B activation to a level at which there might be errors in task performance, when noise is paired with the extreme tiredness from sleep deprivation it would have less overall impact. Since at that point tension would be antagonistic to tiredness, temporarily at least, noise would raise bodily activation. Thus, sleeplessness and the associated performance errors would be reduced.

Aside from the above research, the relationship of tiredness and tension is difficult to document in any conclusive way from the existing literature. Susceptibility to anxiety during states of fatigue or tiredness is known to practicing clinicians (e.g., see Meares, 1963), but there is an apparent absence of systematic observations of anxiety-prone individuals who are experiencing increasing sleepy–tiredness. However, certain everyday experiences consistent with the assumed relationship are probably familiar to many readers. For example, in numerous self-observations, this author has found that following a full day of taxing activities, late-night (e.g., after normal sleep time) ruminations about potentially disturbing situations can be very anxiety provoking. Often, problems that seemed unmanageable, and that have been associated with anxiety at 1:00 AM, appear innocuous (or at least less anxiety-provoking) on the following midday after a good night's sleep. The change is sometimes quite dramatic. Another example of the same phenomenon comes from observations of children. There appears to be a certain periodicity in some of their distraught behavior which is seemingly extrasituational, but which could be closely tied to the circadian rhythm of Dimension A activation. Not unlike other children, my two small girls are most on edge and bothered by little frustrations at the last waking hours of their days, especially very tiring days. They are least that way on late mornings, when they probably feel rested and energetic. In both of the above anecdotal examples, the common condition of the tension-related behaviors is low energy–vigor and high sleepy–tiredness. And in both examples, this low Dimension A activation occurs at times of tiredness and low energy or periodically in the general sleep–wakefulness cycle when it would be most predicted. Naturally, it is risky to assume too much from these kinds of informal observations because there are many potentially confounding variables. But taken together with other evidence, explanations employing the present theory are quite plausible.

High Dimension A Activation, Low Dimension B Activation

Just as high Dimension B activation is associated with reduced Dimension A activation, this negative correlation is also assumed to exist when Dimension A activation is high. That is, high energy–vigor is associated with low tension and increased placidity–stillness. At the present time, there is no directly applicable AD ACL evidence for this assumption, but there is indirect support for the idea of an inverse relationship between energy–vigor and tension at high levels from a variety of other sources.

If we assume that physical exercise increases energy–vigor—an idea strongly supported by Study 2 above, and by the claims of many exercise enthusiasts—then the inverse relationship between energy–vigor and tension may be demonstrated at least indirectly by the literature showing that exercise reduces anxiety. For example, de Vries and Adams (1972) conducted a well-designed experiment that relates particularly closely to the present model. They compared the immediate, 30-minute, and 1-hour effects of treadmill walking with the same time effects of meprobamate, and with a lactose placebo. Meprobamate is a tranquilizer commonly used to reduce anxiety. The experimental subjects were elderly people with chronic anxiety complaints. These investigators found that in all measurement periods the walking condition significantly decreased muscular tension. Neither meprobamate nor the placebo had a significant effect on muscular tension, however. Furthermore, there was clear evidence that the changes in muscle action potentials that were used as the dependent variable were not due to muscular fatigue but rather they reflected relaxation effects.

The counteractive effects of exercise on self-reported anxiety were demonstrated in an experiment by Girodo and Pellegrini (1976). Subjects in this experiment were shown an arousal-inducing film, which depicted industrial accidents, while they either pedaled an exercise bicycle or sat inactively. They then rated their anxiety. Exercising subjects reported significantly less anxiety than inactive controls, and a postexperimental test concerning film content indicated that the results were not due to differential attention to the film.

Other exercise studies have shown similar results, but most of this research involves the effects of protracted exercise on chronic anxiety complaints. Use of this literature in support of the present model requires acceptance of the untested assumption that regular exercise can result in long-term increases in Dimension A activation. Nevertheless, this idea seems reasonable if one considers the numerous reports of people who exercise frequently that they generally feel more vigorous and energetic (e.g., Cooper, 1968).

Dodson and Mullens (1969) studied a variety of types of psychiatric patients under control, light exercise, and jogging conditions. Psychological measurements were taken following 3 weeks of experience in each of the conditions. Consistent with the present model, light exercise (requiring moderate energy expenditure) slightly increased manifest anxiety, but jogging (requiring high energy expenditure) reduced manifest anxiety somewhat and reliably reduced anxiety-related states measured by Hs and Pt MMPI scales. Self-reported anxiety was found to reliably decrease in another study that employed jogging, and in which the reports of the emotion were obtained with adjective checklists after a 16-week course (Folkins, Lynch, & Gardner, 1972). de Vries (1968) found that muscular tension was reliably decreased in college students immediately following a 5-minute exercise period. In addition, he observed a similar significant tension decrease in older subjects following a long-term exercise program. In this case the greatest changes occurred in those subjects who described themselves as usually tense or nervous in various ways. In addition to the specific studies reviewed above, there is a widely held belief among clinicians that physical exercise is beneficial for psychiatrically disturbed patients (Rudd & Margolin, 1969), and psychiatric disturbances often involve anxiety as a central problem.

There is much casual evidence that physical exercise reduces anxiety, as any athlete or dancer could readily testify. The anxiety and apparent tiredness that often precede an athletic or theatrical performance invariably disappear when the individual is engaged in the activity. These reductions of anxiety and tiredness are frequently interpreted as due to cognitive factors (i.e., the individual no longer attends to anxiety-producing stimuli). However, consistent with the present model, the phenomenon additionally could be interpreted as evidencing the negative correlation between Dimension A and B at high levels of energy expenditure.

Other possible evidence of this negative correlation, and also of the reciprocal nature of energy–vigor and sleepy–tiredness within Dimension A, comes from several information-processing and performance experiments that have potential importance in the conceptualization of arousal. Broadbent (1971) points out that a number of studies concerned with such arousal-affecting conditions as loud noise and sleeplessness have shown adverse performance effects only in the late part of the work period. That is, when the subject is enthusiastic and highly motivated to perform, many stressful conditions have relatively little effect. It is only when the individual loses his enthusiasm and becomes tired of the task that performance deteriorates. In the present model, enthusiasm and motivation to perform well would be mediated by the energy–vigor pole of Activation Dimension A. Although no formal evidence of that mediation can be offered at the present time, it seems self-evident that enthusiasm is frequently accompanied by energetic and vigorous feelings. In any event, if it is assumed that high Dimension A activation mediates enthusiasm then the somewhat confusing findings regarding the late work period effects of sleeplessness and noise are quite understandable. The temporary energy–vigor present at the beginning of a task would counteract the sleepy–tiredness from sleep deprivation. High Dimension A activation would also temporarily reduce the effect of loud noise that is mediated by Dimension B. In both cases performance would be temporarily improved.

For the proposed model to be fully symmetrical, it would have to be assumed that high levels of placidity–stillness interact with energy–vigor in the same way that high levels of sleepy–tiredness interact with tension. That is, placidity–stillness would predispose the individual to potential feelings of energy–vigor, and extreme levels of placidity–stillness would reduce energy–vigor. The only relevant AD ACL evidence concerning placidity–stillness comes from the meditation condition in Study 3 above. In that study, the pronounced increases in placidity–stillness were associated with corresponding increases in sleepy–tiredness, and decreases in both energy–vigor and tension. Those results are consistent with the model if it is assumed that the placidity–stillness produced by the meditation was only moderate in level. It will be recalled that within moderate levels of energy expenditure Activation Dimensions A and B are positively correlated.

An argument that high levels of placidity–stillness might result in a corresponding state of high energy–vigor could be made on the basis of the popular meditation literature with the reasonable assumption that major effects of meditation occur in Activation Dimension B. There are frequent claims that regular meditation produces a state of reduced anxiety and increased calmness (Bloomfield, et al., 1975).

TWO DIMENSIONS OR MORE?

Two other matters require some attention before this exposition is complete. First, it is probably correct to assume that each of the two activation dimensions is unidimensional as represented by two pairs of AD ACL factors. However, the assumption of unidimensionality may not be correct simply because each pair usually acts in a relatively unidimensional fashion. The factor analyses that provide important evidence of the two-dimensional theory (Thayer, 1978) indicate two pairs of negatively correlated factors. But these negative correlations are not near unity, and this suggests some independence within each of the two pairs. This absence of high negative correlations could be explained at least partially by the error implicit in the recordings and the type of response format, but there are other necessary considerations as well. Although two sets of reciprocal relations are generally the rule, in certain experimental studies the reciprocal relations have not held. For example, Thayer and Cox (1968) found that only G Act of the four AD ACL factors predicted performance on the verbal learning tasks;

D-S1 did not predict the performance. Similarly, Thayer and Moore (1972) found that H Act showed a linear relation to the anxiety manipulation, but in the high anxiety condition G Deac actually changed slightly in the opposite-to-expected direction. In the self-reported depression study described above, H Act was a very important predictor of depression states, as were G Act and D-S1, but G Deac showed little or no variation with depression. These examples suggest that there are four separate activation dimensions that usually, but not always, act as two reciprocal pairs.

Finally, one other matter is of substantial importance, but it will be confronted only briefly in this paper. It has been assumed that Dimensions A and B are the only major activation dimensions. However, the available evidence does not provide complete assurance for this assumption. Activation Dimension B is at least associated with anxiety and with a reciprocal state of deactivation. Many other emotions could be represented with this tension placidity–stillness continuum. Another possibility is that various emotions are represented by the two general dimensions together with cognitive factors (see Schachter, 1964). Still another possibility is that the state represented by reported placidity–stillness could be the common deactivation pole for several distinct kinds of emotional activation (i.e., tension, fear, anger, sex). Alternatives and additional dimensions to the present two-dimensional formulation must await further experimental evidence. It should be noted that the present two-dimensional model, while assumed to account for all activation states, would not be useless and invalid if additional activation dimensions corresponding to separate emotions were found to exist. Knowledge of the separateness and interaction of Activation Dimensions A and B would be important for behavior theory even if additional activation dimensions were later deemed necessary.

OTHER MULTIDIMENSIONAL MODELS

Apparent dissociations among bodily systems and inconsistent behavioral evidence have led several researchers to propose multidimensional models that include two or more activation continua. In this section, some perspective for the proposed self-report theory will be provided by briefly describing three other models, each representing a somewhat different level of analysis. I will also comment briefly on the relationship of the present model to the other three. A number of other multidimensional systems have been suggested (e.g., Berlyne, 1967; Cattell, 1973; Kahneman, 1973; Pribram & McGuinness, 1975), but space limitations make it impossible to deal with all of them.

Broadbent has approached the concept of activation within the context of human information processing. Although his model is quite speculative and not well developed, it is worth mentioning here because of the wide usage of arousal concepts in information processing research. His two-dimensional system was generated because of various observations that were difficult to explain with a unitary arousal continuum. For example, the effects of noise and sleeplessness appear to be counteractive, but these effects only occur late in any given work period. Within his model, one dimension (Lower Level system) is cautious and unreactive at one extreme and hyperactive at the other. It mediates stressor effects such as those occurring from sleeplessness and noise. The second mechanism (Upper Level system) is general in function. It maintains behavioral constancy so long as it is efficient, and only as it loses efficiency do noise and sleeplessness affect performance.

Activation Dimension B in the present model is assumed to mediate stressful noise effects just as Broadbent's Lower Level mechanism does. But Broadbent sees the other end of his arousal mechanism as associated with sleeplessness, while in the present system that condition would be associated with Dimension A. The assumed tendency of Broadbent's Upper Level mechanism to maintain behavioral constancy seems roughly comparable to what might be expected from Activation Dimension A. But, unlike relationships in Broadbent's model, vigorous (or enthusiastic) activity in the present system would counteract sleeplessness because of the reciprocal relationship between energy–vigor and sleepy–tiredness, and noise effects would be counteracted because high Dimension A activation is negatively correlated with Dimension B activation.

Based primarily upon neurophysiological evidence, Routtenberg (1968) has proposed two interacting arousal systems. Arousal System I is related to the reticular activating system, and it has primary responsibility for tonic neocortical desynchronization. Arousal System II is related to the limbic midbrain area. This system is sufficient to maintain wakefulness, and it can produce cortical desynchronization; however, elimination of this second system may produce somnolence or disruption of basic vegetative functions while cortical desynchronization persists. Neither system directly mediates sleep, but both are involved in wakefulness. Arousal System I provides response energy, and it is associated with drive and the organization of responses. Arousal System II mediates reward and incentive effects. Brain structures facilitated by System II tend to quiet autonomic functions, and this system is suppressed in turn by the structure that mediates negative incentive or aversive states.

Some features of Routtenberg's Arousal System I seem very similar to Activation Dimension A characteristics. For example, like Dimension A, System I is assumed to mediate drive and to be responsible for energizing organismic responses. Functions associated with System II, such as the reduction of aversive states, the quieting of the organism, and the depression of the sympathetic nervous system, seem very close to the probable functions of the placidity–stillness pole of Dimension B. But an important difference exists as Routtenberg makes no mention within his System II discussion of tensionlike states. In fact, the aversiveness attributed to extreme excitation of System I seems to be more related to tension states than to extreme states of energy–vigor. Much of Routtenberg's theory concerning the opposing action of his two arousal systems can be identified more easily with the reciprocal states of tension and placidity–stillness within Dimension B than with the inverse relationship between Dimensions A and B at high levels of energy expenditure.

Other differences also exist. For example, Routtenberg claims that high activity in Arousal System I is aversive, and we must assume that System II would be associated with positive tone because of its connection with incentive and reward effects. These relationships are opposite to expectations if one assumes that Dimension A is analogous to System I.

The suppressor effects exercised between Routtenberg's Systems I and II would be quite similar to the inverse relationship of energy–vigor and tension if the pairs of systems were comparable between the two models. However, as indicated above, some of the characteristics of each of Routtenberg's two systems are similar to the characteristics of both Dimensions A and B. Nevertheless, it is worthwhile to note that Routtenberg has presented some interesting neurophysiological evidence of mutually facilitating and suppressing brain systems and physiological processes. Since the exact functions of most of these systems and processes is yet to be established, parallels with Dimensions A and B could yet be found.

Eysenck (1967) has approached the dimensionality of activation mainly from a behavioral perspective, but his model includes numerous anatomical and physiological concepts as well. In particular, his formulations are related to his questionnaire-based theory of introversion–extraversion and neuroticism. He proposes two partially interacting arousal dimensions called the corticoreticular system (producing arousal) and the visceral brain (producing activation). The corticoreticular system includes the ascending reticular activating system and its associated cortical projections, the classical afferent and collateral reticular pathways, and the projections from the cortex to the ascending RAS. This system is concerned with the kind of arousal and inhibition that is central to introversion and extraversion. The corticoreticular system mediates information processing and may have responsibility for general motor activity. The visceral brain includes the hippocampus, amygdala, cingulum, septum, and hypothalamus. This system mediates emotions and other vegetative processes. Activation differences associated with neuroticism can be interpreted readily within the functions of this system.

Eysenck believes the two systems are somewhat interdependent but also independent. Both are responsible for cortical desynchronization. Autonomic activation (visceral brain system) may be indexed in terms of cortical arousal, but activity of the corticoreticular system is not necessarily reflected in autonomic activation. In Eysenck's view, the two activation dimensions are positively correlated in highly emotional individuals and during times that produce a strong emotional activation. However, only a small portion of the lives of most people is spent in such times of extreme emotion. Therefore, cortical arousal is essentially independent of emotional activation most of the time.

The assumed association of high Dimension A activation with aspects of cognitive functioning and with gross motor activity suggests a close similarity with Eysenck's cortical arousal, a system that similarly is thought to mediate such behaviors. Activation Dimension B also has a close counterpart in Eysenck's autonomic activation dimension, the system believed to mediate emotions. One major difference between the present model and that of Eysenck concerns the relations between activation dimensions. His cortical arousal and autonomic activation are believed to have equivalent actions at high levels. Furthermore, he assumes that cortical arousal cannot be indexed from measures of autonomic activation. Of course, these relations are different from the presumed positive and negative correlations between Dimensions A and B at different levels of energy expenditure.

In respect to important behaviors mediated by each activation dimension, the present model is closer to that proposed by Eysenck than to any other multidimensional model. To some extent, the makeup of the dimensions in each theory and, particularly, the interactions between dimensions in each theory present the clearest separations between the two models. However, it should be noted that while the present model for the most part deals with states of the individual or transitory activation levels, Eysenck primarily has proposed a trait model of extraversion and neuroticism and the associated activation systems. At some time in the future it may be found that the two models complement each other as state and trait conceptualizations often do (e.g., see Spielberger, 1966).

DISCUSSION

The present model builds upon past heuristic conceptualizations of activation (e.g., Duffy, 1962; Lindsley, 1951; Schlosberg, 1954). This is particularly apparent in the assumption of a single continuum of energy expenditure and in the view that activation states energize diverse behaviors. Important differences from past conceptualizations exist, however. Instead of the traditional single activation dimension that ranges from vigorous activity and intense emotion on one extreme to calmness and sleep on the other, the present model includes at least two separate but interrelated activation dimensions. Another important difference concerns the approach taken to activation measurement. Previously employed constructs have relied upon a complicated and poorly understood physiological substrate. Consistent with that viewpoint, researchers have sought a single physiological measure that would reflect general organismic activation changes. But no such measure has been found. I have argued that controlled self-report, based as it is on the bodily integration present in conscious awareness, does provide gross but useful insights into total organismic activation.

Although activation models have been extremely influential and continue to be widely utilized, they have not been wholly successful in accounting for all behavioral variation. Some of the problems encountered with unidimensional activation or arousal constructs could be clarified by an understanding of interrelationships between activation dimensions in the present model. Consider the possibility that researchers assuming a one-dimensional activation model could make an easy mistake by employing experimental manipulations of activation on one dimension to affect behaviors mediated by another dimension. Such an invalid procedure probably would produce some positive results because Activation Dimensions A and B are positively correlated within moderate levels of energy expenditure. However, the invalid procedure could also produce unexpected results because of the negative relationship of Dimensions A and B at high levels of energy expenditure. As a consequence, positive results might or might not occur depending upon the kind of activation manipulation and the level of activation present in the subjects.

Briefly presented, a few research examples will indicate the kinds of new questions that might be raised on the basis of the characteristics of the proposed model. The relationship between anxiety and verbal learning which in the past has generated so much interest in psychology (Spence & Spence, 1966) offers an excellent example. It was assumed that Manifest Anxiety scores, as indicants of a single generalized drive state, would predict many aspects of cognitive performance. But in the present model, Activation Dimension A, not B, is primarily associated with several kinds of cognitive performance (e.g., see Thayer & Cox, 1968). Could the observed relationship between anxiety and cognitive performance be related to the positive covariation of Dimensions A and B at moderate levels of energy expenditure? Another possibility is that there are two kinds of cognitive effects, one related to Dimension B and one related to Dimension A.

Another good example concerns the widely researched social psychological phenomenon that has come to be known as social facilitation. According to a prominent theory by Zajonc (1965), humans and other animals are facilitated or inhibited in performance on various tasks by the mere presence of other species members, and these effects are mediated by arousal (assumed to be unidimensional). This matter has been complicated by the demonstration of Cottrell and his associates (Cottrell, Wack, Sekerak, & Rittle, 1968) that the arousal effect is, at least in part, due to a kind of evaluation anxiety present when people are observed, and implicitly evaluated, by others. Still, considering the wide variety of evidence that has been offered, social facilitation does not appear to be fully accounted for by evaluation anxiety (Zajonc, 1972). Could there be arousal effects on Activation Dimension B that are generated by evaluation anxiety and other Dimension A effects (primarily energy–vigor) that are related to the enthusiasm associated with the mere presence of other persons when no evaluation is occurring (see Thayer & Moore, 1972)?

Research on information processing offers yet another example. Experiments in this area have incorporated a variety of arousal manipulations including time of day, sleep deprivation, noise, incentive, and various drugs (Broadbent, 1971). As has been suggested above, it is risky to assume that all these manipulations affect a single activation dimension by either increasing or decreasing arousal as a linear function of different intensities of stimulation. Activation Dimension A probably mediates time of day, sleep deprivation, and incentive where no extra anxiety-inducing treatments are employed. On the other hand, noise, and possibly certain kinds of drugs (e.g., tranquilizers) could be expected to primarily influence Dimension B activation.

In addition to the above theoretical issues, many problems involving anxiety might be better understood with reference to the present model. As a case in point, occupational and other kinds of activity therapies have long been successfully employed (Rudd & Margolin, 1969), although it has not been certain exactly how physical activity affects anxiety. Of course, in the present model the oppositional relationship between physical activity (associated with Dimension A) and anxiety (Dimension B) is quite explicit. With a thorough understanding of the parameters of this relationship it may be possible to design activity-based therapies more effectively. Also, within the clinical area, it may be helpful to have an understanding of the exact relationship between the activation states of low vigor and high tiredness and the increased vulnerability to tension. It may also be helpful for clinicians to recognize that vulnerability to tension rises and falls with the circadian rhythm of Dimension A activation.

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