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CIRCADIAN BODY TEMPERATURE AND ACTIVATION RHYTHMS AND THE WELL-BEING OF INDEPENDENT OLDER WOMEN

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ABSTRACT

This study examined changes in the circadian parmeters of body temperature and activation and their relationship to the well-being of the older woman. The literature on human rhythms provided the background for the hypothesized relationships.

A relatively homogeneous sample of 18 healthy, older women aged 65 to 80 years and living outside of institutions, took oral temperature readings with the IVAC 2000 electronic thermometer and completed one of 12 alternate forms of the Activation-Deactivation Adjective Check List every two hours during the waking hours for 7 consecutive days. Approximately two hours before going to bed, subjects completed the General Well-Being Questionnaire that was modified for this study to measure daily fluctuations in well-being.

The temperature and activation data were analyzed using consinor analysis to determine whether statistically significant 24-hour periods existed and the parameters of amplitude and acrophase for each subject's rhythms. Acrophase desynchrony scores were calculated as deviations of each subject's daily acrophases from their mean acrophase. Pearson correlations were calculated between the parameters of the rhythmic variables and the total well-being scores

for each subject.

Hypothesis one predicted that temperature and activation would manifest circadian periodicities, and was supported, particularly for body temperature: 15 of 18 subjects had statistically significant ($p<.05$) circadian rhythms in temperature, 11 of 18 in general activation, and 9 of 18 in deactivation-sleep.

Hypotheses two and three were not supported. These hypotheses proposed that there would be positive relationships between the amplitudes of temperature and activation, respectively, and the well-being of the older woman. Hypotheses four and five also were not supported. They proposed negative relationships between desynchrony in the acrophases of the temperature and activation rhythms, respectively, and the well-being of the independent older woman.

Additional analyses revealed that the subjects as a group demonstrated statistically significant ($p<.001$) circadian periodicities in all rhythmic variables. The data also suggested that the temperature and activation rhythms are driven by separate oscillators. The mean and mesor of the subjects' termperatures were found to be lower than the values reported for younger subjects.

The theoretical and methodological problems with the study were discussed. Conclusions and recommendations for further research were included.

CHAPTER I

THE PROBLEM

Temporal organization is a characteristic of living systems. Integrated human functioning is dependent upon a rhythmic pattern among biological functions. When the constant timing or phase relationships among these biological functions is altered--a phenomenon known as dissociation--disturbance in the organism's functioning results, such as disturbed sleep. Such dissociation may be important in the occurrence of disease, as well as in longevity (Aschoff, 1976).

Research has demonstrated that a change in temporal organization is characteristic of aging organisms (Pittendrigh & Daan, 1974; Halberg, J., Halberg, Regal, & Halberg, 1981). Although relatively little research has been done on the temporal organization of the aging human (older adult), Scheving, Pauly and Tsai (1978) and others (Samis & Capobianco, 1978; Casale & de Nicole, 1984) have documented that changes in the characteristics, or parameters, of certain rhythms occur in the older adult. For example, the timing of the peak of a particular rhythm may change with aging.

It has been assumed from studies of younger adults, that the temporal changes associated with aging are detrimental. This has yet to be demonstrated in older adults. In addition, most of the studies of temporal organization in aging humans were done in laboratory settings or nursing homes. Further study of the changes in temporal organization that occur with aging and their relationship to the well-being of the older adult are needed in a non-laboratory setting.

The Problem

What is the relationship between the circadian rhythms of body temperature and activation and the well-being of the independent older woman?

Sub-problems

1. Do body temperature and activation in the independent older woman manifest a 24-hour periodicity?
2. Is there a relationship between the amplitude in body temperature rhythm and the well-being of the independent older woman?
3. Is there a relationship between the amplitude in activation rhythm and the well-being of the independent older woman?
4. Is there a relationship between desynchrony of body temperature rhythm and the well-being of the independent older woman?
5. Is there a relationship between desynchrony of activation rhythm and the well-being of the independent older woman?

Definition of Terms

Temperature rhythm - the consistent variation in body temperature between a peak and a low value that occurs approximately every 24 hours. Body temperature is measured by the IVAC 2000 oral electronic thermometer and expressed in Fahrenheit degrees.

Activation rhythm - the phenomenological awareness of general bodily energy state that reflects a consistent 24-hour pattern. Activation is measured by self-report of two factors (general activation and deactivation-sleep) of Thayer's Activation-Deactivation Adjective Check List (Thayer, 1967) using alternate forms developed by Hoskins (1978).

Well-Being - an index of daily subjective well-being and distress, as measured by a modified version of the Dupuy's (1973) General Well-Being Questionnaire.

Circadian rhythm - a biological cycle of about 24 hours in length (its period), characterized by a peak (acrophase), trough, amplitude and mesor (Halberg, F., Carandente, Cornelissen & Katinas, 1977). It is determined by the best-fit of a cosine curve to data obtained by repeated measurement of a variable of interest (cosinor analysis using the method of least squares by Halberg, F. et al, 1972).

Period - the time interval occupied by a wave, or one complete cycle. A wave is a complete pattern that is repeated at regular intervals. The period may be measured from peak to peak of the best fit of a cosine curve to the data.

Amplitude - a measure of one-half of the difference between the highest and lowest values in a wave accounted for by the best fit of a cosine curve to the data. It is expressed in the units of the variable under consideration; e.g., Fahrenheit degrees for temperature.

Acrophase - the time of the peak value of the cosine curve fitted to a rhythmically oscillating variable as determined by cosinor analysis, using midnight as the reference time from which the acrophase is calculated. The acrophase will be expressed in both clock hours and arc degrees. The degrees expression is derived from a 360 degree arc representing the 24 hour period; thus, 15 degrees equals one hour.

Mesor - rhythm-adjusted mean; it is the mean of the cosine curve fitted to the rhythmic variable.

Desynchrony - changes in the timing of the acrophase of a rhythmic variable from day to day in an individual. It is the difference between the individual's mean acrophase of the rhythmic variable for all days of observation and the individual's daily acrophase. It is expressed in arc degrees.

Independent older woman - woman who is 65 years of age or older, living in her home environment and able to independently perform the activities of daily living.

Delimitations

The sample was limited to subjects who are mentally and physically able to engage in self-measurement of temperature and activation (autorhythmometry), and free of any acute or disabling chronic disease. To control for extraneous variables that may influence circadian rhythmicity, individuals who were employed fulltime or otherwise externally required to maintain a rigid daily routine were excluded from the study. To provide for a relatively homogeneous sample, individuals whose usual time of awakening was not between the hours of Ø53Ø and Ø9ØØ were also excluded.

Brown (1978) has proposed that the temporal changes that occur with aging result from decrements in the organism's ability to perceive environmental time cues, or synchronizers. If this theory is accurate, then failing vision and hearing may influence the extent of temporal organization of the aging human. While controlling for sensory integrity in the older adult is difficult at best, older adults with obvious sensory losses were excluded from the study. Such sensory losses include reported legal blindness or a diagnosed hearing loss that required an increase in normal conversational volume for the older adult to discern the investigator's speech accurately.

Since an association between mood and well-being has been established (Fazio, 1977; Larson, 1978) and since endocrine supplements have been shown to influence circadian rhythms (Samis & Capobianco, 1978), individuals who were taking medications that alter mood or endocrine supplements were excluded from the study.

Significance of the Study

No direct studies have been done to determine the relationship between the changes in temporal organization that are associated with aging and the health, functioning, or well-being of the older adult. Certainly, the indirect evidence for associating decrements in well-being with changes in temporal organization of older adults can suggest new ways of thinking about problems commonly associated with aging. For example, depression in the elderly has been associated with loneliness and loss; however, changes in circadian patterns, such as the sleep-wake cycle, of the older adult may also be related to their depression (Wehr, Wirz-Justice, Goodwin, Duncan, & Gillin, 1979). In addition, the relationship between isolation and depression in some older adults may be mediated by the circadian rhythm of melatonin secretion, an excess of which has been associated with depression. The circadian rhythm of melatonin secretion has been shown to be dramatically influenced by the light-dark cycle, with light suppressing its secretion (Lewy, Wehr, Goodwin, Newsome, & Markey, 1980; Wurtman, Baum, & Potts, 1985).

If the older adult is less sensitive to or isolated from sufficient light, particularly sunlight, melatonin secretion can lose its rhythmic pattern and lead to depression.

If changes in the temporal organization are harmful to the older adult, can some of this be prevented or repatterned? Can some temporal organization be promoted by imposed exogenous synchronizers? If, as one theory suggests, the elderly become circadian dyschronics (absence of a prominent daily rhythm where normally one is found) because of failing receptivity to environmental time cues (Brown, 1978), then strengthening the older adult's ability to perceive the environment or strengthening the environmental time cues may be worthwhile aims to improve functioning and longevity. Indeed, it has been suggested through two studies of older adults in institutions that temporal organization in the older adult can be promoted by a highly regular living routine (Wessler, Rubin & Sollberger, 1976; Todero, Gibson & Boosinger, 1986). Since this study will be the first to examine a stable rhythm such as temperature in independent older adults in non-laboratory or institutional settings, a greater variability in rhythmicity in this sample as compared with studies of institutionalized older adults would add support to the importance of strengthening environmental time cues for this population where possible.

If some change in temporal organization is inevitable with aging, more data will be needed to determine the nature of this change. This study will contribute to the knowledge base of age-related changes in the range of "normal" values, or "reference intervals" (Halberg, F., 1982) for body temperature. In addition, this study will be the first to examine the rhythm of activation in older adults.

Establishing norms for temperature and activation rhythms in the older adult will enable nurses and other health professionals to consider the temporal pattern of an older adult in planning interventions. Chronobiologic theory holds that human response to any stimulus will depend upon the time of day when the stimulus is applied (Aschoff, 1965, 1976). The outcomes of interventions such as teaching, drug therapy, and exercise can vary from detrimental to rehabilitative, depending upon the timing of the intervention. Given that the temporal organization of humans changes with aging, how can the nurse determine the optimum time for such interventions, as well as for planning rest and relaxation periods? Since there is a relationship between the rhythms of body temperature and activation and some measures of performance (Monk & Folkard, 1983), this study will contribute to the literature necessary to consider temporal factors in planning health care for older adults.

Theoretical Rationale

A basic component of all living organisms is temporal organization, or rhythmicity of processes and functions, on cellular through total organism and man-environment levels. Although the organism is thought to have an endogenous or internal clock or clocks, the environment acts as a synchronizer, or Zeitgeber. However, as an organism ages, its temporal organization changes. Studies of the older adult have demonstrated decreased amplitudes, decreased mesors, changes in the timing of the acrophases of various rhythms, and greater within group variability in older adults (Samis & Capobianco, 1978; Halberg, E., Halberg, Halberg, Southern, & Levine, 1981; Scheving et al., 1978; Keane, Smith, & Webb, 1977) as compared with young and middle aged adults who have been the subjects for most chronobiological research on humans. Several propositions have been offered to explain these temporal changes in the older adult.

One proposition coincides with the "programmed" theories of aging (Edmunds, 1978; Wilson, 1974) and holds that aging is an inherent component of the organism's time structure. Aging is viewed as the result of a genetically predetermined program for temporal disorganization. Such a position accounts for steadfast lifespans in humans and other animals (Capobianco & Zajac, 1978; Pittendrigh, 1974).

The second proposition falls into the category of "accumulated error" theories of aging (Edmunds, 1978) and holds that, as the organism ages, disruptions in temporal organization result from the lifetime accumulation of assaults or mutations on cellular processes and structures. Such cellular malfunctions would result in a disturbance of the synchronization of that cell(s) with the rest of the internal environment of cells, organs, and systems. Because of the loss of functional and adaptive capacity that occurs with aging, the cell or organism is unable to re-entrain such phase dissociations with the same efficiency and recovery as younger beings. Samis (1968) points out that even slight dissociations that remain uncorrected will accumulate and lead to greater degrees of phase dissociation, resulting in a loss of coordination among various interdependent oscillating systems and a further loss of functional potential and adaptive capacity. Samis suggests that this position may encompass a genetic basis as well, stating that "some progressive loss of temporal organization in such a complex network of interdependent but loosely connected processes may be a property of the system itself" (p. 101).

The third proposition argues that there are no internal clocks; rather, an organism's rhythms are adaptive genetic patterns timed by a geophysical clock of an electromagnetic nature, that depends upon organism-environment interaction. Because of the loss of sensory perception that occurs with aging, the organism is thought to be unable to sense the primary environmental timer and experiences dissociations of its own internal rhythms (Brown, 1978).

Although this last proposition is not widely accepted, essentially because it negates the existence of an endogenous clock or clocks, other investigators have proposed that aging organisms have a reduced capacity to perceive environmental time cues (Halberg,F. & Nelson, 1978). Such a position would not necessarily be contradictory to either the first or second propositions. It is reasonable to propose that while there is some degree of programmed temporal change that is part of the aging process (and may contribute to functional decline and reduced longevity), this change is exacerbated by the reduced adaptive capacity of the organism and by a reduction in the strength of entrainment or synchronization of the organism to the environment.

Aschoff (1965) uses oscillation theory to explain the occurrence of this reduced entrainment. He defines entrainment as two coupled oscillators having the same frequency (or frequencies of an integral ratio) and a constant phase relationship. In other words, two rhythms are entrained if they have the same period (or periods of an integral ratio) and the timing of their respective acrophases, or peaks, remains constant. This entrainment is determined by several factors, including the natural frequencies of the two oscillators, the strength of the Zeitgeber, and the strength of the organism's own oscillator.

Concerning the factor of natural frequency, there is some evidence (Pittendrigh & Daan, 1974) that the period of endogenous rhythms of an organism shortens with aging. In a study by Weitzman, Moline, Czeïsler, & Zimmerman (1982), the period of the temperature rhythm of older adults was 31 minutes shorter than that of younger adults, when subjects were under laboratory isolation conditions in which all known environmental time cues are eliminated, permitting the human rhythms to "free-run" or assume their own natural internal rhythm. If the organism's endogenous period does shorten with aging, then entrainment of the circadian rhythm by a Zeitgeber could become more difficult, since oscillation theory, as described by Aschoff (1965), holds that "a self-sustained oscillation can be entrained only to frequencies which are not too far from its natural frequency" (p. 265). The natural frequency is the frequency which the oscillator would assume if it were not entrained. Although it has been demonstrated that young adults are able to adapt to a 21 hour day and a 27 hour day (Mills, Minors, & Waterhouse, 1977), this has yet to be studied in older adults.

Aschoff (1965) identifies the strength of the

Zeitgeber as an important factor in determining the extent of entrainment. If the organism's ability to perceive the Zeitgeber is reduced, then the relative strength of the Zeitgeber itself is reduced. Indeed, Brown (1978) and Aschoff (cited in Halberg,F. & Nelson, 1978) have proposed that the reduced entrainment is due to a decreased sensitivity of the organism to its environment. Reduced sensory capacity is a well documented change that is considered to be a normal part of aging (Birren & Schaie, 1977). One of the strongest Zeitgebers in humans has been noted to be social cues (Wever, 1979), which may be diminished in socially isolated, retired older adults.

It is reasonable, then, to postulate that the temporal changes that occur with aging are associated with a lack of resonance of human rhythms with those of the environment. This lack of resonance can be postulated to result from: 1) a change in the natural frequency of circadian rhythms with aging due to a genetic program and accumulated errors in the oscillating system; and 2) a decreased ability of the aging organism to perceive the environment, resulting in a decrease in the relative strength of the Zeitgeber and, thus, of entrainment of the organism to the environment. Accompanying these propositions about temporal organization and aging is the assumption that the temporal changes are unwanted and detrimental to well-being.

An alternate view can be offered. Rogers (1970, 1980) holds that change occurs through a rhythmic patterning of waveforms that continually transform the human and environmental energy fields in the direction of greater complexity and diversity and higher frequencies. Rather than assuming that older adults have decrements in their temporal organization or their abiity to perceive their environment, a Rogerian perspective would suggest that the older adults are evolving and perceive their environment differently.

Some support for this Rogerian perspective in a non-elderly population is offered by Floyd (1983, 1984) in her tests of theorems derived partially from Rogers' conceptual system, through the study of the sleep-wake rhythms of hospitalized versus non-hospitalized psychiatric patients. Evidence from an older adult population comes from the aforementioned isolation study by Weitzman et al. (1982) that did not use Rogers' conceptual system. Their finding that isolated, free-running older adults demonstrate a shortened period in body temperature rhythm lends support to Rogers' proposition that humans are energy fields that are continually evolving to higher frequency waveforms. In addition, other studies of aging humans have suggested that there is greater within-group variability in the rhythms of older adults compared with younger adults (Scheving et al., 1978; Serio, et al., 1970; Hayter, 1983), lending support to the view of increasing diversity with human development. Thus, from a Rogerian perspective, changes in the temporal organization of older adults may be associated with high levels of well-being.

This assertion is contrary to evidence of temporal changes in young and middle-aged adults. Studies of these age groups have demonstrated that desynchronization of the individual's rhythms with the environmental rhythm results in changes in the parameters of the individual's rhythms, such as shifting acrophases, decreased amplitudes, and changes in periods (Lobban, 1965). This temporal disorganization has been associated with decrements in performance, activation, and other variables related to human health and well-being (Akerstedt & Froberg, 1975; Mills & Fort, 1975; Folkard & Monk, 1979). For example, Hauty and Adams (1965) demonstrated that disturbances in body temperature rhythms created by transmeridian jet flight resulted in impairment of reaction time and information processing, and an increase in subjective fatigue.

Although there have been no studies of the relationship between temporal changes in the older adult and measures of performance, health or well-being, the studies on young and middle aged adults suggest that temporal repatterning will be inversely related to such measures in the older adult.

Hypotheses

1. Body temperature and activation in the independent older woman will manifest circadian periods.
2. The amplitude of body temperature rhythm will be positively related to the well-being of the independent older woman.
3. The amplitude of activation rhythm will be positively related to the well-being of the independent older woman.
4. Desynchrony of the body temperature rhythm will be negatively related to the well-being of the independent older woman.
5. Desynchrony of the activation rhythm will be negatively related to the well-being of the independent older woman.

CHAPTER II

REVIEW OF RELATED LITERATURE

To facilitate the discussion of the literature on temporal organization and aging, this chapter begins with a review of the literature that describes temporal organization in general--a body of knowledge that was built primarily upon studies of animals and young and middle aged adults. The two rhythmic independent variables used in this study--temperature and activation--will be explored in particular depth. Circadian periodicities in aging will then be discussed. The chapter concludes with a review of the literature related to the dependent variable of well-being with emphasis on its relationship to circadian rhythms.

Temporal Organization of Living Systems

Rhythmicity in living systems can be found at every level of organization, from cellular (Edmunds & Cirillo, 1974) to social behavior (Hoskins et al., 1979). Such rhythms can be described in terms of a cosine curve, which in turn is characterized by four parameters: period, or length of one cycle of the rhythm (or its reciprocal--the frequency); mesor, or mean of the values of all data points comprising the curve; acrophase, or timing of the curve's peak; and amplitude, or one-half the distance between the curve's peak and trough (Halberg, F., & Ahlgren, 1979). The period of these rhythms varies from less than a second (such as a heart beat) to a year or longer. The circadian ("about a day") period is one of the best known and most important to human functioning. While different rhythms within the same organism will vary in these parameters, the relationship or synchronization between the period and acrophase of one rhythm and the period and acrophase of another is relatively constant.

Two mechanisms have been thought to be responsible for maintaining this synchronization of an organism's internal rhythms: the organism's own genetically programmed internal clock or, more likely, clocks that drive a system composed of multiple oscillators (Goto, Laval-Martin, & Edmunds, 1985); and environmental time cues, or Zeitgebers, that phase, or entrain, circadian rhythms (Takahashi & Zatz, 1982). These represent endogenous and exogenous mechanisms, respectively.

The genetic basis of an endogenous, self-sustaining internal oscillator(s) was first established from animal studies (Pittendrigh & Bruce, 1959; Aschoff, 1965; Takahashi & Zatz, 1982). Evidence that humans possess an internal clock has been generated from isolation studies in which all known environmental time cues are removed so that the person's rhythms are allowed to "free-run"; that is, they assume their natural period (or, according to Pittendrigh [1974], one of a narrow range of periods or natural frequencies) which is often somewhat longer than 24 hours (Wever, 1979). The fact that free-running rhythms often vary in length and phasing from when they are entrained, or synchronized to the environment, is used to support the proposition that the organism has its own inherent temporal pattern.

While there may be one or more primary internal clocks or pacemakers, evidence for multiple secondary oscillators that are responsible for phasing a variety of circadian rhythms has been demonstrated in animals (Swann & Turek, 1985; Pittendrigh, 1974) and, to a lesser extent, in humans (Aschoff, 1965, 1970; Wever, 1979; Turek, Earnest, & Swann, 1982), primarily through isolation studies. These studies have demonstrated that certain rhythms will assume different free-running periods (and their phase relationships may change dramatically), suggesting that they are driven by different clocks or are coupled to different oscillators. Environmental time cues phase or entrain the organism's endogenous rhythms (Aschoff, Daan, & Honma, 1982). Light is generally the most effective Zeitgeber for plants and animals (Lobban, 1965; Aschoff, Daan, & Groos, 1982). Social cues, however, are probably more important for humans (Wever, 1979; Vernikow-Danellis & Winget, 1979). Regularly scheduled activities, such as mealtimes or taking medications at the same time every day, can synchronize a human's rhythms to a 24-hour period (Aschoff, 1978).

Body Temperature: Its Regulation and Rhythmicity

Core body temperature is one of the most stable of human circadian rhythms. Its daily rise and nocturnal fall in subjects on a day-wake/night-sleep schedule, has been repeatedly documented and found to occur independently of such factors as fever, environmental temperature, and activity (Conroy & Mills, 1970). Because of its stability and relative ease of measurement, body temperature rhythm has been used as a marker for studying the whole timing system in humans (Halberg, E. & Halberg, F., 1980).

The stability of core body temperature is the result of an efficient thermoregulatory system responsible for balancing heat loss and heat production via negative feedback. Thermal receptors throughout the body (such as in the skin, gut and spinal cord) sense changes in body temperature from external or internal stimuli and signal the posterior hypothalamus. It then triggers physiological reponses for heat loss, through mechanisms such as sweating, panting, and peripheral vasodilation, and for heat production, via responses such as shivering and increasing the metabolic rate (Bloch, 1964; Wenger, Roberts, Stolwijk, & Nadel, 1976; Moore-Ede, Sulzman, & Fuller, 1982). Behavioral factors modify this physiological temperature regulation and include activity, clothing and housing adjustments (Cabanac, 1972; Corbitt, 1970; DeCastro, 1978).

Although synchronized by environmental cues, the circadian temperature rhythm has been shown to be endogenous; that is, it is intrinsic and persists in the absence of external synchronizers (Wever, 1979). Under free-running conditions, the period of the temperature rhythm becomes slightly longer than 24 hours. In fact, Minors and Waterhouse (1981) suggest that the endogenous component of the circadian temperature rhythm is stronger than the exogenous component, which may be why the rhythm has such great stability compared with other circadian periodicities.

While the body has its own endogenous temperature rhythm, certain exogenous factors have been shown to modulate this rhythm. Light is a powerful Zeitgeber and is thought to influence temperature rhythms in some manner (Fuller, Sulzman, & Moore-Ede, 1978a). Subjects in continuous dark or light in the Arctic and subjects who were totally blind showed a loss of amplitude and of synchronization of some circadian rhythms, but did not lose all rhythmicity (Lobban, 1965).

Environmental temperature, while challenging the thermoregulatory system, has only a small influence on the rhythmic nature of body temperature (Aschoff, Biebach, Heise, & Schmidt, 1974). Similarly, while food intake can increase heat production, the thermoregulatory system is able to adjust to such a change, so that little effect is seen in the circadian patterning of core body temperature (Kleiber, 1961). Wever (1979) demonstrated that fasting humans maintained their circadian periodicity in body temperature; however, the time of food presentation may serve as a synchronizer for the temperature rhythm's period (Krieger, 1979).

Although body temperature rhythm is influenced by the activity rhythm, the temperature rhythm does not depend upon activity for its rhythmicity. Subjects kept on bedrest or deprived of sleep are able to maintain a circadian rhythm in body temperature (Moore-Ede et al., 1982; Benoit, Foret, Merle, & Reinberg, 1981). It is well established that the lowest value in body temperature occurs during sleep in individuals who are normally awake during the day (Conroy & Mills, 1970). However, under some circumstances, e.g., free-running experiments, the nadir may not occur during sleep, but a drop in temperature can usually be found with the onset of sleep (Weitzman, Czeisler, & Moore-Ede, 1979). This is referred to as a "masking effect" that appears to be independent of the endogenous periodicity and may be seen with daytime naps (Minors & Waterhouse, 1981). In addition, exercise has been shown to elevate body temperature, particularly at night (Wenger et al., 1976; Kanecko, Zechman, & Smith, 1968).

A number of studies have contributed to defining the parameters--period, mesor, amplitude, and acrophase--of the rhythm of body temperature. While it has been established that the endogenous period of the core body temperature rhythm is slightly longer than 24 hours, the rhythm can be entrained to periods slightly shorter and longer than this (Aschoff, 1970). For individuals on a day-work/night-sleep schedule, the body temperature is at its lowest during sleep between 0400 and 0600 hours. Thereafter it begins a sharp rise until 1000 hours, and then gradually continues to increase until it reaches its peak between 1700 and 2200 hours, coinciding with the end of the activity time. The temperature then drops rapidly over the late evening and night (Mellette, Hutt, Askovitz, & Horvath, 1951; Conroy & Mills, 1970; Colquhoun, 1972).

Some of the variance in the timing of the rhythm is related to the individual's daily sleep/wake patterns, such that "larks", or people who prefer to arise early, show an earlier peak in temperature rhythm than "owls", or people who prefer to arise later and go to bed later (Kleitman, 1963). Mellette et al. (1951) reported an average temperature range equivalent to an amplitude of 1.33 Fahrenheit degrees in men and 1.07 Fahrenheit degrees in women, while Hockey and Colquhoun (1972) report a 1.1 to 1.2 Fahrenheit degree amplitude.

Activation: Theories and Measurement

Level of activation has been used to refer to the sleep-waking-excitement continuum (Malmo, 1959) and has been noted to be correlated with performance (Fort & Mills, 1972), as well as body temperature (Thayer, 1970). While used by some investigators to indicate a state of arousal or level of drive, the term "activation" has been used by others to refer to the phenomenological awareness of general bodily energy state" (Hoskins et al., 1979; Thayer, 1967). Changes in the definition of the term reflect the evolution of three theoretical approaches underlying investigations of activation: neurophysiological, behavioral, and learning or drive.

The basis for the neurophysiological approach to activation arose from early electroencephalographic (EEG) studies by investigators who were particularly interested in measuring emotion. Lindsley (1951) called for measurement procedures for emotion that "are reasonably representative of the activity of the organism as a whole" (p.474), because of the complex interactions of physiological mechanisms associated with emotion. He put forth an "activation theory of emotion," relating it to emotional behavior, sleep-wake, and EEG manifestations of cortical activity. He demonstrated that changes in subject alertness are associated with changes in the EEG and concluded that there is a mechanism within the brain that is responsible for alertness, which in turn is related to emotion.

Malmo (1959) reviewed related studies and elaborated on Lindsley's activation theory. He held that one's level of activation varies from deep sleep to excited states and is a function of cortical stimulation of the reticular activating system in the brain stem. This system can be stimulated by external cues, such as sights and sounds, and by internal cues, such as thought processes. The system then stimulates other areas of the brain to energize the body, leading to increased arousal, psychological and motor activity, and information processing (Kroeber-Riel, 1979).

Duffy (1934; 1951; 1957; 1962; 1972) built upon Lindsley's work and developed a behavioral theory of activation. She proposed that level of activation is an indicant of the intensity dimension of behavior or total organismic energy release. This intensity of behavior is distinct from the direction of behavior. It varies on a continuum from sound sleep to frantic emotion, intense mental work, or strenuous physical effort. Duffy recommended measuring activation not by overt behavior, but "...by the activity of those processes which supply the energy for overt behavior" (1934, p. 194) using such physiological indices as galvanic skin resistance, muscle tone, pulse, and respirations. Duffy regarded these physiological measures as holistic indicants of the pattern of the organism.

Hebb (1955) described activation from a learning/ drive perspective, suggesting that motivation refers to the goal-directed energizing of behavior, with drive being regarded as a more specific facet of motivation. He held that learning is dependent upon drive; however, this is not a linear relationship. Rather, he described an inverted U-shaped curve of arousal and learning response, such that optimal learning occurs in the mid-range of arousal. Learning is thus inhibited when arousal is too low or too high. Malmo (1959) argued that the underlying physiological mechanism of the neurophysiological approach was responsible for this learning/drive approach to activation and supported the use of physiological measures of drive.

Although all three theoretical approaches embraced the use of physiological measures of activation, problems with these measurements were noted. Lacey and Lacey (1958) pointed out that little intersubject correlation of physiological variables had been found. While Duffy (1951) attributed this poor correlation to measurement errors and the compensatory nature of physiological systems, other researchers documented that subjects have unique physiological patterns of activation--a "symptom specificity"--that will vary among individuals but will be consistent within an individual under different conditions of stimulation (Lacey &

Lacey, 1958). For example, Schnore (1959) found that subjects demonstrate different patterns of response on some physiological variables such as heart rate and blood pressure, but each individual's pattern remains stable when experimental conditions are altered to stimulate changing levels of activation. Schnore concluded that use of one physiological variable to measure activation is insufficient.

Such problems with physiological measures of activation led Thayer (1967) to develop the Activation-Deactivation Adjective Check List (AD-ACL), for measuring activation regardless of theoretical approach. It measures, through self-report on a list of adjectives, the individual's phenomenological awareness of their bodily energy state in terms of four dimensions, or factors: general activation, general deactivation, high activation, and deactivation-sleep. Thayer undertook validation studies in which correlations between physiological measures (and composites of such measures) and the AD-ACL were examined. He concluded that the AD-ACL was "more representative of general bodily activation than any single peripheral physiological system" (p.677). Subsequent studies have generally upheld Thayer's claims (Clements, Hafer, & Vermillion, 1976; Thayer, 1970).

As inconsistencies persisted in the results of studies using physiological indices of activation, it became increasingly evident that the construct of activation is not unidimensional (Lacey, 1967). Duffy (1972) noted that activation is both a general level and specific to the situation. Kroeber-Riel (1979) identified a relatively enduring general pattern of arousal (tonic), characterized by a circadian fluctuation, and a briefer state of arousal resulting from immediate stimuli (phasic). Such theoretical schema differentiating between tonic and phasic activation cause one to raise questions regarding other research studies that have experimentally varied level of activation and measured the same, without differentiating between the two dimensions of activation, using physiological variables. While such questions require continued scrutiny, it remains that the factors in Thayer's AD-ACL appear to enable the researcher to differentiate between the tonic (general activation, deactivation-sleep) and the phasic activation (high activation).

Activation as a Rhythmic Variable

While Kleitman (1939) suggested a pattern of arousal that varied with time of day using physiological measures of arousal, other researchers have demonstrated rhythms in activation that are circadian and of other durations. Thayer (1967) studied the validity of the AD-ACL to determine whether it was sensitive to such a time of day fluctuation. Fifty male and female freshman subjects completed four AD-ACLs at the following times: immediately upon arising in the morning, just before lunch, just before dinner, and before going to bed. A diurnal fluctuation in level of activation was found, with general activation being greatest at midday and decreasing to a low at bedtime. General deactivation predictably inversely mirrored general activation, achieving its lowest point at midday. Deactivation-sleep paralleled general deactivation, but at lower average levels, except that the former had a steeper rise in the evening until it surpassed general deactivation shortly before bedtime. High activation showed the least diurnal fluctuation, but did show a midday peak.

The circadian pattern of activation has been documented in other studies that have used a variety of measures of activation. These studies have revealed that the circadian rhythm of activation is characterized by low morning values that increase towards noon, followed by an afternoon dip and a further decrease towards bedtime (Akerstedt, 1977; Cairns, Knowles, & Maclean, 1982). Akerstedt and Froberg (1975) found circadian rhythms in activation using self-report of alertness on a five-point scale under normal sleep-wake conditions and self-report of fatigue on an 11-point scale under 75 hours of sleep-deprived, isolation conditions. The latter suggests that activation is in itself rhythmic, and not merely the product or reflection of the sleep-wake cycle. In these studies, activation was lowest during the night between approximately 0300 and 0530 hours and was highest in the mid-afternoon around 1500 hours.

Dermer and Berscheid (1972) further documented the temporal pattern of activation of 51 male and female college students using a self-report measure of arousal with a scale from -10 for extreme tiredness, boredom, or fatigue, to +10 for extreme alertness, hypersensitivity, or excitement. These ratings were made hourly during waking hours over several days in diaries kept by the subjects. Using the cosinor analysis, Dermer and Berscheid found 24-hour periods of arousal in 36 of 51 subjects. The amplitude and acrophases of the subjects were used to compute the group parameters of arousal rhythm. When midnight was used as a reference point, the acrophase was 1739 hours with 95% confidence intervals of 1642 to 1837 hours. In addition to the circadian period, significant 8- and 12-hour periods were also noted, suggesting an ultradian, or less than 24-hour, component to the rhythm of activation, as well as a circadian pattern. Others have suggested that there may be more than one oscillator underlying the rhythm of activation (Monk, 1982).

Dermer and Berscheid (1972) also noted a high degree of correspondence between the circadian acrophase of activation and the circadian acrophase of body temperature as reported in other studies. Four out of the five studies reviewed showed temperature acrophases that approximated activation acrophases, leading the researchers to suggest that "temperature may be a good but relatively neglected measure of arousal" (p.427). Other researchers have demonstrated that the peak in activation generally precedes that of body temperature, leading some to speculate that the rhythm of activation underlies the rhythm of body temperature (Humphreys, Revelle, Simon, & Gilliland, 1980).

A dual oscillator model of circadian rhythms suggests that the rhythms of activation, as a reflection of the activity/rest and sleep/wake cycles, and body temperature are driven by separate endogenous oscillators, but interrelated or mutually entrained (Moore-Ede et al., 1982; Weitzman et al., 1982; Wever, 1979; Monk & Folkard, 1983). When humans are under isolated conditions, their circadian temperature and activity/rest rhythms share a common period (approximately 25 hours) initially and then, in about 16% to 30% of the cases, the rhythms dissociate and reveal their intrinsically different frequencies, with the activity/rest period being longer than that of temperature. However, these rhythms can mutually entrain and influence each other through hormonal and neural feedback mechanisms.

Circadian Periodicities and Aging

Several studies of circadian rhythms in aging humans have demonstrated changes and greater variability in the parameters of the rhythms of blood and urine constituents (Lobban & Tredre, 1967; D'Agata, Vigneri & Polosa, 1974; Serio et al., 1970). For example, Casale and de Nicole (1984) studied 42 different blood constituents of 213 older adults in nursing homes or hospitals using blood samples drawn every four hours around the clock. Changes in mesors, amplitudes, and/or acrophases were found when a 24-hour cosine curve was fitted to the data for each variable. While both increases and decreases in mesors and amplitudes were found, the researchers point out that "the most frequently observed characteristics in the comparison between young and elderly persons are the tendencies toward diminution of amplitude and/or mesor in circadian rhythms during aging" (p.281). They also suggest that a cause of the decrease in amplitudes may be the social isolation that often accompanies aging, leading to an absence of social synchronization.

Touitou et al. (1979) studied circadian rhythms in blood variables using 7 young men (19 to 32 years of age), 6 elderly men (72 to 93 years; mean = 82.5 years), 6 elderly women (67 to 94 years; mean = 81.2 years), and 6 "demented" elderly, 4 of whom were men (67 to 92 years; mean = 80.5 years). Blood samples were drawn every four hours during the waking hours. Differences between the groups were found in the mesors, amplitudes, and/or acrophases in such factors as red blood cells. When acrophase changes occurred they were generally between groups, rather than within groups, suggesting that changes in the phasing of certain circadian rhythms are characteristic of aging, as well as gender and abnormal cognition. In addition, much greater deviation in mesors of all variables was found in the elderly groups compared with the young men.

In a study of metabolic rhythms of older adults (Alberti et al., 1975), 8 young adults (24 to 35 years of age) were compared with 11 older adults (65 to 96 years). Using indwelling catheters, blood samples were drawn every 2 hours during waking hours and every hour during sleep. Differences between the two groups in the concentrations of serum metabolites and hormones led the researchers to conclude that "metabolism...alters with age with progressive loss of fine homeostasis. Metabolic 'normality' should be defined differently for the aged" (p.133). The researchers also noted a flattening of the mealtime peaks of insulin concentration in the older adults. Changes in the shape of the circadian waveform have been noted in other studies as well (Wessler et al., 1976) and has been suggested as another characteristic of rhythms in aging.

Differences in the circadian patterning of aging men and women have also been demonstrated. Cugini et al. (1982; 1984) compared the circadian rhythm parameters of endocrine systems of 9 young women (20 to 26 years of age), 10 older women (70 to 78 years), 10 young men (23 to 29 years), and 10 older men (70 to 81 years) from central Europe, who were on a schedule of sleep from 2300 to 0700 and three mealtimes. Samples of venous blood were drawn every three hours between 0700 and 2200. Assays of different hormones, such as aldosterone and cortisol, were analyzed by fitting 24-hour cosine curves to the data. A statistically significant difference was found in the mesors, amplitudes, and/or acrophases of these variables in the older adults, as compared with the younger group, and most frequently in older women. A prominent sex difference was evident in the cortisol and aldosterone rhythms. For example, while serum aldosterone rhythms were established in each group, statistically significant differences in young and old women were found in their aldosterone acrophases ($p<.05$) and in decreased amplitudes ($p=.003$). These differences were not found between the young and old men, leading the researchers to suggest that "the female adrenopause is a physiologic phenomenon that starts shortly after menstrual cycle ceases" (1984, p. 322), and precedes the male adrenopause.

These studies of older adults demonstrate that changes with aging can be found in the amplitudes, acrophases, and mesors of a variety of circadian rhythms under environmentally entrained conditions. They also suggest that there are changes in the waveform of the rhythm and greater within-group differences in the rhythms of older adults compared with younger subjects. To separate whether changes in temporal patterning with aging occur from altered responsiveness to the environmental zeitgebers or from internal timing disruptions, comparative isolation studies are needed. Such studies can compare the periods (as well as other rhythm parameters) of free-running rhythms in older versus younger adults.

Two such isolation studies have been reported in the literature to date. Weitzman et al. (1982) compared a group of 6 young (aged 23-30 years) with 6 older (53, 54, 58, 59, 63 and 70 years of age) men in an isolation laboratory from three to 8 weeks per subject. For the first three to 6 days in the isolation lab, the subjects were given time cues that entrained them to a 24-hour schedule with their usual amount of sleep time, as determined from logs kept by the subjects for two to four weeks prior to entering the isolation lab. After this period of entrainment, the subject was told that he would no longer be given any time cues, that he could sleep whenever and for as long as he chose (although subjects were asked to avoid napping), and that he could decide when and what kind of meal he would eat and what activity he would do.

Both young and older adults showed statistically signficant ($p<.05$) temperature and sleep-wake rhythms greater than 24 hours during free-running conditions. Although no significant differences between the young and older adults were found under free-running conditions for sleep-wake rhythms, the older adults demonstrated a significantly shorter free-running temperature period (31 minutes, $p<.05$). The researchers point out that "...since the measured core body temperature rhythm is under the control of a relatively stable underlying oscillator, a mean decrease in the temperature period strongly suggests that the aging process may decrease the period of the oscillator" (p.300). They also point out that a shortened period in the temperature rhythm would change its phase relations with the sleep-wake rhythm and the environmental Zeitgebers that entrain one to a 24-hour period.

The findings of Weitzman et al. (1982) conflicted with findings from the only other earlier study of freerunning rhythms of older adults. Wever (1979) reported no shortening of the period of the temperature rhythm with aging in 159 subjects; however, only four of these subjects were 60 years of age or older and one of these was a woman who was studied twice--at 60 years of age and at 61 years--and had the shortest free-running temperature period of all 159 subjects.

Wever also reported that there was a persistent difference in the periods of the activity and temperature rhythms of the older adults--which Weitzman and colleagues reported in two of their 6 older subjects--lending support to the existence of two separate oscillators driving these rhythms.

It should also be noted that Weitzman et al. (1982) found changes in the circadian patterning of the "older adults" even though only one of these subjects was over the age of 65 years, which is a commonly accepted lower boundary for classification as "older adult." Even if this definition is stretched to 60 years of age, only one more subject would be included. Thus, the changes in circadian patterning that are associated with aging may begin in the middle adult years. In addition, the subjects were essentially healthy, which may indicate that overt illness is not always or immediately associated with the temporal changes that occur with aging. While the aging individual begins to experience internal temporal changes, the changes may not become apparent in terms of overt dysfunction until later, perhaps after many years of declining compensation.

At least one non-isolation study has suggested that perception of the environmental cues may play a significant role in the temporal changes that occur with aging. A study by D'Alessandro, Bellastella, Esposito, Colucci, and Montalbetti (1974) suggested that perception of light could be a factor in temporal organization of older adults. Using a sample of 18 "normal" older adults aged 62 to 88 years (mean of 73.11 years), 11 cerebrovascular hemiplegic patients aged 62 to 83 years (mean of 67.09 years), and 11 patients who had been totally blind for 4 to 12 years, aged 65 to 93 years (mean of 74.27 years), blood was drawn every three hours for 24 to 48 hours and analyzed for cortisol level. While the first two groups of older adult subjects had significant cortisol rhythms, the blind subjects did not, leading one to question whether the changes in rhythm parameters that have been found in older adults are related to the sensory decrements that are associated with aging, but perhaps not assessed or reported by researchers.

While no studies have been done of activation rhythms in older adults, sleep-wake/rest-activity rhythms have been related to arousal and data are available on these two rhythms in older adults. Changes in the sleep-wake patterns of the older adult have been repeatedly documented, although some findings have been conflicting, which may reflect the greater variability in temporal patterning with aging (Webb, 1982; Guilleminault, 1982; Webb & Swinburne, 1971; Kahn & Fisher, 1969). Miles and Dement (1981) have summarized these findings; those concerned with circadian patterning will be emphasized here.

First, older adults are generally more dissatisfied with sleep, reporting complaints of nonspecific sleep disturbances, awakenings during the night, and greater use of sedative-hypnotic medications. The time spent in bed increases from both subjective estimates and objective observations of older adults. The length of the actual sleep period, however, is quite variable, from increasing to decreasing to unchanging. Furthermore, the total sleep time (sleep period minus the time spent awake and in movement during the sleep period) is either decreased or unchanged with aging. Thus, sleep efficiency (ratio of total sleep time to nocturnal time in bed) is decreased. In addition, some of the findings regarding changes in sleep patterns suggest an altered response to underlying arousal levels and an advance in the timing of the circadian sleep-wake rhythm, so that older adults often become "morning types" or "larks" and awaken earlier than they did in their young and middle adult years (Akerstedt & Torsvall, 1981).

The circadian rhythms of both sleep and activity in nursing home residents were studied by Wessler et al. (1976) with a sample of 30 subjects (two males and 28 females aged 68 to 94 years) who were mentally competent and were free of movement restrictions and acute (but not chronic) conditions. For a 10-day period, observations about the subjects' activity and sleep-wakefulness were recorded every two hours activities. Dichotomous scoring of these variables was used: sleep = 1, wakefulness = 0; the presence of activity = 1, absence of activity = 0. Sine curve fitting and spectral analysis were done on each individual. Both activity and sleep rhythms manifested best-fit periods of 24 hours, although statistically significant periods of 6, 12, and 22.5 to 25 hours were also apparent. Generally, there was great consistency from day to day in each individual's activity and sleep rhythms, as well as a higher than expected degree of synchrony among individuals, which the researchers suggest may be due to the highly structured environment of the nursing home.

Parameters of the temperature rhythm in older adults have been reported in three important studies. Weitzman et al. (1982) described the parameters of the temperature rhythm under entrainment, as well as under the free-running conditions previously described, and reported the period to be 24.02 hours (+/- 0.14). While there was no significant difference between the young and older adults in the mean acrophase of temperature, the nadir or trough, was higher and the amplitude smaller in the older subjects. This difference in amplitude and nadir is related by the researchers to a decrease in Stage 3 and 4 sleep and an increase in the number of arousals at night in older adults.

These researchers also reported greater within-group variability in older adults compared with younger adults. Such variability demands caution in the interpretation of group means and amplitudes, as well as in generalizations of findings.

The variability in temperature rhythm was also found to exist under the regimented schedule of a nursing home, albeit less than was expected. Scheving et al. (1974) studied 8 older adults (aged 69 to 86 years, with a median age of 82.5 years) in the same nursing home for 10 days with three-hour sampling intervals during the waking hours. The subjects all had chronic cardiovascular disease, as well as other diseases, and were receiving a variety of medications. By the nursing home's routine, sleep was scheduled from 2130 hours to 0600 hours and three scheduled meals were given to each subject daily.

Cosinor analysis was used to analyze data collected on oral temperature, as well as other variables. A 24-hour curve was fitted to the temperature data of all subjects and only one (an 81 year old woman) proved not to be statistically significant ($p<.01$). The group was found to have a temperature rhythm that peaked (acrophase) at 1652 hours with a .95 confidence interval ($p<.004$) between 1456 and 1852 hours. Compared with young adults (Scheving et al., 1978), the older adults showed a significantly lower amplitude in temperature rhythm ($p<.02$) and greater variability in the timing of acrophases of temperature.

Scheving et al. (1974) do suggest that what synchronization among the nursing home subjects was present could have been related to a sychronizing effect of the medications being taken by all of the subjects. They also point out that while these subjects were in a nursing home and had evidence of a variety of diseases, they represented some of the most alert and active older adults in this and other nursing homes.

A seemingly less structured self-care wing of a home for older adults was the site of another study of circadian rhythms, including temperature. Todero et al. (1986) studied 23 residents--five men and 18 women aged 72 to 92 years (median age = 83 years)--with three objectives in mind: (1) to determine their sleep-wakefulness patterns; (2) to determine if the subjects established circadian rhythmicity for temperature, pulse, and respiration (using cosinor analysis); and (3) to determine if these patterns influenced their environmental interaction. The subjects were observed hourly for 14 days to determine if they were asleep or awake. Temperature, pulse, and respirations were recorded every three hours during the subjects' waking hours (generally 0600 to 2100). The researchers used separate tools for assessing physical ambulation, physical activity, and social activity. Ratings of sleep-wakefulness were graphed for each individual and then for the sample as a whole. Subjects were determined to be "good" sleepers or "poor" sleepers depending upon the regularity or irregularity of their sleep-wake habits.

Five of the 23 subjects did not demonstrate a statistically significant circadian rhythmicity in temperature. In the 18 subjects who did, their temperature acrophases occurred between 1230 and 1800 hours. Twenty-one of the 23 subjects demonstrated rhythms for at least one component of the three vital signs. Eight showed circadian rhythms in all three components; 8 subjects were rhythmic in two components; and five subjects in only one component. Two subjects had no circadian pattern in any of the vital signs and were among the "poor" sleepers. Only one of the four "poor" sleepers demonstrated a circadian rhythm in one of the components of vital signs other than temperature.

The findings of this study lend support to the hypothesis that the temporal changes that occur in older adults are associated with changes in functioning and possibly in well-being. No direct support of an inverse relationship between the changes in temporal organization accompanying aging and the individual's well-being is available; however, studies of younger adults are the basis for predicting this inverse relationship.

Well-Being and Temporal Organization

Well-being is a multidimensional construct that has been variously defined and operationalized. It has been conceptualized as both an internal construct and one that is influenced by the environment. It frequently has been interchanged and correlated with terms such as life satisfaction, morale, quality of life, happiness, and health (Lawton, 1975; Lohmann, 1977). These terms have underlying conceptualizations and operational definitions that overlap, such that Larson (1978) recommends adopting subjective well-being as a single summary construct that characterizes some portion of all of the other terms and points out that "the similarities between measures appear to be of more significance than the differences" (p.110).

Herzog and Rogers (1981) point out that well-being must be studied in terms of both qualitative and quantitative age differences. Noting previous findings suggesting that well-being is different for different age groups (Cutler, 1979), they analyzed data from two national surveys of multidimensional "life satisfaction." They concluded that while there was greater variance on the health factor among older adults and some differences by age in the interrelationships of the underlying factors themselves, there was sufficient evidence that there is a common set of factors underlying life satisfaction for adults aged 25 to 75 years.

Consistently, perceived health status is the factor most strongly related to perceptions of well-being in older adults, followed by socioeconomic factors, social interaction, marital status, and living conditions (Larson, 1978; Spreitzer & Snyder, 1974; Kozma & Stones, 1983; Burckhardt, 1985). Other studies have demonstrated a correlation between subjective well-being and measures of psychiatric symptoms, depression, and anxiety (Himmelfarb & Murrell, 1983; Fazio, 1977).

Subjective well-being, then, is a construct that is strongly correlated with health. As the picture of humans as temporal beings unfolds, definitions of health and well-being that include temporal organization become necessary. One definition of health with a chronobiologic perspective has been provided by Franz Halberg (1978): "the predictable rhythmic biologic variation of physiologic functions, in many frequency ranges with internal time relations and relations to external synchronizers, modulators and influencers" (p.332). While Halberg has overlooked psychological and social functioning in his definition, it does provide a beginning for defining a temporal dimension of health.

Mager (1980) has elaborated on defining in temporal terms the illness end of the health-illness continuum. He proposes that disease states can be regarded as an uncoupling of internal rhythms:

> ...the uncoupling yields a disorganization of the spatiotemporal behavior and one expression

> is that pathologically changed oscillations of biosystems can be observed. A transition from illness to a normal state occurs by recoupling, where oscillations are an excellent criteria of the effectiveness of the therapy. (p.56)

While certain illnesses have been associated with changes in circadian periodicities (e.g., urinary excretion rhythm in congestive heart failure and disturbed sleep/wake rhythm in depression and schizophrenia), whether the illness causes the rhythm change, results from it, or is merely associated with it has not been clearly established (Moore-Ede et al., 1982). However, some evidence has accumulated that abnormal amplitudes or acrophases can be early indicators of developing disease (Hermida-Dominguez, Del Pozo, & Halberg, 1982; Halberg, F., et al., 1984).

One principle of chronobiology that has been demonstrated in plants and animals is that an organism will function most effectively when it is synchronized to a period that is close to its own natural frequency (Pittendrigh & Minis, 1972). Pittendrigh (1960) further asserts that "the impairment of growth and longevity must be attributed to disruption of the organism's 'normal' internal temporal order" (p.451), specifically the loss of phase relations among body rhythms that can result when the environmental time cues are disrupted. This principle has been demonstrated in research on animals whereby the longevity of the animals was significantly reduced by repeated phase shifts (Pittendrigh, 1974; Hayes & Cawley, 1978).

Although little evidence is available to support these propositions in aging humans, studies of young and middle adults under conditions of isolation, shift work, or jet travel support a relationship between temporal organization and well-being. Early evidence of the relationship arose from one of the first human isolation studies. Aschoff (1965) reported that a subject studied under isolation conditions made diary notations on days when he felt especially well and fit; and these notations coincided with times when his dissociated, free-running rhythms of temperature, activity, and other functions happened to be in phase with each other, which occurred every three or four days.

Subjects who engage in shift work experience a conflict between their circadian system's inclination to remain entrained to the normal day-light cycle that coincides with a variety of other social cues, versus assuming the phasing of the "work by night, rest by day" cycle with its cues (Aschoff, 1965). This conflict can result in changes in normal periodicity of different functions and processes, as well as disturb the phase relationships among them. For example, in a study (Akerstedt, 1977) of 36 habitual dayworking men exposed to three weeks of nights (resulting in an inversion of the sleep-wake cycle), a flattening of the temperature rhythm could be seen to the point that the otherwise stable circadian periodicity in this variable sometimes became undetectable. Activation, as measured by a self-rated alertness scale, showed a less pronounced time of day variation.

Well-being and optimal functioning are associated with fully developed, high amplitude circadian functions (Akerstedt, 1979), the loss of which occurs with shiftworking. Shiftworkers have been reported to show impaired performance efficiency and accuracy, fatigue, mood changes, an increase in subjective estimates of distress, and decrements in subjective measures of physical, social, and mental well-being (Akerstedt & Torsval, 1978; Folkard & Monk, 1979; Colquhoun, Folkard, Knauth, & Rutenfranz, 1975) The main complaints of shiftworkers involve digestive and sleep disorders, which have been substantiated by objective measures (Rutenfranz, Knauth, & Colquhoun, 1976; Michel-Briand, Chopard, Guiot, Paulmier, & Studer, 1981; Meers, Maasen, & Verhaegen, 1978).

Circadian desynchronization and decrements in well-being are also associated with transmeridian jet travel. With travel involving a 12-hour shift in clock hours, an individual's rhythms will shift to the new time after about 6 days (Moore-Ede et al., 1982). Even 8-hour phase shifts are associated with a flattening of temperature, performance and reaction time curves (Klein et al., 1972). Until the individual's circadian rhythms are able to shift to be in synch with the new environment, the individual feels tired and less efficient (Hauty & Adams, 1965).

With or without the imposed phase shifting of shiftwork or jet travel, a strong relationship has been demonstrated between the sleep-wake cycle and well-being. People generally have difficulty sleeping when their temperature is at its high point and feel tired when their temperature is low (Minors & Waterhouse, 1981). Regular stable sleep-wake schedules are associated with optimal levels of subjective mood and performance efficiency; conversely, irregular sleep schedules are associated with decrements in physiological arousal, performance, and subjective mood (Miles & Dement, 1981).

The relationship of the temporal coordination of sleep and temperature to human well-being is also evident in the recognition of disturbed sleep as a primary symptom in endogenous depression and other psychological disorders. Nikitopoulou and Crammer (1976) demonstrated that while the circadian rhythm of body temperature was essentially normal during the manic phase of manic-depressive illness, the daytime temperature became disorganized during depression, often falling in the morning instead of rising and appearing to adopt a 12-hour periodicity. Moreover, it has been demonstrated that advancing the sleep cycle of depressive patients by several hours alters the internal phase relationships between the sleep-wake cycle and other circadian rhythms and can result in a rapid remission of symptoms that is relatively long lasting (Wehr et al., 1979; Wirz-Justice, Groos, & Wehr, 1982).

It is becoming clear that humans and other organisms do not function at peak efficiency and effectiveness when internally desynchronized. While most of the studies have been done on young and middle-aged adults, older adult subjects have been shown to adapt less easily than younger subjects to marked time shifts, such as with shiftwork (Akerstedt & Torsvall, 1981). The fact that older adults suffer from sleep disturbances that are associated with changes in the sleep-wake cycle seems fairly well established (Miles & Dement, 1981). These disturbances have been related to a loss of rhythmicity in other circadian variables, as demonstrated in the previously discussed study of residents of a self-care wing of a nursing home (Todero et al., 1986), in which two subjects who had no circadian rhythmicity in temperature, pulse, and respiration were among the study's four "poor sleepers."

Summary

Chronobiologic research has established that humans are rhythmic beings who are dependent upon temporal coordination of their various systems and subsystems and of the individual with the environment for optimal functioning. This rhythmicity is controlled by endogenous and exogenous timing mechanisms. There are at least two endogenous oscillators that have been demonstrated to separately drive the temperature and rest-activity rhythms, although these oscillators are interdependent.

Body temperature is a particularly important variable for this study because it is one of the body's most stable rhythms, has a stronger endogenous than exogenous component, and is considered a marker rhythm by which the circadian system can be evaluated. In addition, no studies have been done on body temperature rhythms in independent older adults using autorhythmometry, except for isolated, single subject, investigator-as-subject reports.

Activation, defined as the phenomenological awareness of general bodily energy state, is a concept that has evolved from the study of arousal and has been demonstrated to correlate with body temperature. While it has become apparent that activation is multidimensional, at least one of these dimensions (tonic) shows remarkable circadian periodicity. Since the circadian rhythm of activation closely parallels the rest-activity cycle of day active people, it may be a manifestation of the secondary endogenous oscillator. No studies of the circadian periodicity of activation have been done with older adults.

A growing body of research is demonstrating that as humans age, they undergo changes in their temporal patterning. These changes include altered mesors, amplitudes, acrophases, and even a shortening of the circadian period in a variety of variables. In fact, some variables show a loss of circadian rhythmicity altogether. While two isolation studies of free-running older adults suggest that these changes are endogenous, altered responsiveness to environmental time cues remains a viable explanation.

Regardless of why these changes occur, it is important to determine whether they are associated with decrements in well-being. Studies of isolation, shiftwork, and jet lag in young and middle-aged adults suggest that alterations in the temporal organization of humans are associated with decrements in well-being. Although one study has pointed to an association between loss of rhythmicity in vital signs and quality of sleep, the relationship between what appears to be temporal disorganization with aging and well-being must be established before judgments are made regarding whether to try to prevent, restore, or support the temporal changes of aging.

CHAPTER III

METHODOLOGY

The Sample

The intensive study of individuals over time requires the most precise methods available. A repeated measures design permits the investigation of variations within and between subjects, rather than limit the study to a single time of measurement in a large sample. This study's sample consisted of 18 older women, which is a relatively large sample for time series research in the area of chronobiology.

The guidelines for determination of sample size in a repeated measures design are less precise than those for a descriptive study wherein independence of observations is assumed (J. Cohen, personal communication, April 3, 1986). Since the circadian day is considered the unit of observation for this and similar time series studies, the appropriate sample size was determined to be 16 subjects, each of whom would provide 6 days (later changed to 7 days) of data for a total of 96 sets of observations. On the basis of accepted guidelines for calculation of sample size for descriptive research, this provides a power of 0.91 for an effect size of r = 0.30 when alpha is .05 (Cohen, 1969). The actual sample of 18 subjects, inclusive of two subjects who participated in the pilot study, provided 124 sets of observations (16 subjects x 7 days, plus two subjects x 6 days).

Subjects were recruited through the investigator's professional contacts with individuals and groups in academic, health care, and community settings. These individuals and groups were asked to circulate to potential subjects a letter describing the study, as well as the criteria for and nature of participation (see Appendix A). The letter asked interested subjects to contact the investigator by phone or mail. Those who initiated this expression of interest were interviewed by the investigator to determine eligibility according to the study's delimitations (See Chapter 1) and to make certain that subjects understood what their participation would entail.

Subjects ranged in age from 65 to 80 years (mean of 71.6 years). Ten (55.6%) were married, 6 (33.3%) were widowed, and two (11.1%) were single. The 10 married subjects were all living with their spouses, while five (27.8%) subjects were living alone and three (16.7%) were living with other family members.

Seven (38.9%) subjects described themselves as in "excellent" health, 9 (50%) in "good" health, and two in "fair" health. Fourteen (77.8%) subjects stated that they did not have any health problems that were disruptive of their daily living, although the same number stated that they did have one or more health problems. While these problems were varied, none were acute. Three (16.7%) subjects took no medications, 6 (33.3%) took one, four (22.2%) took two, and five (27.8%) took three or more. Some of these medications included vitamin and mineral supplements. One subject took an arthritis medication with antipyretic properties (subject 13). Except for this subject, none of the medications that subjects took are known to influence temperature, activation, or well-being.

Only three (16.7%) subjects stated that they had experienced any major disruptive events within the past two months, one of whom listed potential knee surgery and became distraught during the data collection period when it was confirmed that she needed the surgery (subject five). Subject 18 listed a forthcoming move across the country to live with her daughter.

All subjects reported usual daily rising times between 0500 and 0830 hours, although subject five occasionally would sleep until 1100 hours. Two subjects routinely set an alarm clock, but both reported that they frequently awoke before the alarm. Usual bedtimes of the subjects were from 2030 to 2400 hours, with three subjects reporting that they sometimes retired past midnight. These patterns suggest a relatively homogenous sample of individuals with an orientation of activity early in the day rather than in the evening.

Instruments

Three instruments were used in this study. Twelve alternate forms of the Activation-Deactivation Adjective Check List (AD-ACL) were used to measure activation. The investigator developed a modified version of Dupuy's (1973) General Well-Being Questionnaire to measure daily well-being. The IVAC 2000 electronic thermometer was used to measure body temperature.

The Activation-Deactivation Adjective Check List

Thayer's (1967) AD-ACL consists of four factors: general activation, high activation, general deactivation, and deactivation-sleep. Thayer originally noted that "these factors roughly approximate four points on a hypothetical activation continuum" (1967, p. 668). Later (Thayer, 1970; 1971; 1978), he suggested that activation may be multi-dimensional and proposed a two-dimensional model of activation. In this model, Dimension A is represented by subjective states of energy-vigor (general activation versus deactivation-sleep), whereas Dimension B is represented by tension (high activation versus general deactivation). Negative correlations between general activation and deactivation-sleep (-.58 and -.49) and between high activation and general deactivation (-.50 amd -.41) were reported (Thayer, 1978). Factor analytic studies revealed two general dimensions, with Dimension A showing stronger circadian variation than Dimension B. Thayer (1971) indicates that general deactivation is a relatively unstable dimension and suggests caution in interpreting this factor score. For this study, only Dimension A--the factors of general activation and deactivation-sleep--was analyzed.

Thayer (1967) initially established the validity of the AD-ACL by supporting his hypothesis that the AD-ACL "would correlate more highly with physiological composites than individual peripheral measures correlate among themselves" (p. 668). He reported statistically significant correlations of .58, -.56, -.68, and .60 ($p<.01$) between the physiological composites (of heart rate and skin conductance) and the factors of general activation, general deactivation, deactivation-sleep, and high activation, respectively, on samples of male college students. Only two of the correlations between the AD-ACL factors and the isolated physiological measures were significant: a correlation of .49 ($p<.05$) between heart rate and general activation, and -.43 ($p<.05$) between heart rate and general deactivation. The fact that the AD-ACL correlates better with physiological composites than with isolated physiological measures supports its validity as a measure of general bodily energy state.

An additional validation study reported by Thayer (1967) included an anxiety-producing stimulus and resulted in significant correlations of −.68 ($p<.01$) and .49 ($p<.05$) between the physiological composites and the factors of deactivation-sleep and general activation, respectively. The AD-ACL is responsive to situations that influence one's general bodily energy state, a finding that was supported by two other similar studies using female college students.

Further evidence of the validity of the AD-ACL was obtained in a study in which Thayer (1967) correctly predicted that the AD-ACL would demonstrate the diurnal variation of activation, such that activation would increase from the time of the subjects' awakening in the morning to a peak four to 8 hours later, and then decrease to a low point at bedtime. Fifty male and female college students participated in this study. In another study of 67 male and female college students, he successfully predicted that the subjects' level of activation would be higher during the waking hours of a typical day than just prior to bedtime. The factor of high activation showed the least circadian variation, a finding that has been demonstrated in other studies (Hoskins & Halberg, 1983).

The reliability of the AD-ACL was established using 145 college students divided into four groups. The original AD-ACL was administered to two groups, while students in the other two groups took a shortened version. All groups subsequently completed another form of the AD-ACL, thus permitting the calculation of test-retest reliability coefficients for 8 of the activation adjectives. The correlations ranged from .87 to .57, with a median coefficient of .75.

The 12 alternate forms of the AD-ACL developed by Hoskins (1978) (see Appendix F for sample form) were used in the present study. Hoskins initially constructed 16 different forms, each with 8 adjectives from Thayer's AD-ACL, and conducted a pilot study of a sample of married couples and working adults "to test the factor-adjective reliability, the reliability of each factor, the sensitivity to time of day, and the bipolarity of the factors" (1978, p. 76). Correlations of adjectives with their factors ranged between .72 and .97 for general activation, .77 to .97 for deactivation-sleep, .76 to .91 for high activation, and .61 to .95 for general deactivation. The reliabilities for each factor were .96, .92, .93, and .95, respectively. The factors were not found to be bipolar.

Based upon the data from this pilot study, Hoskins constructed 12 alternate forms of the AD-ACL for use in a repeated measures design. The factor of general deactivation was omitted on the basis of Thayer's cautions for use and interpretation of this factor. Each form consists of 9 adjectives, three from each of the remaining three factors of general activation, deactivation-sleep, and high activation. Some items were reverse scored to reduce response set. The subject is instructed to determine the extent to which the adjective in each dimension describes how he/she is feeling at the moment. A four-point rating scale is used, consisting of definitely feel (4), feel slightly (3), cannot decide (2), and definitely do not feel (1). A significant time of day sensitivity on the factors of general activation and deactivation-sleep has been demonstrated using this form of the checklist (Hoskins, 1979, 1986).

Modified General Well-Being Questionnaire

The General Well-Being Questionnaire was developed by Dupuy (1973) for the psychological section of the Health and Nutrition Examination Survey conducted by the National Center for Health Statistics between 1971 and 1975. Dupuy reported on the General Well-Being Questionnaire as administered to the first 876 subjects who participated in the national survey. The General Well-Being Questionnaire was designed to assess both subjective well-being and distress during the past month or year.

The General Well-Being Questionnaire consists of a total of 18 items that are divided among 8 subscales: health worry or concern (two items); energy level (three items); positive expressions of general well-being (two items); emotional stability and control (three items); depressed vs. cheerful mood (four items); and tension, stress, anxiety, and nervousness (four items). Dupuy pointed out that somatic complaints were not included in the General Well-Being Questionnaire because these were assessed in other portions of the national survey. Physical health status was included only indirectly, particularly through the subscale of health worry and concern.

Response options to the questions vary in semantics and content. The first 14 items include 6 with response options that are expressed in terms of frequency and 8 with options that use more qualitative terms. These items all have scoring ranges of one to 6. Six of the first 14 questions were stated in the positive, 8 in the negative form. The last four items on the scale use rating scales with scores between zero and 10. The higher the score, the greater the well-being, with total scores ranging from 14 to 110.

While Dupuy (1973) cautioned that the data from the sample were not necessarily representative of any specific population, the subjects included 415 males and 461 females with a mean age of 49.8 years (range of 25 to 74 years). Males reported higher levels of well-being than females, although there were no apparent trends in well-being scores by age within sex.

Dupuy reported an internal consistency reliability coefficient of .92 for the entire scale with correlations among subscales ranging from .29 to .76. Validity of the tool was suggested by an examination of the General Well-Being Questionnaire scores in relation to several criterion items that were included at the end of the questionnaire to indicate disorders of psychological functioning during the previous one or more years. Scores between 70 to 110 were regarded as indicative of positive well-being, whereas scores of 14 to 69 were regarded as negative well-being, or a state of distress.

Ninety-four of the examinees with well-being scores between 70 and 110 reported a psychological problem or disorder in the past year, compared with 573 subjects in the same range of General Well-Being Questionnaire scores who did not. On the other hand, 140 of the subjects who scored between 14 and 69 on the General Well-Being Questionnaire reported a problem, while only 69 subjects in the same range of scores did not report a problem. It was concluded that the General Well-Being Questionnaire was able to differentiate between people with and without self-reported psychological problems. Dupuy reported that the correlation of .67 betwewen the General Well-Being Questionnaire and the sequential ordering of subjects according to number of psychological problems was indicative of concurrent validity of the questionnaire.

Fazio (1977) demonstrated concurrent validity of the General Well-Being Questionnaire in a study of 195 college students. A personal interview was conducted with each subject at the end of the testing period. The interviewer rated the degree of depression evident in the subject during the interview. In addition, one group of the subjects completed the Zung Self-Rating Depression Scale and the College Health Questionnaire while a second group completed the Personal Feelings Inventory. All subjects completed the General Well-Being Questionnaire and the Minnesota Multiphasic Personality Inventory.

The General Well-Being Questionnaire and its depressed mood subscale correlated better with interviewer ratings of depression (.44 and .47, respectively; $p<.001$) than any of the other measures' subscales except for the Personal Feelings Inventory subscale of depression (.50; $p<.001$). Correlations between the General Well-Being Questionnaire and the depression subscales of the other health and psychological measures were .53 to .80; for the anxiety subscales of these measures, the correlations with the General Well-being Questionnaire were .52 to .76. Thus, Fazio demonstrated concurrent validity for the General Well-Being Questionnaire, although this validity was for the distress or negative aspect of the well-being construct.

Fazio also found that the General Well-Being Questionnaire subscales had intercorrelations that ranged between .16 and .72 ($p<.01$). The health worry and concern subscale had the lowest correlations with the other subscales; however, it was noted that the two health worry and concern subscale items had a correlation of .49 ($p<.01$), which was higher than either item correlated with any other subscale. These findings indicate that the General Well-Being Questionnaire may consist of two factors or dimensions: one related to psychological well-being, the other related to general health or physical well-being. However, Fazio also reported that a cluster analysis of the subscales suggested that "all of the separate subscales were at least partially independent of each other" (1977, p.11). Because the health worry and concern subscale only has two items, its reliability and interpretation as a separate dimension is questionable.

Fazio established test-retest reliability for the General Well-Being Questionnaire by readministering it to 41 of the original subjects approximately three months after the first testing. The correlation coefficient was .85. He reported internal consistency correlations of .91 for males and .94 for females and concluded that the questionnaire has a respectable level of test-retest reliability.

While the General Well-Being Questionnaire has reliably measured subjective estimates of general well-being or distress, it was deemed necessary to modify it for the present study for several reasons. First, it approaches well-being as a relatively enduring state, rather than as a condition that may be influenced by daily or weekly changes in the individual.

Second, the number of items on the subscales needed to be increased. Indeed, Fazio (1977) noted that "the major weakness of the General Well-Being Questionnaire seems to be that the subscales have too few items to provide...reliable subscales for individual assessment of well-being or distress" (p.12). This is of particular concern in relation to the health worry and concern subscale since it may represent one of two dimensions of the General Well-Being Questionnaire (perceived health and psychological well-being).

Further suggestion of a possible two-factor structure to the questionnaire is provided by O'Rourke (1983) in a study of the relationship between the General Well-Being Questionnaire and both perceived health and self-reports of menstrual and nonmenstrual symptoms in 633 employed women between the ages of 21 and 44 years. Perceived health status accounted for most of the variance in the General Well-Being Questionnaire (semipartial correlation coefficient =.1161; $F=64.61$; $df=1,462$; $p<.001$). The number, severity and type (but not source--menstrual or nonmenstrual) of physical symptoms also contributed significantly to the variance in well-being.

Third, the General Well-Being Questionnaire violates several psychometric principles (Nunnally, 1978; Waltz, Strickland, & Lenz, 1984). Many of the first 14 items on the General Well-Being Questionnaire include several concepts in one item. For example, one question consists of three concepts: "Have you been anxious, worried, or upset?" In addition, the response options vary in wording from item to item and equidistance between responses is questionable. Furthermore, the subject is required to choose from among 6 responses, a task that could be difficult and of questionable accuracy and consistency for older adults.

The General Well-Being Questionnaire was initially modified in several ways. All items and the general instructions were reworded to refer to the current day. The number of items was increased to 45 by separating the multiple concepts into single items, changing the bipolar rated items into questions, and adding additional items, particularly to the health subscale. The response options were changed to a consistent four-choice format: very much so; some; a little; very little, if at all.

The modified General Well-Being Questionnaire was assessed for content and face validity by 6 professional nurses who were knowledgeable in gerontological nursing and research, and one lay older adult. As a result of their recommendations, 8 items were added and the responses changed to: very much so, moderately so, some, very little.

The resultant 53-item modified General Well-Being Questionnaire was then tested in a pilot study. Volunteer subjects who were 60 years of age or older were recruited. Individuals who were interested in participating in the study received an addressed, stamped envelope with a cover letter (Appendix G), a Personal Data Sheet (Appendix H), and the modified General Well-Being Questionnaire (Appendix I). The cover letter described the study, assured confidentiality of their participation, and instructed them to complete the forms about two hours before bedtime.

One hundred (100) questionnaires were distributed and 68 subjects returned completed forms. Of these, subjects who completed the form in the beginning of their day were elminated from the pilot study. Such subjects would have based their responses on a limited portion of the day, which may be different from how they would rate their well-being at the end of the day. In addition, the reliability computer program eliminated those cases with missing responses to items on the modified General Well-Being Questionnaire, leaving 54 cases on which the following analyses were done.

Of these 54 subjects, 45 (81.8%) were women, 10 (18.2%) were men. They ranged in age from 60 to 81 years with a mean of 70 years. Almost equal numbers of subjects were single (16 or 29.1%), married (17 or 30.9%) or widowed (17), while four (7.3%) were divorced and one was separated. The majority (33 or 60%) were living alone. Asked to rate their "current health status," the majority (33 or 60%) rated it as good, compared with 13 (23.6%) rating it as excellent, 7 (12.7%) as fair, and two (3.6%) as poor.

The possible range in the total score for the modified General Well-Being Questionnaire was 53 to 212, with a high score indicative of a high level of perceived well-being. The total scores for the sample ranged from 111 to 212, with a mean of 190.109 and a standard deviation of 22.5. Age had a significant, low inverse correlation with the total score ($r= -.22$, $p=.05$). Subjects differed in their well-being scores according to their reported health status (ANOVA: $F=15.193$, $p=.001$). Income, sex, marital status, and living arrangements were not significantly related to the total well-being score.

The internal consistency of the modified General Well-Being Questionnaire was demonstrated by an alpha coefficient of .96. The corrected item-total correlations were used in deciding which items to eliminate from the questionnaire. The corrected item-total correlations are between an item and the total score minus that item. All low correlations (<.45) were eliminated. In addition, the individual item response frequencies were used to eliminate items that showed the least discriminatory potential, indicated by 80% or more of the subjects choosing one response to an item and the item having a low variance.

The final version of the modified General Well-Being Questionnaire that was used in this study (Appendix J) contains 34 items representing all of the subscales in the original General Well-Being Questionnaire: 6 in health worry or concern, five in energy level, five in satisfying or interesting life, 7 in cheerful or depressed mood, 6 in relaxed versus tense-anxious, and five in emotional-behavioral control. The range in total score for the pilot sample was 66 to 136 (possible range of 34 to 136), with a mean of 121 (SD=15.88). The alpha coefficient remained at .96, and the corrected item-total correlations ranged from .47 to .80. Since almost 20% of the subjects indicated on their forms that a response option of "no" was needed to provide a true indication of their feelings, the last response option was restored to "very little, if at all." It should be noted that approximately half of the items are reverse scored to reduce reponse set.

The alpha coefficient for internal consistency for the full sample of 18 subjects in the present study for all days of observation was .98 with corrected item-total correlations ranging from .62 to .86. The subjects' total scores ranged from 68 to 136, with a mean of 120 (SD=20.91).

Electronic Oral Thermometer

Body temperature was measured every two hours during the waking hours using the IVAC 2000 electronic oral thermometer. The electronic thermometer was selected for the present study on the basis of several factors: 1) accuracy within +/- 0.2 degree Farenheit (a measurement error that meets the acceptable standard set by the United States Bureau of Standards [Purinton & Bishop, 1969]); 2) 20 to 30 second speed of measurement; 3) accuracy without lip closure; and 4) good acceptance by subject (Ferguson, Gohrke, & Mansfield, 1971; Baker, Cerone, Gaze, & Knapp, 1984). In addition, the IVAC 2000 model is compact and portable and its digital display of the temperature is relatively easy to read. A red light is displayed and an audible signal played when the measurement is completed.

The procedure used in this study for subjects' self-measurement of their oral temperature (Appendix K) was adopted from Hoskins (1978) and Mansour (1983). Subjects were instructed to wait 15 minutes after drinking hot or cold liquids before taking the temperature. To ensure reliability, subjects took two temperature measurements at each testing time, recording them immediately. If the two measurements differed by a minimum of 0.5 Fahrenheit degrees, a third reading was required. The frequency of third readings for each subject ranged from 0 to 15 (Mean= 6.5; SD=4.5), in an average of 80 temperature testing times per subject. The total number of third temperature readings for all subjects was 73, out of a total of 1055 temperature testing times.

Procedures for Data Collection

The investigator met with each subject prior to the data collection period to 1) obtain informed consent for participation (Appendix B), 2) review the procedures for the data collection, and 3) observe a return demonstration of the procedures. Thereafter, the investigator contacted the subject periodically to ensure that the data collection was proceeding accurately and to answer any questions that the subject may have. The instructions were given verbally, and then written instructions were reviewed and left with the subject (Appendix C). The forms for each measurement time and day were coded and placed in envelopes for each day. Subjects were also requested to complete and return a Personal Data Inventory (Appendix D).

Subjects were to maintain their usual routines during the testing time. They were asked to take their oral temperature and complete one of the 12 randomly sequenced AD-ACL forms every two hours during the waking hours, beginning within 10 minutes of rising and ending at bedtime. They were advised that they could take their temperature during the night if they awoke and felt like doing so, but not if it would disrupt their sleep further. Subjects completed the modified General Well-Being Questionnaire about two hours before going to bed. They were provided with an alarm clock to cue them to the two-hour testing intervals, although some reported that they were able to rely on their own sense of timing. A recording sheet was provided for temperature readings (Appendix E), times of arising and retiring, and notations regarding anything that may have affected their readings.

This procedure for data collection was established and evaluated in a pilot test of two subjects. A minimum of 6 measures per day (every two hours during the waking hours) of body temperature and activation were collected for 6 days. Well-being was assessed once at the end of each day. Subjects were to follow this procedure for Tuesday, Wednesday, and Thursday of two consecutive weeks to avoid any weekend effects that might influence subjects' rhythms, since social cues are strong Zeitgebers in humans.

After completion of the data collection, Dr. Franz Halberg (personal communication, June 21, 1986), Director of the Chronobiology Laboratories of the University of Minnesota, was consulted. It was determined that the days of data collection should be changed to 7 consecutive days, Monday through Sunday, to provide an uninterrupted data series that would permit identification of a 7-day periodicity if present (Liu et al., 1986).

In addition, the first subject had difficulties following the procedures accurately the first day. This day was used as a trial day for her and she added another day of data collection to provide 6 days of data. Subsequent subjects had a trial day of data collection on a day of the week prior to the actual testing period.

The above procedures provided data from 6 to 10 measurement times per day. A minimum of 6 measurements per day is optimal for cosinor analysis (Halberg, F., Halberg, Halberg, & Halberg, 1973). Days with fewer than 6 measurements were not analyzed; this occurred only once with subject five (day five).

CHAPTER IV

ANALYSIS OF DATA

A major strength of time series studies is that they permit intensive sampling of variables that have a time-dependent pattern with a small number of subjects. A more complete description of the variables under study is provided than would a single or limited number of samplings of large numbers of subjects; however, repeated measurement of the same subjects precludes the assumption of independence of observations, upon which most inferential statistics are based. For this reason, hypothesis testing, in the strict sense of the phrase, was not done in the present study. Rather, with one exception that will be explained later, correlations were reported for each subject and interpreted in terms of the strength of the relationships in each and all subjects, but without significance testing.

Values for the three variables measured in this study were computed in the following ways. First, the average of the two body temperature readings at each time of measurement were calculated for each subject. Where three readings were taken because of a difference greater than Ø.5 degrees Fahrenheit between the first two, the two readings that had a difference of less than Ø.5 degrees Fahrenheit were used for the average. Second, scores for each of the factors of general activation and deactivation-sleep on the AD-ACL were calculated by summing the scores for the items on each factor at each measurement time. Hypotheses that involve activation were examined in terms of each of the factors treated separately. The high activation factor was not used since both the literature and the data on the subjects in this study suggest that it does not have a stable circadian pattern (Hoskins & Halberg, 1983). Third, a daily well-being score was computed by summing the item reponses on the modified General Wellbeing Questionnaire.

Determination of the parameters of the rhythms of body temperature and activation were done in two ways. First, the raw data from these two variables were graphed and examined for sinusoidality. Second, the raw data were subjected to cosinor analysis for determination of the amplitude, acrophase, and mesor of a 24-hour period for each variable on each day.

Cosinor analysis involves the fitting of a cosine function to a time series by the method of least squares. It assumes the following model:

$$y_i = Y(t_i) + e_i = M + C(\cos(wt_i + A)) + e_i; \; i=1,2,...N$$

where y_i are measurements of the rhythmic variable at times t_i, totaling N in number; M is the mesor; C, the amplitude; w, the angular frequency (in this case, 360 degrees/24 hours = 15t); and A, the acrophase. The e_i are assumed to be the independent random errors with zero mean and unknown amplitude (Halberg, F., Johnson, et al., 1972). Cosinor analysis thus finds the numeric estimates of M, C, and A which, for a given period, will minimize the sum of squared deviations between the data of the time series and the cosine curve. This method does not require equally spaced data over each rhythm cycle, a particular advantage when sampling is not done during the night, or when a measurement time may be missed. It does, however, require that the period be known or assummed _a priori_ (Monk, 1982), which in this case was 24 hours.

Cosinor analysis employs what is referred to as the "zero amplitude test", in which a null hypothesis of no amplitude inherent in the data, or no circadian rhythmicity, is rejected; i.e., Ho: C = 0. Rejection of this hypothesis indicates that the data are better represented by a cosine curve than a straight line. This is determined by the following variance ratio test:

$$F = \frac{\text{Variance due to regression}}{\text{Residual variance}} = \frac{\sum [\, y_i - \bar{y} \,]^2 / 2}{\sum [\, y_i - Y_i \,]^2 / (N-3)}$$

where Y is the observed value and y the predicted value at time t_i, and $\bar{y}$ is the mean, with (2, N-3) degrees of freedom (Halberg, F., Johnson et al., 1972; Bingham, et al., 1982).

It should be noted that this hypothesis testing was done in relation to each subject, rather than inferring to a population as is done in usual inferential statistics. In the present case, the statistical inference is made to the individual from a representative, albeit nonrandom, sample of the universe of possible measurements for that individual. An alpha level of $p<.05$ was used to reject the null hypothesis; however, the "percent rhythm accounted for", which is equivalent to the percent variance accounted for, was interpreted to determine whether the fit of the cosine curve to the data is a meaningful one (Monk, 1982).

Using a cosinor analysis program that was adapted to a microcomputer (Vokac, 1983), the temperature data and the activation data were examined via the single cosinor model for each subject and for each day. In other words, the 6 to 8 data points for oral temperature for subject one on day one were analyzed; followed by day two through day 6. This analysis was repeated for all subjects for body temperature and the two factors of activation. This single cosinor program provides the percent rhythm accounted for by the best-fitting curve, the statistical significance of the zero amplitude test, the amplitude and acrophase and their standard errors. (The daily cosinor data for temperature, general activation, and deactivation-sleep for each subject are in Appendices L, M, and N, respectively.) Since these daily parameters are based upon only 6 to 10 data points, the percent rhythm accounted for is a more useful statistic than the level of significance.

The daily cosinor data for each variable for each subject were used to determine the mean cosinor parameters for each subject. Both the percent rhythm accounted for and the p-value are useful at this level of analysis.

Hypothesis 1: Body temperature and activation in the independent older adult will manifest circadian periodicities.

Tables 1, 2, and 3 provide the mean cosinor parameters for each subject for the rhythms of temperature, general activation and deactivation-sleep, respectively. The hypothesis was supported in 15 of the 18 subjects on the variable of temperature; 11 subjects on general activation; and 9 subjects on deactivation-sleep. Of those that reached statistical significance (zero amplitude test, $p<.05$), the percent rhythm ranged from 33.6% to 78.5% for temperature (26.1% to 78.5% for all subjects, regardless of statistical significance); 44.6% to 80.4% for general activation (21.7% to 80.4%, all subjects); and 38.9% to 66.3% for deactivation-sleep (14.9% to 69.4%, all subjects).

Graphs of the data demonstrated the sinusoidality of the rhythms for subjects with statistically

Table 1

Mean Cosinor Parameters for Body Temperature for All Subjects

Subject	Percent Rhythm	p-Value	Amplitude	Mesor	Acrophase degrees/hours	
1	78.5	.001	.86	97.3	-242.2	1609
2	26.1	.441	.22	97.3	-203.2	1333
3	64.7	.005	.82	98.3	-243.3	1613
4	52.0	.01	.45	97.6	-215.9	1424
5 [a]	46.3	.123	.38	97.6	-334.1	2216
6	50.8	.001	.4	98.1	-278.8	1835
7	66.3	.001	.94	97.5	-263.3	1733
8	60.8	.001	.74	97.7	-227.3	1509
9	40.7	.001	.37	96.8	-278.9	1836
10	63.0	.002	.99	97.6	-246.2	1625
11	43.5	.005	.69	97.5	-212.4	1410
12	61.3	.001	.7	97.6	-248	1632
13	33.6	.025	.33	97.7	-233.1	1532
14	42.9	.013	.49	97.9	-238	1552
15	57.9	.028	.92	96.6	-247.7	1631
16	53.2	.004	.36	98.1	-229.7	1519
17	37.7	.004	.38	96.9	-232.2	1529
18	31.7	.34	.23	98.1	-210.1	1400

[a] Mean parameters based upon 6 of 7 days since the fifth day had only 5 data points.

Table 2

Mean Cosinor Parameters for General Activation for All Subjects

Subject	Percent Rhythm	p-Value	Amplitude	Mesor	Acrophase degrees/hours	
1	47.7	.043	2.05	8.0	-217.4	1430
2	57.3	.004	3.09	6.0	-210.9	1404
3	41.3	.146	2.03	5.3	-194.5	1258
4	49.5	.007	2.31	8.7	-225.7	1503
5[a]	39.0	.061	.85	3.0	-226.8	1507
6	21.7	.607	.41	6.7	-84.6	0538
7	50.9	.024	2.72	4.9	-226.1	1504
8	55.1	.008	4.05	7.2	-208.1	1353
9	74.0	.001	3.36	6.3	-198.9	1316
10	51.5	.005	3.81	6.5	-204.9	1340
11	44.6	.007	2.20	8.3	-168.2	1113
12	40.3	.085	.69	10.6	-228.8	1515
13	49.9	.081	1.86	5.5	-196.7	1307
14	51.5	.192	1.04	10.3	-212.1	1408
15	40.5	.177	1.48	7.1	-208.4	1354
16	80.4	.01	2.4	9.6	-172.1	1128
17	71.4	.009	3.43	7.1	-193.5	1254
18	72.0	.001	1.27	10.5	-124.5	0818

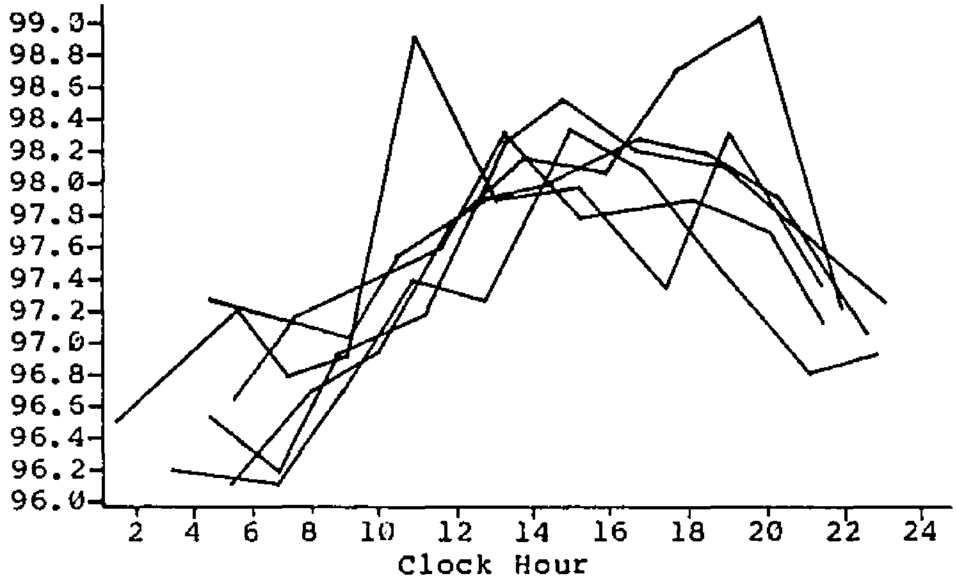
[a] Mean parameters based upon 6 of 7 days since the fifth day had only 5 data points.

Table 3

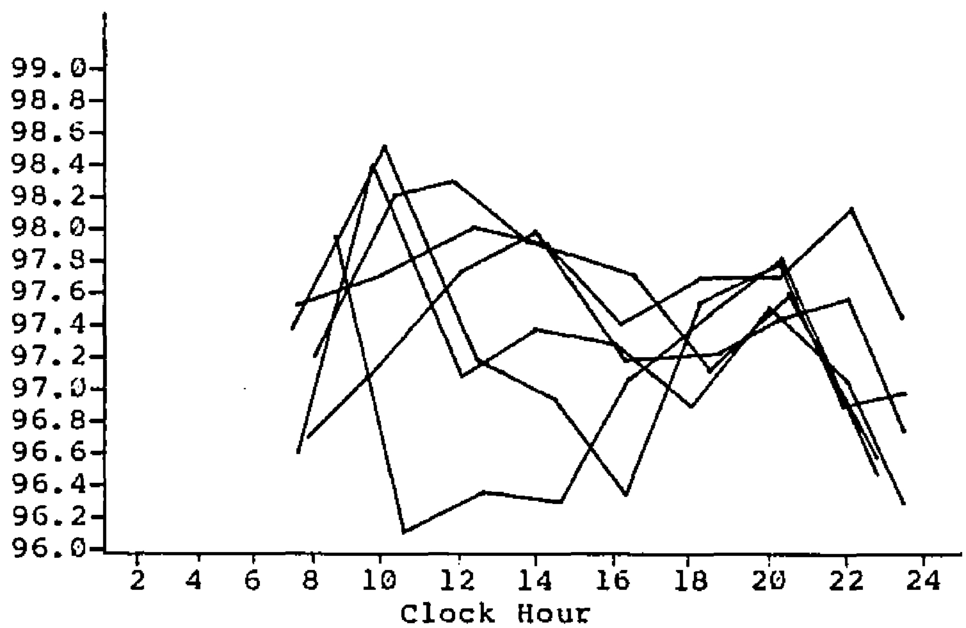
Mean Cosinor Parameters for Deactivation-Sleep for All Subjects

Subject	Percent Rhythm	p-Value	Amplitude	Mesor	Acrophase degrees/hours	
1	54.4	.105	1.58	4.3	-48.7	0315
2	58.3	.003	3.08	6.1	-40.1	0240
3	52.3	.119	1.82	6.8	-36.3	0225
4	48.8	.004	2.04	6.3	-29.0	0156
5[a]	39.4	.059	1.74	10.1	-53.4	0334
6	14.9	.222	.55	5.4	-98.2	0633
7	45.4	.047	2.3	7.2	-57.0	0348
8	60.9	.001	4.66	7.7	-33.9	0216
9	50.3	.39	1.52	6.1	-16.5	0106
10	36.5	.108	1.64	5.5	-34.4	0218
11	38.9	.01	2.56	6.6	-341.0	2244
12	52.6	.001	.44	3.3	-59.4	0357
13	51.8	.001	2.69	5.7	-16.7	0107
14	46.8	.229	1.02	4.2	-5.5	0022
15	69.4	.098	1.45	4.9	-346.9	2308
16	60.3	.004	1.76	4.9	-341.2	2245
17	66.3	.016	2.83	5.3	-4.8	0019
18	58.4	.808	.37	5.0	-6.7	0027

[a] Mean parameters based upon 6 of 7 days since the fifth day had only 5 data points.



a) Significant Rhythm (Subject One)



b) Non-Significant Rhythm (Subject Two)

Figure 1. Graph of raw temperature data on two subjects: a) one with a statistically significant mean cosinor temperature rhythm; b) one with a mean cosinor temperature rhythm that was not statistically significant.

significant mean cosinor rhythms in temperature; whereas, the rhythms were not as smooth for the three subjects whose mean cosinor percent rhythms did not reach statistical significance. Figure 1 demonstrates this discrepancy. Even with two outliers (one reading taken shortly after the subject came out of a sauna, the other immediately upon returning from a walk in the heat), the graph of the data from a subject whose rhythm was statistically significant illustrates a portion of a sinusoid. The graph of the other subject, whose rhythm was not statistically significant, is slightly bimodal.

Based upon these findings, hypothesis one is supported, particularly for body temperature, and to a lesser extent for general activation and deactivation-sleep.

Hypothesis 2: The amplitude in body temperature rhythm will be positively related to the well-being of the independent older adult.

Correlations between the amplitude of the temperature rhythm and the total well-being scores ranged from -.93 to +.92 with a mean of -.012 (SD=.473) for all subjects. Ten of the subjects had positive correlations, although four of these were .14 or less. When correlations for only those subjects who demonstrated statistically significant mean cosinor temperature rhythms were used, the mean correlation was .041

(SD=.5). Appendix O lists the individual subjects' correlations, as well as the average. Based upon these findings, the hypothesis was not supported.

Hypothesis 3: The amplitude in activation rhythm will be positively related to the well-being of the independent older adult.

For all subjects, the correlations between the amplitude of the general activation rhythm and total well-being scores ranged from -.58 to .75, with a mean of .087 (SD=.371). Ten subjects had positive correlations, with three of these being .20 or less. For only those subjects who had statistically significant mean cosinor rhythms in general activation, the mean of the correlations was .017 (SD=.357).

The results were similar for the correlations between the amplitudes of deactivation-sleep and total well-being: for all subjects, a range of -.78 to .68, a mean of -.076 (SD=.45); 8 subjects had positive correlations, four of which were .21 or less; and for only subjects with statistically significant mean cosinor rhythms in deactivation-sleep, the mean of their correlations was .08 (SD=.402).

Based upon these findings, the hypothesis was not supported. Appendix O lists the correlations for all subjects for both rhythmic variables.

Hypothesis 4: Desynchrony in the temperature rhythm will be negatively related to the well-being of the independent older adult.

Daily desynchrony scores in body temperature for each subject were computed by subtracting the acrophase value for the day (determined by the single cosinor method) from the mean acrophase (mean cosinor method) for the individual, and using the absolute value of this difference score.

Acrophases can be expressed and determined in different ways. For the present analysis, they are expressed in degrees, with the 24-hour period being comparable to a 360 degree arc; therefore, one hour equals 15 degrees. Although the reference time for the starting point of this arc can be either midsleep or midnight (Halberg, F., & Simpson, 1967), only the midnight reference time was used in this study. The midsleep reference time is used to eliminate spurious differences between subjects that are due to time zone differences and to control for different rising and bedtime patterns, neither of which was judged to be a factor in the relatively homogenous sample in this study. In addition, Halberg and Simpson note that mid-sleep "is not advocated as the sole or even as the primary phase reference for circadian rhythms" (1967, p. 411), particularly when sleep is disturbed, as it may be with older adult subjects and was with several of this study's subjects.

The correlations for all subjects ranged from -.65 to .63, with a mean correlation of .023 (SD=.37). Eight of the subjects had negative correlations, with three of these (-.003, -.07, and -.21) being low correlations. For subjects with statistically significant mean cosinor rhythms, the mean of the correlations was .009 (SD=.376). Therefore, hypothesis four was not supported. The correlations for individual subjects are listed in Appendix P.

Hypothesis 5: Desynchrony in the activation rhythm will be negatively related to the well-being of the independent older adult.

The procedure used to examine hypothesis four was used to examine hypothesis five, using data on the two factors of activation instead of body temperature. When the acrophases fell close to the end or beginning of midnight (-360 degrees or 2400 hours), as occurred with some of the deactivation-sleep acrophases, the method of computing the desynchrony score proved to be misleading since it needlessly distinguishes between the end of one day and the beginning of another. For example, a mean acrophase of -15 degrees (0100) and a daily reading of -345 degrees (2300) would have resulted in a desynchrony score of 330, rather than the actual difference between the two readings of 30 (2 hours). In these cases, the actual span of time between the mean and daily acrophases was computed, then converted to degrees.

For all subjects on the factor of general activation, the correlations ranged from -.89 to .53, with a mean correlation of .041 (SD=.4). Seven subjects had negative correlations, with three of these (-.17, -.02, -.17) being low. For subjects with statistically significant mean cosinor rhythms, the mean of the correlations was .171 (SD=.312).

For all subjects on deactivation-sleep, the range was -.65 to .59, with a mean of .07 (SD=.377). Eight subjects had negative correlations, with four of these ranging from -.003 to -.26. For subjects with statistically significant mean cosinor rhythms in deactivation-sleep, the mean of the correlations was -.1 (SD=.393). Therefore, the hypothesis was not supported. Appendix P lists each subject's correlations.

Additional Analyses

Additional correlations were determined for percent rhythm of each rhythmic variable and total well-being. These were all quite variable in degree and sign, with means close to zero (See Appendix Q).

For subjects with statistically significant mean cosinor rhythms in the respective rhythmic variables, correlations between the percent rhythm of temperature and that of general activation ranged from -.41 to .64, and averaged .177 (SD=.312); between percent rhythm of temperature and that of deactivation-sleep ranged from -.83 to .9, and averaged -.117 (SD=.611); but between percent rhythm of general activation and that of deactivation-sleep ranged from .86 to -.11, with an average correlation of .63 (SD=.371). Appendix R provides the individual subject's correlations.

Human chronobiologic studies that use repeated measures and cosinor analysis usually report on the mean cosinor values of the time-dependent variables for all subjects studied, whether or not the independence or randomness of error is tested for. Table 4 provides the mean values for the rhythms of temperature, general activation, and deactivation-sleep for the whole sample. All three group rhythms were highly significant ($p<.001$) with substantial percent rhythms. The peak or acrophase of general activation preceded that of temperature by three hours.

Table 4

Mean Cosinor Parameters for All Subjects

Variable	Percent Rhythm	Amplitude	Mesor	Acrophase Degrees/Hours	
Temperature	51.2*	.53	97.6	-242.9	1612
General Activation	52.1*	2.0	7.3	-201.3	1325
Deactivation-Sleep	50.3*	1.71	5.9	-24.6	0136

* p<.001

CHAPTER V

DISCUSSION

Relatively little research has been done on the temporal organization of aging humans. What research has been done suggests that humans are similar to other animals in that they become different temporal beings in their later years. Four of the five hypotheses of this study reflected what has been assumed in much of the prior research in this area--that changes in temporal organization are unwanted correlates of aging and are associated with decrements in well-being. These hypotheses were not supported. The first hypothsis was supported, as statistically significant (zero amplitude test, $p<.05$) circadian periods were found in body temperature and, to a lesser extent, in activation. After a discussion of the nature and extent of this rhythmicity, explanations will be offered regarding the lack of support for the remaining hypotheses from theoretical and methodological perspectives.

The extent of circadian rhythmicity in body temperature of the subjects reflects the stable nature of this rhythmic variable. Of the three subjects (aged 65, 71, and 74 years) who did not have statistically significant mean rhythms in temperature, two were among the three subjects who stated that they had experienced disruptive events within the past two months, although the event for one subject was a forthcoming move across country to live with her daughter. The subject spoke of this move in great length with the investigator during the orientation to the testing procedures.

The second subject was subject five, who was noted previously to have become very distraught during the testing period after being told that she would need a total knee replacement. While disruption of the activation rhythm was anticipated, the lack of circadian rhythmicity in body temperature was not. This subject also had the lowest mean total well-being score of all subjects and was the only subject to not reach statistical significance in any of the rhythmic variables.

The third subject who did not have a statistically significant circadian rhythm in body temperature stated that she awoke by her husband's alarm and follwed his sleep-wake routines to a large extent. Hoskins' (1979) work on circadian rhythms in adult marital dyads (30 to 49 years of age) demonstrated that the women in these couples contributed less than half of the percent rhythm found in temperature in the entire group, had acrophases that lagged behind their husbands' by two hours, and had amplitudes that were generally half that of their husbands. While the other married women in the present study did demonstrate statistically significant circadian rhythms in body temperature, further research into older adult dyads is warranted.

The percent rhythm accounted for by the cosine curve for individual subjects' temperature rhythms was variable, but generally substantial (33.6% to 78.5% of statistically significant rhythms). While no comparisons are available from older adult populations, Hoskins (1979) reported a group mean cosinor percent rhythm for body temperature of 24.2% for her sample of married couples; this compares with a group mean cosinor of 51.2% in the present study, a difference that may be accounted for by the different lifestyles of an employed sample versus one largely of retirees spending more time with their own established routines at home.

The extent of circadian rhythmicity in body temperature in the group as a whole corresponds with the finding's of Scheving et al. (1974) in their study of 9 nursing home residents, 8 of whom showed statistically significant rhythms ($p<.01$) in oral temperature. The researchers reported an acrophase based upon all subjects' data that was at 1652 hours (-253 degrees), which is approximately 90 minutes later than the acrophase of the group in the present study. Scheving's subjects were on routines set by the nursing home, which could account for differences in the groups' acrophases.

Hoskins (1979) reported a group mesor of 97.92 Fahrenheit degrees for her younger subjects, while Scheving et al. (1974) reported a mesor of 97.31 Fahrenheit degrees for their 9 nursing home subjects. In the present study, the group mesor was slightly higher (97.6 degrees) than in Scheving's study, with the range for individual temperature mesors being 96.6 to 98.1 Fahrenheit degrees. These findings suggest that one's body temperature decreases with aging. This coincides with the finding from a 10 year longitudinal study of a man who began autorhythmometry at 53 years of age and realized approximately a 0.2 Fahrenheit degree decrease in mean body temperature over the 10 years (Halberg, E., Halberg, J., et al., 1981).

Hoskins et al. (1979) provide the only published results of a study that used both Hoskins' alternate forms of the AD-ACL and cosinor analysis to determine rhythms of activation. These researchers reported statistically significant ($p<.05$) rhythms in general activation in 29 of 32 subjects, compared with 11 of 18 subjects in the present study.

A closer examination of the 7 subjects in the present study who did not demonstrate statistically significant rhythms in general activation reveals some possible explanations for their lack of rhythmicity. One subject took midday naps on four of the 7 testing days; although there was a slight dip in her temperature around times of napping, there was a marked drop in her level of general activation that did not appear on other days. Another subject napped on several days with a similar effect; and she drank two cups of coffee on another, which she usually did not do, producing an uncharacteristically sustained high level of activation through the midday. Two subjects had consistently high levels of general activation; indeed, they had the first and third highest mesors of the sample (10.6 and 10.3). These subjects did not take bedtime readings, however, so that the bedtime drop in general activation that is seen with other subjects was not apparent. Another subject called the investigator after the third testing day reporting that she had been unable to sleep and wanted to take a sleeping medication (Dalmane) that she sometimes used; her scores on general activation reflected this lack of sleep. She also took an antihistamine medication for sinus congestion on some days that could have influenced her circadian variability in activation. These anecdotes underscore the importance of precise testing procedures and the need for subjects to maintain their usual patterns.

Changes in the sleep-wake rhythm are associated with aging (Miles & Dement, 1981). As the napping by one subject reflected, it was anticipated that interrupted sleep at night could be related to the lack of rhythmicity in the rhythmic variables of some subjects.

Subject five, who did not have statistically significant rhythms in any of the rhythmic variables, had disturbed sleep patterns during the testing period. However, the other subject with notable nighttime interruptions in sleep was the first subject, who in addition to having a high level of well-being and statistically significant rhythms in temperature, general activation and deactivation-sleep, also had the highest percent rhythm in temperature of all subjects. Interestingly, she reported that she was not distressed with such sleep interruptions, since she was retired and did not have to awake at any particular time. She frequently would take advantage of the additional wake time by reading or even cleaning her apartment. Further research is warranted to determine whether accepting and following the changes in one's own endogenous rhythms as one ages enhances well-being.

The lack of nighttime measurements in activation may account for the fact that half of the sample did not show significant circadian rhythmicity in deactivation-sleep. One expects the peak in this factor to come during the sleep period. Many of the subjects showed a flattened trough at the lowest possible score for this factor throughout most of the day. Hoskins et al. (1979) indicate that the percent rhythm accounted for by deactivation-sleep varied from 20% to about 90%, compared with 15% to 70% in the present study.

The findings of this study provide further support for the premise that the rhythms of temperature and activation are driven by separate oscillators (Moore-Ede et al., 1982). The group mean cosinor showed an acrophase of general activation that preceded the acrophase of temperature by a little more than three hours. For the individual cosinor parameters, all but two subjects, one of whom did not have a statistically significant circadian rhythm in temperature, had acrophases of general activation that preceded the temperature acrophase.

In addition, the correlation between the percent rhythm accounted for in body temperature and that of general activation (and deactivation-sleep) was insignificant, suggesting that the extent of rhythmicity in one variable is not necessarily related to the extent of rhythmicity in the other. On the other hand, the correlation between the percent rhythm accounted for in general activation and that of deactivation-sleep was .63 for subjects with statistically significant rhythms in these two factors (.47 when all subjects were considered), reflecting the relationship between these two factors.

Several explanations are possible for why there was no relationship between well-being and changes in the amplitudes and acrophases of the rhythmic variables of temperature and activation. First, although this study is considered longitudinal rather than crossectional (Monk, 1982), a 7-day testing period may reflect changes in circadian patterns that are related more to the inability to control extraneous variables in the subjects' lives, than to changes from aging. For example, although subjects were asked to maintain their daily routines, these routines often included day-to-day variations (going to a bridge party once a week) or unexpected events (an upsetting telephone call from a relative). Periodically testing the same subjects over a period of many years is more likely to demonstrate changes in temporal organization that accompany aging.

Second, although the General Well-Being Questionnaire, as modified for this study, demonstrates a high level of internal consistency, one could question its validity and reliability as a measure of a state that is at least as enduring as a day and can be recalled. It is a retrospective measure, asking subjects to reflect back on how they felt during the day, and not just at the moment of completion of the questionnaire. How accurate were these subjects at recalling and estimating or averaging their well-being for the previous 12-hour time period? It may be helpful to compare responses on the tool used in this study with daily averages of scores on the tool modified to ascertain one's well-being at the moment of completion of the tool and administered several times during the day.

Even if one were to undertake a longitudinal study that periodically measured the same subjects over a span of many years, one must question whether the well-being tool would be an appropriate one. Except for subject five, the older adults in this study reported high levels of well-being. No comparisons with other aged samples are available for the modified tool. Although subject five demonstrates that the tool differentiates between distress and positive well-being and that such distress may be associated with disturbances in temporal organization, it may be that non-distressed, healthy older adults adjust their estimates of or expectations for defining high level well-being as they adjust to the changes that accompany aging. In a study of age-related variations in the dimensions underlying "life satisfaction," Cutler (1979) demonstrated that such variations in underlying dimensions exist even among the age groupings of 55 to 64 years, 65 to 74, and 75 to 90, while reported total scores on multidimensional life satisfaction tools may remain constant. Combining subjective and objective tools for assessing health and well-being may enhance the accuracy of measurement.

The complexities of temporal organization in humans require sophisticated and reliable means of measurement and analysis. Cosinor analysis fits the data to a cosine curve. This may not be the most appropriate waveform for analyzing the rhythms of older adults, since one of the temporal characteristics of aging has been suggested to be a change in the waveform of the rhythm (Scheving et al., 1978). Even with cosinor analysis, more sophisticated and versatile programs have been developed (Nelson, et al., 1979; Cornelissen et al., 1980) than the one used in this study (Vokac, 1983). For example, the graphed data and additional analyses to search the data for shorter periods suggested that some of the subjects may have had significant rhythms with shorter periods, such as 6 or 8 hours. Computer programs that search for harmonics in the rhythms need to be more readily available so that more accurate, statistical descriptions of the waveforms may result than can be obtained from macroscopic analysis of graphed data.

In addition, subjects were instructed to begin the two-hour testing times within 15 minutes of awakening. This resulted in daily variations in the testing times and subsequent variations in the acrophases of the rhythms as computed by the cosinor analysis, even if, for example, the subject had the exact same sequence of scores on general activation for the days of differing measurement times. This would lead to artificial variations in the desynchrony of acrophases.

Another complication arises in applying the single cosinor analysis to 6 to 10 data points. This does not often result in statistically significant parameters, so that one must question how much confidence one can have in the daily cosinor parameters that were used in the correlations.

Certainly, the study would benefit from more frequent measurement times for accurate estimates of the parameters of the rhythms. However, the two-hour interval used in this study proved to be fatiguing to some subjects. At the end of the study, most subjects expressed their pleasure at being finished with the intensive data collection, and one commented several times on her daily temperature sheets that she was annoyed with the frequency of the measurements. A few subjects did not mind the autorhythmometry at all and offered to participate in similar studies. Periodic sampling of these latter subjects over a number of years may yield data that are more reflective of the aging process.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Humans are characterized by a temporal organization that facilitates coordination of internal systems, as well as synchronization to the external environment. Studies of aging animals and the comparatively few studies of aging humans suggest that this temporal organization changes with aging. It has been assumed from studies of temporal changes in younger humans that the temporal changes associated with aging are undesirable and are indicants of the deterioration of the individual (Samis & Capobianco, 1978). The purpose of the present study was to examine the relationship between changes in circadian rhythmicity in older adults and their well-being.

Summary

Temporal organization is an internal property of humans, with circadian rhythms being important to functioning in the 24-hour cyclic external environment. Human rhythms have been shown to have both an inherent endogenous component and an exogenous one from Zeitgebers, or synchronizers, in the environment. Aging is thought to be associated with changes in the endogenous component through accumulated mutations or a programmed deterioration in the timing mechanism. It has also been postulated that decrements in the sensory capacity of the aging human to perceive, and thus remain synchronized with the environment, can explain the temporal changes associated with aging.

Body temperature was selected as a rhythmic variable for this study because it is one of the most stable rhythms in humans and has been shown to have a strong endogenous component. It is thought to be driven by an oscillator that is different from, but interdependent with, the oscillator that drives the activity and sleep-wake rhythms. Activation, as the phenomenological awareness of one's general bodily energy state, was proposed to represent these latter rhythms. This is the first study to investigate activation rhythms in older adults using Hoskins' (1979) alternate forms of Thayer's (1967) Activation-Deactivation Adjective Check List (AD-ACL).

Studies of older adults have demonstrated predominantly dampened amplitudes, decreased mesors, changes in acrophases, and shortened free-running periods in comparison with younger adults (Scheving, et al., 1978; Casale & de Nicole, 1984). Such changes are also seen in young and middle-aged adults who are engaged in shiftwork or jet travel, and have been associated with decrements in well-being (Folkard & Monk, 1979; Moore-Ede et al., 1982). Changes in rhythm parameters are also associated with psychological and physical illness (Nikitopoulou & Crammer, 1976; Halberg, F. et al., 1984).

This study examined changes in rhythm parameters in relation to well-being. Well-being was conceptualized as a global contruct that encompasses one's health, energy level, emotional control, mood, stress and life satisfaction. Dupuy's (1973) General Well-Being Questionnaire was modified to improve on its psychometric properties and to give it a daily or state orientation rather than a trait or more enduring focus. A pilot study of the modifed tool resulted in an alpha coefficient of .96. Further modifications were made and the resultant tool was used to measure well-being in the present study.

Five hypotheses were proposed in this study:

1) Body temperature and activation in the independent older woman will manifest circadian periods.

2) The amplitude of the body temperature rhythm will be positively related to the well-being of the independent older woman.

3) The amplitude of the activation rhythm will be positively related to the well-being of the independent older woman.

4) Desynchrony of the temperature rhythm will be negatively related to the well-being of the independent older woman.

5) Desynchrony of the activation rhythm will be negatively related to the well-being of the independent older woman.

A sample of 18 essentially healthy, older women living independently (outside of institutions of any kind) participated in the study. They ranged in age from 65 to 80 years; 10 were married and living with their spouses. None of the subjects worked (employed or volunteer) fulltime. They were homogeneous in their sleep-wake times, although their sleep was often interrupted, as is characteristic of many older adults.

Subjects collected data from Monday through Sunday. Every two hours during the waking hours they took their temperature with an IVAC 2000 electronic thermometer and completed one of the 12 alternate forms of the AD-ACL. About two hours before bedtime, subjects completed the modified General Well-Being Questionnaire.

The factors of general activation and deactivation-sleep from the AD-ACL were used in the analyses. These two factors and the temperature data were analyzed for rhythmic variation by graphing and cosinor analysis. The cosinor analysis was applied first to each day's data (single cosinor) and then to the parameters from all days combined (mean cosinor for the individual). The mean cosinor was used to determine whether temperature and the activation factors had statistically significant (zero amplitude test, $p<.05$)

circadian periods and to describe their circadian parameters of amplitude and acrophase. The single cosinor was used to describe the parameters on a daily basis. Desynchrony of acrophase was computed by subtracting the daily acrophase from the individual's mean acrophase. Pearson Product Moment Correlations were computed between the parameters of the rhythmic variables and total well-being scores.

Conclusions

In this study of 18 essentially healthy, women between 65 and 80 years of age living outside of institutions:

1) There were statistically significant ($p<.05$) circadian periods in temperature (15 of 18 subjects), general activation (11 of 18 subjects), and deactivation-sleep (9 of 18 subjects).

2) There were no relationships between the amplitudes in temperature and activation rhythms and the well-being of the subjects.

3) There were no relationships between the desynchrony of acrophases in temperature and activation rhythms and the well-being of the subjects.

Recommendations

This study generates several questions for further study:

1) Do the parameters of body temperature and activation change as one ages?

2) Do older adults differ from younger adults in terms of the relationship between the acrophases of body temperature and activation?

3) Do older adults manifest ultradian (periods shorter than circadian) rhythms in body temperature and activation?

4) Does the marital dyad influence the extent of circadian rhythmicity in older adults?

5) Is the patterning of one's activity to be in concert with the changes in the endogenous sleep-wake rhythm associated with positive well-being in older adults?

6) Is daily well-being a construct that can accurately be measured in older adults by recall?

7) Is there a relationship between changes in circadian rhythmicity as one ages and objective and subjective measures of health and well-being?

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APPENDIX A

STUDY OF DAILY RHYTHMS AND WELL-BEING IN OLDER ADULTS

There is increasing evidence that changes in daily rhythms occur with aging. Research is needed to determine the nature of this changing rhythmicity and its relationship to the health and well-being of the older adult. If you are 65 years of age or older, you may be eligible to participate in a study of daily rhythms and well-being.

Eligiblity

Besides age, other criteria for participation in the study include: not living in an institution such as a nursing home; free of any acute illnesses; able to carry out the activities of daily living independently; not currently taking any tranquilizers, sleeping pills, or mood-altering medications; not have disabling limitations in hearing or vision; and not holding a full-time volunteer or employed position.

Participation

Participation in the study involves taking your oral temperature with an electronic thermometer supplied by me, the investigator, every two hours while awake; and, at the same times, completing a brief nine-item questionnaire on how you are feeling at the time. If you do not have one, I will provide you with an alarm clock or other device to remind you of testing times. Each evening, you will complete a different questionnaire that asks you questions about how you felt during the day. This procedure must be carried out for seven consecutive days, from Monday through Sunday of one week. At the beginning of the data collection period, you will be asked to complete a personal data sheet and consent form.

I will demonstrate the procedures for you and work with you until you are comfortable doing them yourself. I will also call you during the testing period and otherwise be available to you to discuss any questions or problems you may encounter with the procedures.

Informed Consent and Confidentiality

Be assured that you may withdraw from the project at any time. The consent form points out that your anonymity will be maintained. The data will be coded and analyzed as part of a group. The only document with information that will identify you is the consent form, which will be kept separate from the data.

Results

Because this study requires a commitment of time and attention by subjects, I will be pleased to analyze the data on your daily temperature rhythm separately and share the results with you after the full study has been completed. I will also provide you with a summary of the results of the entire study, if you are interested.

For More Information

If you would like to volunteer to participate in this study, or if you need additional information about it, I can be reached at the telephone number below. If I am not at home, leave your name and telephone number on my answering machine and I will return your call as soon as possible. A request for further information will not constitute a commitment to participation.

Thank you for your interest in this study.

Investigator: Diana J. Mason, R.N.,C., M.S.N.
Ph.D. Candidate
Division of Nursing
New York University

Address: [redacted]

Telephone: [redacted]

APPENDIX B

CONSENT FORM

I hereby consent to be a participant in the research project, "A Study of the Circadian Rhythms of Body Temperature and Activation and the Well-being of Independent Older Adults". I have been informed and understand the purpose and nature of my participation in the study. I understand that all data will remain confidential; furthermore, data will be coded for analysis to maintain my anonymity. I also understand that, should I decide to do so, I am free to withdraw from this project at any time.

Date: Signature:

Address:

Telephone Number:

Investigator: Diana J. Mason, R.N.,C., M.S.N.
Ph.D. Candidate
Division of Nursing
New York University

Address: [redacted]

Telephone: [redacted]

APPENDIX C

GENERAL INSTRUCTIONS

Time of Measurements:

Temperature and checklist measurements are to be taken every 2 hours while you are awake, beginning within the first fifteen minutes of getting out of bed (and before taking anything by mouth). Do this for seven consecutive days, beginning on a Monday morning and ending Sunday night.

At the beginning of each testing time, begin by setting your alarm watch for the next time, which will usually be 2 hours later. However, you should not use the alarm for getting up in the morning; rather, follow your usual awakening method.

If you miss one measurement time, complete the measurement as soon as possible, noting the correct time when the measurements were actually taken. You should aim for obtaining the measurements within a 15 minute period before and after each testing time.

Measurement Procedures:

You are provided with an envelope for each testing day. Each envelope contains 3 different kinds of forms:

1. A TEMPERATURE DATA SHEET, on which you will record your temperature readings every two hours for that day, as well as some additional information, such

as time of going to bed and awakening for the prior night. You will reuse this sheet at each testing time during the day. Please be sure to record the exact time when you take your temperature. Refer to the "Instructions for Taking Temperature" sheet for details on taking your temperature.

2. Ten CHECKLISTS:

a. Use one checklist at each testing time, recording on the form the exact time when you complete the checklist.

b. Please do not read the checklists before the designated times for completion.

c. When filling out the checklist, try to determine how you feel AT THE MOMENT on each item. Do this as accurately as you can, even though the forms may seem repetitive.

d. Do not try to recall how you may have answered an item on a previous occasion. Individuals differ at different times and the present study is interested in those variations.

e. After you complete a checklist, place it in the back of the packet of checklists and return the forms to the envelope for safe-keeping. Note that you may have one or more unused checklists remaining in the day's packet at the end of the day, depending upon the length of your wake period. Leave unused checklists in the envelope.

3. One EVENING QUESTIONNAIRE

a. This questionnaire should be the last page in each envelope.

b. Complete the evening questionnaire approximately 2 hours before going to bed, or at the next to the last testing time.

c. Note that the questionnaire asks you to reflect on how you FELT GENERALLY OVER THE COURSE OF THE DAY, and NOT how you are feeling at the moment.

d. Upon completion of this questionnaire, return it to the envelope. Again, do not try to recall how you answered this questionnaire on previous days.

You will begin a new envelope on each subsequent day.

Please do not hesitate to call the investigator at [redacted] if you have any questions or problems with the measurements or procedures. Accurate and ongoing measurements are essential to this study.

Thank you for your participation.

PERSONAL DATA INVENTORY

1. Age________ 2. Sex: ___Female ___Male

3. Present marital status:

___Single ___Married ___Divorced/Separated ___Widowed

4. Present living arrangement:

___Living alone ___Living with a spouse/partner
___Living with a friend ___Living with other family
___Other (Please specify____________________________)

5. Do you get up at approximately the same time every day?

___Yes ___No

6. Do you use an alarm clock to get up in the morning?

___Yes ___No ___Sometimes (Explain:____________________
____________________________)

7. What time or range of times do you usually awaken?

____

8. Do you go to bed at about the same time every night?

___Yes ___No

9. What time or range of times do you usually go to bed?

____

10. How would you rate the quality of your sleep most nights?

___Excellent ___Good ___Fair ___Poor

11. How would you rate your current health status?

___Excellent ___Good ___Fair ___Poor

12. Do you now have any health problems that are disruptive to your daily living? ___Yes ___No

If yes, please specify:

13. Do you have any other health problems that you believe are <u>not</u> necessarily disruptive to your daily living?
___Yes ___No

If yes, please specify what these health problems are:

14. Have there been any major disruptive events in your life within the past two months? ___Yes ___No

If yes, please specify the event and approximate date:

15. Please list the medications you are currently taking and the times of day you take them:

<u>Medication</u> <u>Times of Day</u>

16. What is your usual intake of alcoholic beverages:

___None ___Every day ___Every weekend ___On social occasions only

17. What is your approximate annual income:

___Under $10,000 ___$10,000-$20,000 ___$20,000-$30,000 ___Over $30,000

TEMPERATURE DATA SHEET

Date______________________

Upon arising, please indicate:

a. Time you went to bed last night:____________________

b. Time you got up this morning:______________________

C. Number and length of awakenings during the night:

____

d. Quality of sleep last night:

___Excellent ___Good ___Fair ___Poor

Time	Temperature Readings: First	Second	Third	Comments*

*Comments: Note time and duration of NAPS, EXERCISE, MEAL-TIMES, SNACKS within the previous half-hour, non-routine MEDICATIONS, uncomfortably cold or hot ENVIRONMENTAL TEMPERATURE, or any other factor that may have affected your measurements.

Date and time: ______________________ Code number: ______________

Each of the words below describes a particular feeling. Please use the rating scale next to each word to describe your feeling at this moment.

EXAMPLES:

relaxed	XX	X	?	no	If you circle the double check(XX) it means that you definitely feel relaxed at the moment.
relaxed	XX	X	?	no	If you circle the single check (X) it means that you feel slightly relaxed at the moment.
relaxed	XX	X	?	no	If you circle the question mark it means that the word does not apply or you cannot decide if you feel relaxed at the moment.
relaxed	XX	X	?	no	If you circle no it means that you are definitely not relaxed at the moment.

Work rapidly, but please mark all the words. Your first reaction is best.

VIGOROUS	XX	X	?	no
FEARFUL	XX	X	?	no
WIDE-AWAKE	XX	X	?	no
ACTIVATED	XX	X	?	no
LIVELY	XX	X	?	no
TIRED	XX	X	?	no
ANXIOUS	XX	X	?	no
CLUTCHED-UP	XX	X	?	no
SLEEPY	XX	X	?	no

To Whom It May Concern:

As the number of older adults in our society increases, there is a growing need to identify factors that promote their health and well-being. Little research has been done on daily variations in the subjective well-being of older adults.

If you are 60 years of age or older, you are invited to participate in a preliminary study of well-being. You are not asked to identify yourself on any of the forms, thus assuring your anonymity. Return of the attached forms will indicate that you consent to participate in this study.

Participation in the study includes the following:

1. Select a time in the middle of your evening, approximately two hours before you go to bed, to complete the forms.
2. Complete the Personal Data Sheet.
3. Complete the Questionnaire.
4. Please pay careful attention to the instructions on the questionnaire, with particular attention to the following:
   a. For each item, determine how you felt over the course of that day only.
   b. Many of the items are similar. Please do not try to recall how you answered a previous item.
   c. Although the items are numerous and may appear repetitious, please answer each item carefully.
5. Place the completed forms in the stamped, addressed envelope provided and mail the envelope <u>as soon as possible</u>.

Your participation in this study is greatly appreciated. If you would like a summary of the results of the study, write your name and address on the back of this letter and return it with the other materials. Thankyou.

Diana J. Mason, RN, MSN
[redacted]

Personal Data Sheet

Please complete each of the following items:

1. What time is it now? ______AM ______PM

2. Your age: __________ 3. Your sex: ___Female ___Male

4. Marital status: ___Single ___Married ___Divorced ___Widowed

5. Present living arrangements:
   ___Living alone ___Living with partner, friend, or family
   ___Other (please specify ______________________________)

6. What is your usual time of awakening? ______AM ______PM

7. What is your usual bedtime? ______AM ______PM

8. What time did you go to bed last night? ______AM ______PM

9. What time did you awaken this morning? ______AM ______PM

10. How would you rate your current health status?
    ___Excellent ___Good ___Fair ___Poor

11. Do you now have any health problems that are disruptive to your daily living? ___Yes ___No If yes, please list:

    ______________________ ______________________

    ______________________ ______________________

12. Please list any additional health problems you have:

    ______________________ ______________________

    ______________________ ______________________

13. Have there been any major disruptive events in your life within the past year? ___Yes ___No If yes, please list:

    ______________________ ______________________

    ______________________ ______________________

14. Please list any events or factors that you believe may have affected your well-being <u>today</u>:

    ______________________ ______________________

    ______________________ ______________________

15. What is your approximate annual income?
    ___Under $10,000 ___$10,000-20,000 ___$20,000-30,000 ___Over $30,000

Go on to questionnaire.

INSTRUCTIONS:

A. COMPLETE THIS FORM IN THE EVENING, APPROXIMATELY TWO HOURS BEFORE GOING TO BED.

B. THE QUESTIONS CONCERN HOW YOU FELT AND HOW THINGS WENT OVER THE COURSE OF THIS DAY. THIS MAY BE DIFFERENT THAN HOW YOU FEEL AT THE MOMENT.

C. PLEASE ANSWER EACH ITEM SEPARATELY. DO NOT REFER BACK TO YOUR ANSWERS ON PREVIOUS ITEMS, EVEN THOUGH MANY OF THE ITEMS MAY APPEAR TO BE REPETITIOUS.

D. PLEASE ANSWER EACH ITEM CAREFULLY, MARKING (X) THE ANSWER THAT BEST DESCRIBES HOW YOU FELT TODAY.

1. IN GENERAL, DID YOU FEEL IN GOOD SPIRITS TODAY?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

2. WERE YOU BOTHERED BY NERVOUSNESS OR YOUR "NERVES" TODAY?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

3. DID YOU FEEL THAT YOU WERE IN CONTROL OF YOUR BEHAVIOR TODAY?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

4. DID YOU WAKE UP FRESH THIS MORNING?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

5. WERE YOU BOTHERED BY ACHES OR PAINS TODAY?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

6. DID YOU FEEL AS THOUGH YOU HAD SO MANY PROBLEMS THAT YOU WONDERED IF ANYTHING WAS WORTHWHILE?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

7. DID YOU FEEL SAD DURING THIS DAY?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

8. WERE YOU UNDER OR DID YOU FEEL YOU WERE UNDER ANY STRAIN OR PRESSURE TODAY?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

9. DID YOU WAKE UP RESTED THIS MORNING?
   ___VERY MUCH SO
   ___MODERATELY SO
   ___SOME
   ___VERY LITTLE

10. WERE YOU PLEASED WITH YOUR PERSONAL LIFE TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

11. WERE YOU BOTHERED BY ANY BODILY DISORDERS TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

12. DID YOU FEEL THAT YOU WERE IN CONTROL OF YOUR EMOTIONS TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

13. DID YOU FEEL STRESSED TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

14. DID YOU FEEL DISCOURAGED TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

15. WERE YOU HAPPY WITH YOUR LIFE TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

16. DID YOU FEEL TIRED TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

17. DID YOU FEEL PHYSICALLY WELL TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

18. DID YOU FEEL THAT YOU WERE IN CONTROL OF YOUR FEELINGS TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

19. WERE YOU ANXIOUS TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

20. DID YOU HAVE A SENSE OF HOPELESSNESS TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

21. DID YOU FEEL INTERESTED IN THE THINGS YOU WERE DOING TODAY?
___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

22. DID YOU FEEL WORN OUT TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

23. DID YOU HAVE ANY FEARS ABOUT YOUR HEALTH TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

24. DURING THIS DAY, DID YOU WONDER IF YOU WERE LOSING CONTROL OVER THE WAY YOU ACT OR TALK?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

25. DID YOU FEEL WORRIED TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

26. DID YOU HAVE A DIFFICULT TIME STAYING AWAKE TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

27. DID PHYSICAL PROBLEMS LIMIT YOUR FUNCTIONING TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

28. WERE YOU DISAPPOINTED WITH YOUR LIFE TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

29. DID YOU FEEL PEPPY TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

30. WERE YOU BOTHERED BY ANY CHANGES IN YOUR BODY'S FUNCTIONING TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

31. DURING THIS DAY, DID YOU WONDER IF YOU WERE LOSING CONTROL OVER THE WAY YOU THINK, OR YOUR MEMORY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

32. DID YOU FEEL CALM TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

33. WERE YOU UPSET TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

34. DID YOU SLEEP WELL LAST NIGHT?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

35. DID YOU FEEL CHEERFUL TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

36. WERE YOU BOTHERED BY HOW THINGS WENT FOR YOU TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

37. WERE CHANGES IN YOUR BOWELS OF CONCERN TO YOU TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

38. DID YOU FEEL EMOTIONALLY STABLE TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

39. DID YOU FEEL LIKE YOU HAD TO PUSH YOURSELF TO DO THINGS TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

40. WERE CHANGES IN YOUR SLEEP OF CONCERN TO YOU TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

41. DID YOU FEEL RELAXED TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

42. WERE YOU BOTHERED BY ANY CHANGES IN YOUR STRENGTH, COORDINATION, OR BALANCE TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

43. DID YOU FEEL OUT OF SORTS TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

44. WERE YOU BOTHERED BY HOW THINGS WENT FOR YOU TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

45. WOULD YOU RATE YOUR HEALTH AS GOOD TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

46. WERE YOU ABLE TO DO THE ACTIVITIES TODAY THAT YOU WANTED TO DO?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

47. DID YOU FEEL DOWN-HEARTED AND BLUE TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

48. DURING THE DAY, DID YOU FEEL HOPEFUL ABOUT TOMORROW AND THE FUTURE?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

49. DID YOU FEEL THAT YOU WERE IN CONTROL OF YOUR THOUGHTS TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

50. WERE YOU SATISFIED WITH HOW YOU INTERACTED WITH PEOPLE TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

51. DID YOU FEEL SURE OF YOURSELF TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

52. WERE YOU ABLE TO USE YOUR TIME EFFICIENTLY TODAY?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

53. DID YOU HAVE GOOD FEELINGS ABOUT TOMORROW?

___VERY MUCH SO
___MODERATELY SO
___SOME
___VERY LITTLE

<u>THANKYOU</u>

PLEASE MAIL THE PERSONAL DATA SHEET AND QUESTIONNAIRE AS SOON AS POSSIBLE.

EVENING QUESTIONNAIRE

Instructions:

a. Complete this form in the evening, approximately 2 hours before going to bed.

b. The questions concern how you felt and how things went OVER THE COURSE OF THIS DAY. This may be different from how you feel at the moment.

c. Please answer each item separately. Do not refer back to your answers on previous items, even though many of the items may appear to be repetitious.

d. Please answer each item carefully, marking (X) the answer that best describes how you felt today.

1. In general, did you feel in good spirits today?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

2. Did you feel that you were in control of your behavior today?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

3. Did you wake up fresh this morning?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

4. Were you bothered by aches or pains today?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

5. Did you feel as though you had so many problems that you wondered if anything was worthwhile?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

6. Did you have good feelings about tomorrow?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

7. Did you feel sad during this day?
   ___Very much so
   ___Moderately so
   ___Some
   ___Very little, if at all

8. Were you under or did you feel you were under any strain or pressure today?

___Very much so
___Moderately so
___Some
___Very little, if at all

9. Were you pleased with your personal life today?

___Very much so
___Moderately so
___Some
___Very little, if at all

10. Did you feel tired today?

___Very much so
___Moderately so
___Some
___Very little, if at all

11. Did you feel physically well today?

___Very much so
___Moderately so
___Some
___Very little, if at all

12. Did you feel stressed today?

___Very much so
___Moderately so
___Some
___Very little, if at all

13. Did you feel discouraged today?

___Very much so
___Moderately so
___Some
___Very little, if at all

14. Did you feel that you were in control of your feelings today?

___Very much so
___Moderately so
___Some
___Very little, if at all

15. Were you happy with your life today?

___Very much so
___Moderately so
___Some
___Very little, if at all

16. Were you anxious today?

___Very much so
___Moderately so
___Some
___Very little, if at all

17. Did you feel worn out today?

___Very much so
___Moderately so
___Some
___Very little, if at all

18. Did you have any fears about your health today?

___Very much so
___Moderately so
___Some
___Very little, if at all

19. Did you feel worried today?

___Very much so
___Moderately so
___Some
___Very little, if at all

20. Did physical problems limit your functioning today?

___Very much so
___Moderately so
___Some
___Very little, if at all

21. Were you disappointed with your life today?

___Very much so
___Moderately so
___Some
___Very little, if at all

22. Did you feel peppy today?

___Very much so
___Moderately so
___Some
___Very little, if at all

23. Were you upset today?

___Very much so
___Moderately so
___Some
___Very little, if at all

24. Did you feel cheerful today?

___Very much so
___Moderately so
___Some
___Very little, if at all

25. Did you feel like you had to push yourself to do things today?

___Very much so
___Moderately so
___Some
___Very little, if at all

26. Did you feel emotionally stable today?

___Very much so
___Moderately so
___Some
___Very little, if at all

27. Did you feel relaxed today?

___Very much so
___Moderately so
___Some
___Very little, if at all

28. Were you bothered by how things went for you today?

___Very much so
___Moderately so
___Some
___Very little, if at all

29. Were you bothered by any changes in your strength, coordination, or balance today?

___Very much so
___Moderately so
___Some
___Very little, if at all

30. Would you rate your health today as good?

___Very much so
___Moderately so
___Some
___Very little, if at all

31. Were you able to do the activities today that you wanted to do?

___Very much so
___Moderately so
___Some
___Very little, if at all

32. Did you feel down-hearted and blue today?

___Very much so
___Moderately so
___Some
___Very little, if at all

33. During the day, did you feel hopeful about tomorrow and the future?

___Very much so
___Moderately so
___Some
___Very little, if at all

34. Did you feel that you were in control of your thoughts today?

___Very much so
___Moderately so
___Some
___Very little, if at all

The time now is: P.M./ A.M.

Your contact with people today included(check appropriate spaces):

___Family: ___In person ___By phone
Quality: ___Positive ___Negative ___Neutral or mixed

___Friends: ___In person ___By phone
Quality: ___Positive ___Negative ___Neutral or mixed

___Acquaintances: ___In person ___By phone
Quality: ___Positive ___Negative ___Neutral or mixed

___Strangers: ___In person ___By phone
Quality: ___Positive ___Negative ___Neutral or mixed

___I had no contact with people in person or by phone today.

Instructions for Taking Temperature

1. Allow 15 minutes to pass after drinking hot or cold fluids before taking temperature.
2. Remove the probe from its stored position in the face of the thermometer. This automatically turns on the thermometer and a digital display of 94.0°F appears.
3. Insert the probe firmly into a probe cover while the cover is still in its box. Do not push on the probe top, it is the ejection button.
4. Hold the probe loosely between thumb and index finger. Slowly insert and slide the probe back under the front of the tongue along the gum line to the back of the mouth.
5. Hold the probe steady and in constant contact with body tissue until an audible signal is heard and the red light comes on. Remove the probe and record the reading on the DAILY TEMPERATURE RECORD, using actual time of reading.
6. After recording the temperature reading, discard the probe cover by pressing on the top of the probe. Never re-use a probe cover.
7. Return the probe to its stored position in the face of the thermometer. This will automatically turn off and reset the thermometer so that it is ready for the next reading.
8. Repeat steps 2 through 7 for a second reading. A third reading is necessary only if the first and second vary by 0.5° F or more. Always use the same side of the mouth at one recording session.

9. <u>Store the thermometer during sleeping hours in its charging base.</u> When stored, be sure the probe is in its storage position, the temperature display is off, and the charging indicator light is on, indicating proper charging of the rechargeable battery.

APPENDIX L

MEAN AND DAILY COSINOR PARAMETERS FOR TEMPERATURE

	Percent Rhythm	Amplitude	Mesor	Acrophase Degrees/Hour	
Subject 1					
Mean	70.5***	.86	97.3	-242.2	1609
Day 1	82.9**	.78	97.26	-222.3	1449
Day 2	45.0	.72	97.4	-224.3	1457
Day 3	78.9**	.59	97.54	-239.3	1557
Day 4	85.6***	.99	96.95	-239.6	1559
Day 5	84.2**	1.19	97.4	-260.1	1721
Day 6	94.2***	1.07	97.34	-252.4	1650
Subject 2					
Mean	26.1	.22	97.3	-203.2	1333
Day 1	23.6	.42	97.07	-198.9	1316
Day 2	1.1	.04	97.7	-270.4	1802
Day 3	5.7	.2	97.07	-332.7	2211
Day 4	15.8	.36	97.36	-97.1	0628
Day 5	42.1	.49	97.11	-238.3	1553
Day 6	68.3	.75	97.32	-195.4	1302
Subject 3					
Mean	64.7**	.82	98.3	-243.3	1613
Day 1	54.4	.66	98.46	-240.4	1602
Day 2	45.8	.58	98.71	-273.1	1813
Day 3	78.9*	1.11	98.28	-227.0	1508
Day 4	64.5	.62	98.27	-262.6	1730
Day 5	97.0***	1.54	98.02	-243.8	1615
Day 6	80.1*	.69	97.97	-236.5	1546
Day 7	34.0	.69	98.14	-236.7	1547
Subject 4					
Mean	52.0**	.45	97.6	-215.9	1424
Day 1	64.4*	.48	97.72	-209.2	1357
Day 2	40.7	.16	97.75	-212.5	1410
Day 3	40.5	.33	97.72	-226.9	1508
Day 4	71.1*	.83	97.23	-194.9	1300
Day 5	36.7	.36	97.75	-250.4	1642
Day 6	44.5	.37	97.63	-160.1	1040
Day 7	64.4	.81	97.12	-246.8	1627

*$p<.05$ **$p<.01$ ***$p<.001$

continued

Subject 5[a]					
Mean	46.3	.38	97.6	-334.1	2216
Day 1	50.5	.31	97.32	-314.9	2100
Day 2	25.8	.68	97.46	-335.8	2223
Day 3	51.3	.61	97.65	-1.5	0006
Day 4	30.5	.36	97.49	-92.1	0608
Day 5[b]	72.6	1.02	97.9	-250.7	1643
Day 6	39.6	.53	97.57	-279.4	1838
Day 7	80.3*	.65	97.99	-326.3	2145
Subject 6					
Mean	50.8***	.40	98.1	-278.8	1835
Day 1	71.9*	.49	98.07	-263.1	1732
Day 2	57.5	.32	98.15	-282.8	1851
Day 3	15.9	.23	98.34	-264.6	1738
Day 4	28.7	.31	98.05	-239.7	1559
Day 5	57.5	.51	97.93	-296.3	1945
Day 6	67.6	.56	98.25	-290.2	1921
Day 7	56.1	.49	98.03	-290.0	1920
Subject 7					
Mean	66.3***	.94	97.5	-263.3	1733
Day 1	75.0*	1.07	97.45	-261.4	1726
Day 2	74.5*	.84	97.53	-295.4	1941
Day 3	78.3**	1.12	97.3	-265.9	1744
Day 4	79.2*	1.37	97.33	-245.6	1622
Day 5	41.5	.73	97.96	-257.6	1711
Day 6	28.9	.4	97.8	-309.8	2039
Day 7	87.1**	1.42	97.35	-252.6	1650
Subject 8					
Mean	60.8***	.74	97.7	-227.3	1509
Day 1	39.3	.55	97.76	-228.6	1514
Day 2	69.0*	.93	97.7	-231.9	1528
Day 3	36.2	.52	97.65	-230.0	1520
Day 4	58.3	.96	97.64	-231.3	1525
Day 5	75.1*	.78	97.76	-220.1	1440
Day 6	66.0*	.77	97.61	-227.4	1510
Day 7	81.5**	.71	97.76	-220.6	1442
Subject 9					
Mean	40.7***	.37	96.8	-278.9	1836
Day 1	27.6	.31	96.9	-302.1	2008
Day 2	48.0	.59	96.99	-327.8	2151
Day 3	16.9	.4	96.76	-312.5	2050
Day 4	64.6*	.69	97.08	-217.4	1429
Day 5	28.5	.4	96.59	-339.6	2238
Day 6	50.4	.51	97.03	-265.8	1743
Day 7	48.8	.7	96.36	-242.0	1608

$^*p<.05$ $^{**}p<.01$ $^{***}p<.001$

[a]Mean does not include Day 5.
[b]Only 5 temperature readings on this day.

continued

Subject 10					
Mean	63.0**	.99	97.6	-246.2	1625
Day 1	54.5	.73	97.7	-288.1	1913
Day 2	13.7	.4	97.84	-243.0	1536
Day 3	64.4	1.22	97.61	-242.6	1610
Day 4	86.5**	1.38	97.59	-234.8	1539
Day 5	60.6	.97	97.36	-240.7	1603
Day 6	73.3*	1.05	97.64	-257.9	1712
Day 7	88.3**	1.41	97.22	-239.1	1556
Subject 11					
Mean	43.5**	.69	97.5	-212.4	1410
Day 1	61.1	.85	97.89	-215.4	1422
Day 2	49.7	.73	97.74	-222.2	1449
Day 3	61.7*	.52	97.55	-210.7	1403
Day 4	11.3	.43	97.41	-201.9	1328
Day 5	35.1	.73	97.46	-237.2	1549
Day 6	42.8	.54	97.38	-172.7	1131
Day 7	42.5	1.22	97.32	-210.9	1403
Subject 12					
Mean	61.3***	.70	97.6	-248.0	1632
Day 1	30.1	.50	97.89	-257.3	1709
Day 2	70.0*	.66	97.85	-277.5	1830
Day 3	47.2	.90	97.18	-240.4	1601
Day 4	87.8**	.91	97.3	-243.6	1614
Day 5	63.6	.62	97.77	-239.4	1558
Day 6	47.8	.62	97.6	-252.0	1648
Day 7	82.4*	.84	97.78	-237.0	1548
Subject 13					
Mean	33.6*	.33	97.7	-233.1	1532
Day 1	86.9***	.79	97.74	-221.9	1448
Day 2	31.4	.19	97.92	-226.1	1504
Day 3	30.1	.52	97.71	-218.1	1432
Day 4	2.5	.17	97.84	-210.5	1402
Day 5	28.0	.49	97.56	-216.2	1425
Day 6	21.1	.36	97.68	-276.1	1825
Day 7	35.4	.28	97.74	-339.1	2236
Subject 14					
Mean	42.9*	.49	97.9	-238.0	1552
Day 1	10.0	.29	97.67	-222.8	1451
Day 2	20.5	.28	98.04	-221.8	1447
Day 3	68.5	.75	97.96	-235.4	1542
Day 4	83.6**	1.17	97.56	-223.9	1456
Day 5	55.6	.41	97.99	-278.4	1834
Day 6	28.0	.3	97.9	-293.3	1933
Day 7	33.9	.49	97.87	-232.7	1531

*p<.05 **p<.01 ***p<.001

continued

Subject 15					
Mean	57.9*	.92	96.6	-247.7	1631
Day 1	36.9	.37	97.08	-256.9	1708
Day 2	65.0	1.17	96.77	-217.9	1432
Day 3	16.5	.41	96.85	-145.1	0940
Day 4	66.4	.91	97.08	-266.5	1746
Day 5	85.2**	1.52	96.3	-238.1	1552
Day 6	64.9	1.69	95.81	-266.9	1747
Day 7	70.3	1.24	96.03	-262.8	1731
Subject 16					
Mean	53.2**	.36	98.1	-229.7	1519
Day 1	61.4	.38	98.35	-291.1	1925
Day 2	69.7	.43	98.06	-223.5	1454
Day 3	67.6	.27	98.03	-240.6	1602
Day 4	19.8	.28	98.12	-226.8	1507
Day 5	53.6	.31	98.22	-195.2	1301
Day 6	55.3	.64	97.86	-219.3	1437
Day 7	45.1	.5	97.97	-225.5	1502
Subject 17					
Mean	37.7**	.38	96.9	-232.2	1529
Day 1	55.1	.43	96.96	-201.7	1327
Day 2	72.5*	.6	97.06	-233.4	1533
Day 3	28.4	.44	96.65	-195.3	1301
Day 4	10.4	.25	97.11	-248.0	1632
Day 5	62.5	.55	96.65	-289.5	1918
Day 6	24.4	.56	96.89	-237.1	1548
Day 7	10.8	.26	96.91	-207.2	1349
Subject 18					
Mean	31.7	.23	98.1	-210.1	1400
Day 1	19.8	.25	98.13	-245.9	1623
Day 2	4.2	.24	98.25	-30.5	0202
Day 3	53.0	.39	98.74	-91.0	0756
Day 4	30.6	.43	97.93	-208.2	1353
Day 5	2.9	.05	97.97	-270.7	1803
Day 6	58.2	.89	98.01	-214.1	1416
Day 7	53.1	.38	97.88	-233.7	1535

*p<.05 **p<.01 ***p<.001

APPENDIX M

MEAN AND DAILY COSINOR PARAMETERS FOR GENERAL ACTIVATION

	Percent Rhythm	Amplitude	Mesor	Acrophase Degrees/Hour	
Subject 1					
Mean	47.7*	2.05	8.0	-217.4	1430
Day 1	11.1	1.1	7.77	-251.2	1645
Day 2	66.4*	3.69	7.32	-223.3	1453
Day 3	48.0	2.01	8.31	-212.5	1410
Day 4	59.0*	2.81	8.03	-214.0	1416
Day 5	37.8	.75	9.31	-166.4	1106
Day 6	64.2*	2.4	7.07	-215.8	1423
Subject 2					
Mean	57.3**	3.09	6.0	-210.9	1404
Day 1	52.1	3.62	6.9	-237.1	1549
Day 2	59.5	2.89	5.88	-181.6	1207
Day 3	10.8	1.6	5.69	-205.3	1341
Day 4	80.5**	3.93	5.29	-213.6	1414
Day 5	67.6*	3.15	5.52	-205.4	1342
Day 6	73.4*	4.1	6.89	-212.0	1408
Subject 3					
Mean	41.3	2.03	5.3	-194.5	1258
Day 1	14.1	1.14	4.25	-119.2	0757
Day 2	80.0*	5.86	4.43	-206.6	1347
Day 3	5.0	.83	4.27	-258.1	1712
Day 4	65.6	3.02	8.85	-165.5	1102
Day 5	69.4	3.59	9.22	-185.4	1222
Day 6	20.1	.35	2.97	-245.8	1623
Day 7	34.7	1.67	3.3	-226.8	1507
Subject 4					
Mean	49.5**	2.31	8.7	-225.7	1503
Day 1	39.6	1.35	7.24	-164.6	1059
Day 2	50.2	3.05	9.26	-240.6	1602
Day 3	62.2	3.23	8.09	-202.3	1329
Day 4	59.8	3.26	8.79	-212.0	1408
Day 5	18.0	1.38	9.65	-237.8	1551
Day 6	51.3	3.25	8.58	-239.0	1556
Day 7	65.8	2.37	9.4	-262.7	1731

*p<.05 **p<.01 ***p<.001

continued

Subject 5[a]					
Mean	39.0	.85	3.0	-226.8	1507
Day 1	39.3	.80	3.1	-230.7	1523
Day 2	36.3	.61	3.23	-202.0	1328
Day 3	65.8	1.63	3.08	-222.2	1449
Day 4	21.4	.31	3.0	-227.6	1510
Day 5[b]	99.3	1.06	3.94	-108.2	0713
Day 6	49.7	1.5	2.87	-239.6	1559
Day 7	21.4	.36	2.97	-226.0	1504
Subject 6					
Mean	21.7	.41	6.7	-84.6	0538
Day 1	26.9	2.27	5.65	-235.0	1540
Day 2	40.6	4.25	8.96	-43.4	0254
Day 3	5.4	.87	8.1	-30.8	0203
Day 4	8.1	.82	6.03	-204.5	1338
Day 5	15.7	.49	8.03	-147.7	0951
Day 6	17.8	1.76	5.19	-213.2	1413
Day 7	37.4	2.43	5.19	-81.2	0525
Subject 7					
Mean	50.9*	2.72	4.9	-226.1	1504
Day 1	25.4	1.87	5.02	-203.9	1336
Day 2	12.7	1.38	6.76	-146.8	0947
Day 3	48.2	2.23	4.32	-263.6	1734
Day 4	64.5	3.53	4.43	-251.5	1646
Day 5	76.6*	5.26	3.68	-222.4	1450
Day 6	53.8	3.55	4.92	-213.0	1412
Day 7	74.8*	3.42	5.2	-231.9	1528
Subject 8					
Mean	55.1**	4.05	7.2	-208.1	1353
Day 1	55.5	4.9	6.31	-208.5	1354
Day 2	56.8	3.54	5.14	-207.0	1348
Day 3	29.8	4.02	6.39	-197.6	1310
Day 4	17.9	2.21	8.43	-237.0	1548
Day 5	61.6	2.01	10.44	-148.5	0954
Day 6	82.2*	7.2	6.41	-216.3	1425
Day 7	81.8**	5.9	7.4	-212.2	1409
Subject 9					
Mean	74.0***	3.36	6.3	-198.9	1316
Day 1	76.7*	3.7	7.77	-194.4	1258
Day 2	67.5*	2.36	6.95	-215.1	1420
Day 3	61.0*	3.39	6.36	-199.4	1317
Day 4	88.3**	3.46	6.59	-170.1	1120
Day 5	81.5**	4.4	5.61	-201.0	1324
Day 6	71.6*	3.37	5.16	-194.7	1259
Day 7	71.6*	3.66	5.77	-220.9	1443

*p<.05 **p<.01 ***p<.001

[a] Mean does not include Day 5.
[b] Only 5 temperature readings on this day.

continued

Subject 10					
Mean	51.5**	3.81	6.5	-204.9	1340
Day 1	76.6*	5.4	7.03	-225.4	1502
Day 2	13.4	1.9	5.82	-210.1	1401
Day 3	92.2**	5.37	7.34	-157.4	1030
Day 4	58.6	5.11	7.19	-207.3	1349
Day 5	9.5	1.62	4.56	-197.5	1310
Day 6	75.5*	5.87	6.57	-217.6	1430
Day 7	34.6	3.73	6.83	-214.1	1416
Subject 11					
Mean	44.6**	2.2	8.3	-168.2	1113
Day 1	60.6	3.01	8.59	-200.8	1323
Day 2	59.2	2.92	7.44	-142.1	0928
Day 3	54.5	3.06	8.19	-165.5	1102
Day 4	87.3**	3.83	8.09	-182.6	1211
Day 5	8.2	1.38	8.87	-179.6	1158
Day 6	8.3	1.34	8.33	-180.1	1200
Day 7	33.9	1.9	8.25	-104.1	0657
Subject 12					
Mean	40.3	.69	10.6	-228.8	1515
Day 1	64.4	1.7	9.18	-234.9	1539
Day 2	13.5	.63	10.25	-192.9	1251
Day 3	85.5**	1.27	10.77	-275.2	1821
Day 4	35.3	1.52	9.75	-172.5	1130
Day 5	10.3	.2	11.4	-316.1	2104
Day 6	23.6	.22	11.84	-145.7	0943
Day 7	49.4	1.05	11.09	-260.3	1721
Subject 13					
Mean	49.9	1.86	5.5	-196.7	1307
Day 1	62.1*	.47	3.28	-59.7	0359
Day 2	78.2**	2.86	5.55	-212.0	1408
Day 3	1.7	.2	4.42	-344.3	2257
Day 4	46.6	2.22	7.87	-183.4	1213
Day 5	28.5	1.94	6.64	-201.5	1326
Day 6	70.1*	2.53	4.69	-181.7	1207
Day 7	62.3	4.24	6.27	-203.1	1333
Subject 14					
Mean	51.5	1.04	10.3	-212.1	1408
Day 1	69.0	1.36	10.65	-172.5	1130
Day 2	53.1	1.41	9.65	-171.6	1126
Day 3	84.4**	2.54	9.96	-219.9	1440
Day 4	76.7*	2.3	10.38	-254.0	1656
Day 5	3.9	.82	9.87	-107.4	0710
Day 6	4.5	1.02	11.18	-23.3	0133
Day 7	69.1	2.25	10.35	-226.0	1504

*p<.05 **p<.01 ***p<.001

continued

Subject 15					
Mean	40.5	1.48	7.1	-208.4	1354
Day 1	68.1	4.46	6.15	-203.0	1332
Day 2	58.0	2.07	4.78	-197.9	1311
Day 3	4.1	.58	9.72	-173.3	1133
Day 4	73.0	2.95	6.54	-208.2	1353
Day 5	30.1	.51	9.06	-110.5	0722
Day 6	21.6	1.23	6.75	-228.4	1514
Day 7	28.8	1.39	6.65	-326.7	2147
Subject 16					
Mean	80.4**	2.4	9.6	-172.1	1128
Day 1	51.2	.43	11.72	-204.1	1336
Day 2	94.1***	1.66	10.49	-149.7	0959
Day 3	91.3**	2.56	9.51	-158.0	1032
Day 4	73.3*	2.5	9.34	-157.8	1031
Day 5	85.6	3.28	8.99	-156.7	1027
Day 6	78.8*	3.8	8.72	-177.6	1150
Day 7	88.3*	3.71	8.67	-207.4	1350
Subject 17					
Mean	71.4**	3.43	7.1	-193.5	1254
Day 1	94.0***	4.63	6.42	-194.7	1259
Day 2	74.0*	3.77	8.36	-189.2	1237
Day 3	96.6***	5.12	7.04	-206.8	1347
Day 4	79.3**	4.1	6.44	-206.3	1345
Day 5	54.2	2.52	5.74	-173.7	1135
Day 6	89.2**	4.57	7.35	-186.2	1225
Day 7	12.6	.53	8.69	-78.0	0512
Subject 18					
Mean	72.0***	1.27	10.5	-124.5	0818
Day 1	83.1*	1.63	10.76	-124.7	0819
Day 2	25.8	1.14	10.41	-179.2	1157
Day 3	88.9**	1.44	10.73	-154.9	1019
Day 4	69.9*	1.14	10.62	-110.4	0722
Day 5	64.9	1.07	10.24	-126.1	0825
Day 6	92.0**	1.71	10.47	-117.3	0749
Day 7	79.5*	1.92	10.38	-85.9	0544

*p<.05 **p<.01 ***p<.001

APPENDIX N

MEAN AND DAILY COSINOR PARAMETERS FOR DEACTIVATION-SLEEP

	Percent Rhythm	Amplitude	Mesor	Acrophase Degrees/Hour	
Subject 1					
Mean	54.4	1.58	4.3	-48.7	0315
Day 1	51.3	2.51	4.93	-61.2	0405
Day 2	73.9**	3.97	5.68	-52.3	0329
Day 3	67.4	.78	3.57	-21.5	0126
Day 4	43.3	1.36	4.21	-19.9	0119
Day 5	44.2	.34	3.19	-56.1	0344
Day 6	46.7	.87	4.04	-60.3	0401
Subject 2					
Mean	58.3**	3.08	6.1	-40.1	0240
Day 1	39.3	2.91	5.36	-39.5	0238
Day 2	46.6	2.45	6.0	-48.6	0314
Day 3	40.6	2.31	5.89	-56.5	0346
Day 4	86.1**	4.59	7.55	-43.2	0253
Day 5	73.0*	3.2	6.4	-27.0	0148
Day 6	63.9	3.26	5.67	-31.2	0205
Subject 3					
Mean	52.3	1.82	6.8	-36.3	0225
Day 1	14.1	1.14	4.25	-119.2	0757
Day 2	90.5**	4.81	7.37	-22.3	0129
Day 3	22.5	1.78	7.07	-50.9	0324
Day 4	50.9	1.55	4.68	-327.7	2151
Day 5	65.8	2.37	4.6	-14.8	0059
Day 6	77.0	.97	11.16	-133.1	0852
Day 7	45.5	3.68	8.66	-51.2	0325
Subject 4					
Mean	48.8**	2.04	6.3	-29.0	0156
Day 1	23.6	.85	6.68	-293.2	1933
Day 2	59.8*	3.01	6.32	-39.5	0238
Day 3	50.8	2.5	6.86	-11.5	0046
Day 4	80.0**	2.57	6.22	-36.1	0224
Day 5	35.4	1.59	5.21	-6.4	0026
Day 6	62.6	3.3	6.36	-44.0	0256
Day 7	29.1	1.88	6.28	-43.6	0254

*$p<.05$ **$p<.01$ ***$p<.001$

continued

Subject 5[a]					
Mean	39.4	1.74	10.1	-53.4	0334
Day 1	64.8	3.17	8.79	-15.9	0104
Day 2	10.2	.96	10.35	-54.3	0337
Day 3	43.1	2.42	10.1	-67.9	0432
Day 4	58.7	.97	10.99	-146.7	0947
Day 5[b]	99.3	.53	9.53	-288.2	1913
Day 6	32.9	3.09	9.46	-69.7	0439
Day 7	26.6	1.76	10.92	-36.2	0225
Subject 6					
Mean	14.9	.55	5.4	-98.2	0633
Day 1	36.7	1.66	4.83	-56.0	0344
Day 2	20.1	1.56	5.39	-115.7	0743
Day 3	21.4	2.02	5.58	-184.9	1220
Day 4	7.9	1.03	5.87	-120.5	0802
Day 5	13.6	1.09	4.85	-2.6	0010
Day 6	4.2	.68	5.2	-12.0	0048
Day 7	.1	.12	6.11	-94.1	0617
Subject 7					
Mean	45.4*	2.3	7.2	-57.0	0348
Day 1	32.7	2.25	6.07	-45.0	0300
Day 2	8.7	1.21	5.51	-211.9	1407
Day 3	58.2	2.79	7.75	-88.5	0554
Day 4	62.1	2.95	8.2	-74.2	0457
Day 5	65.7	4.25	7.77	-48.9	0316
Day 6	66.6	3.99	8.16	-40.3	0241
Day 7	23.5	1.92	6.79	-37.5	0230
Subject 8					
Mean	60.9***	4.66	7.7	-33.9	0216
Day 1	40.7	5.11	8.12	-41.6	0246
Day 2	75.4*	5.02	9.97	-32.9	0212
Day 3	26.9	3.91	7.54	-37.1	0228
Day 4	43.4	4.04	6.92	-49.1	0316
Day 5	83.0*	3.15	5.71	-348.8	2315
Day 6	81.7*	6.92	8.48	-36.0	0224
Day 7	75.2*	5.61	7.31	-35.2	0221
Subject 9					
Mean	50.3	1.52	6.1	-16.5	0106
Day 1	40.5	1.99	5.19	-352.6	2330
Day 2	21.5	1.05	5.17	-65.5	0422
Day 3	61.0*	3.39	6.36	-199.4	1317
Day 4	55.6	3.09	6.18	-354.5	2338
Day 5	82.6**	4.32	7.72	-23.2	0133
Day 6	42.1	2.11	6.18	-21.6	0126
Day 7	48.5	2.32	6.15	-32.8	0211

*$p<.05$ **$p<.01$ ***$p<.001$

[a] Mean does not include Day 5.
[b] Only 5 temperature readings on this day.

continued

Subject 10					
Mean	36.5	1.64	5.5	-34.4	0218
Day 1	66.4	4.57	6.53	-49.6	0318
Day 2	22.0	3.34	7.17	-50.9	0324
Day 3	32.5	2.63	5.25	-334.4	2218
Day 4	51.3	2.44	4.79	-74.7	0459
Day 5	9.1	1.55	8.59	-348.4	2314
Day 6	54.5	.43	3.27	-36.6	0226
Day 7	19.6	.85	3.04	-238.0	1552
Subject 11					
Mean	38.9**	2.56	6.6	-341.0	2244
Day 1	27.5	1.59	6.45	-21.3	0125
Day 2	55.1	2.76	6.95	-296.9	1947
Day 3	33.1	3.01	6.9	-332.6	2210
Day 4	88.5**	4.43	6.41	-347.7	2311
Day 5	21.0	2.7	6.56	-2.1	0008
Day 6	5.2	1.17	6.15	-334.3	2217
Day 7	41.7	3.64	6.69	-340.9	2243
Subject 12					
Mean	52.6***	.44	3.3	-59.4	0357
Day 1	53.0	.44	3.29	-66.4	0426
Day 2	52.1	.44	3.29	-58.2	0353
Day 3	52.1	.44	3.29	-58.2	0353
Day 4	52.1	.44	3.29	-58.2	0353
Day 5	52.0	.44	3.29	-58.3	0353
Day 6	54.6	.46	3.3	-58.1	0352
Day 7	52.1	.44	3.29	-58.2	0353
Subject 13					
Mean	51.8***	2.69	5.7	-16.7	0107
Day 1	33.6	1.42	5.46	-324.1	2137
Day 2	80.1**	3.97	5.88	-23.6	0134
Day 3	48.9	2.16	6.41	-329.7	2159
Day 4	67.5*	3.18	5.22	-33.0	0212
Day 5	59.1	3.81	5.86	-31.0	0204
Day 6	25.9	3.25	6.36	-32.3	0209
Day 7	47.8	2.7	4.69	-6.4	0025
Subject 14					
Mean	46.8	1.02	4.2	-5.5	0022
Day 1	52.7	.45	3.29	-18.8	0115
Day 2	39.0	2.66	5.46	-354.7	2339
Day 3	82.7*	2.07	4.63	-20.3	0121
Day 4	73.5*	.62	3.44	-76.5	0506
Day 5	11.6	1.05	4.59	-286.3	1905
Day 6	10.7	1.15	3.25	-220.8	1443
Day 7	57.7	2.84	4.95	-25.7	0143

*$p<.05$ **$p<.01$ ***$p<.001$

continued

Subject 15					
Mean	69.4	1.45	4.9	-346.9	2308
Day 1	47.5	3.16	5.68	-345.0	2300
Day 2	91.7**	2.38	6.27	-294.2	1937
Day 3	38.8	.89	3.27	-146.2	0945
Day 4	77.5*	1.82	4.79	-357.8	2351
Day 5	78.6*	1.06	3.74	-3.2	0013
Day 6	61.5	2.56	6.02	-1.9	0008
Day 7	90.1**	1.16	4.3	-6.5	0026
Subject 16					
Mean	60.3**	1.76	4.9	-341.2	2245
Day 1	40.4	1.04	3.11	-253.8	1655
Day 2	20.8	1.55	5.13	-342.0	2248
Day 3	67.2	1.58	4.93	-333.8	2215
Day 4	93.2***	1.76	4.49	-311.9	2048
Day 5	41.6	3.13	7.0	-3.6	0014
Day 6	95.5**	2.82	5.45	-339.8	2239
Day 7	63.8	2.1	4.4	-8.5	0034
Subject 17					
Mean	66.3*	2.83	5.3	-4.8	0019
Day 1	89.5**	4.42	6.3	-354.0	2336
Day 2	51.2	2.13	4.73	-12.4	0050
Day 3	79.4*	3.57	5.56	-21.1	0124
Day 4	79.5**	3.53	5.53	-15.6	0103
Day 5	77.2*	2.9	5.81	-349.1	2317
Day 6	74.1*	4.29	5.4	-14.6	0058
Day 7	13.5	1.21	3.65	-245.4	1622
Subject 18					
Mean	58.4	.37	5.0	-6.7	0027
Day 1	78.6*	1.83	4.47	-345.2	2301
Day 2	10.0	.59	4.27	-127.9	0832
Day 3	81.7*	1.64	4.77	-124.6	0818
Day 4	71.2*	3.28	5.8	-48.6	0315
Day 5	70.4	2.77	3.48	-237.7	1551
Day 6	87.2*	1.44	7.33	-333.3	2213
Day 7	9.4	.53	4.99	-280.6	1842

*p<.05 **p<.01 ***p<.001

APPENDIX O

PEARSON CORRELATIONS BETWEEN AMPLITUDES OF RHYTHMIC VARIABLES AND TOTAL WELL-BEING SCORES (TWB) BY SUBJECT

Subject	Temperature Amplitude and TWB	General Activation Amplitude and TWB	Deactivation-Sleep Amplitude and TWB
1	.92*	-.31*	-.68
2	-.32	-.43*	-.22*
3	.05*	.53	.21
4	.09*	.43*	.62*
5[a]	-.13	-.16	.01
6	-.47*	-.2	.64
7	.08*	-.05*	-.41*
8	-.59*	.54*	.29*
9	.27*	-.58*	-.32
10	.21*	-.16*	-.43
11	.41*	.23*	.11*
12	-.01*	-.2	.2*
13	-.61*	.75	.68*
14	.55*	.2	-.78
15	-.93*	.46	-.1
16	.51*	.11*	-.29*
17	.14*	.14*	-.26*
18	-.38	.27*	-.63
Mean correlation all subjects =	-.012	.087	-.076
(SD) =	(.473)	(.371)	(.45)

*circadian rhythm in the rhythmic variable was statistically significant ($p<.05$) for this subject

[a] based upon 6 days of data

APPENDIX P

PEARSON CORRELATIONS BETWEEN ACROPHASE DESYNCHRONY OF RHYTHMIC VARIABLES AND TOTAL WELL-BEING SCORES (TWB) BY SUBJECT

Subject	Temperature Acrophase Desynchrony and TWB	General Activation Acrophase Desynchrony and TWB	Deactivation-Sleep Acrophase Desynchrony and TWB
1	-.21*	.24*	.16
2	.06	.53*	-.48*
3	.25*	-.6	-.25
4	.63*	-.44*	-.65*
5[a]	-.3	-.17	-.26
6	.25*	.36	.46
7	-.31*	.05*	.27*
8	.08*	-.02*	.12*
9	.48*	.45*	.38
10	-.07*	.46*	.47
11	-.46*	.32*	.59*
12	-.65*	.29	-.003*
13	.21*	-.89	-.36*
14	-.003*	.04	.34
15	.34*	-.17	.3
16	-.52*	.33*	-.05*
17	.12*	-.28*	-.32*
18	.51	.24*	.48
Mean correlation all subjects =	.023	.041	.07
(SD) =	(.37)	(.4)	(.377)

*circadian rhythm in the rhythmic variable was statistically significant ($p<.05$) for this subject

[a]based upon 6 days of data

APPENDIX Q

PEARSON CORRELATIONS BETWEEN PERCENT RHYTHM ACCOUNTED FOR BY THE RHYTHMIC VARIABLES AND THE TOTAL WELL-BEING SCORES (TWB) BY SUBJECT

Subject	Temperature % Rhythm and TWB	General Activation % Rhythm and TWB	Deactivation-Sleep % Rhythm and TWB
1	.71*	.1*	-.92
2	-.39	-.26*	-.59*
3	-.08*	.7	.08
4	-.25*	.33*	.17*
5[a]	-.34	.04	-.04
6	-.36*	-.53	.27
7	.18*	-.18*	-.68*
8	.22*	.79*	.4*
9	.04*	-.19*	-.38
10	.29*	-.14*	-.35
11	.05*	.27*	.21*
12	-.25*	.28	.18*
13	-.33*	.64	.44*
14	.53*	.26	.42
15	-.64*	.27	-.46
16	-.39*	-.02*	.33*
17	.27*	.11*	.11*
18	-.15	-.09*	-.29
Mean correlation all subjects =	-.049	.132	-.061
(SD) =	(.36)	(.35)	(.42)

*circadian rhythm in the rhythmic variable was statistically significant ($p<.05$) for this subject

[a] based upon 6 days of data

APPENDIX R

PEARSON CORRELATIONS BETWEEN PERCENT RHYTHM ACCOUNTED FOR BY THE RHYTHMIC VARIABLES BY SUBJECT

Subject	Temperature % Rhythm and General Activation % Rhythm	Temperature % Rhythm and Deactivation-Sleep % Rhythm	General Activation % Rhythm and Deactivation-Sleep % Rhythm
1	-.28	-.83	.24
2	.48	.37	.75
3	-.03	.09	.69
4	.4	-.03	.82
5[a]	-.12	.01	.001
6	.64	.1	.02
7	-.2	-.58	.58
8	.6	.9	.78
9	.48	-.37	.35
10	.37	.2	.75
11	-.16	-.59	.84
12	-.41	-.52	-.11
13	.18	-.42	-.02
14	.22	.44	.97
15	.21	.84	.3
16	.21	-.62	-.1
17	.21	.25	.86
18	.75	.2	.65
Mean correlation all subjects =	.197	-.031	.465
(SD) =	(.337)	(.505)	(.378)

[a] based upon 6 days of data