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TIME-ZONE EFFECTS ON THE LONG DISTANCE AIR TRAVELER

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I. INTRODUCTION

The main celestial events within our planetary system occur at certain intervals, are repetitive and periodic, and follow predictable time patterns. Since the earth, moon, sun, and other celestial bodies are connected by such basic and ubiquitous phenomena as gravity and radiation, it seems plausible to assume that the variations associated with geophysical and diurnal cycles affect the course of life processes. Well-known examples of periodicities in our daily life are the day-night cycle, the wake-sleep cycle, the work-rest cycle, and the menstrual cycle. Certain physiological cycles appear to depend, therefore, on an "internal clock," a more or less accurate biological mechanism.

Halberg in 1959 introduced the term *circadian* (derived from the Latin *circa dies*) for a time period which approximates 24 hours; thus *circadian* means about the same thing as *diurnal* (*diurnal* is defined as "daily"). Although these circadian periodicities has been known for several centuries, only recently has research on the temporal dependencies of biological systems become systematic and "mission-oriented"[1].

The adverse effects of unusual schedules on the individual's subjective and physical state is noted in the Declaration of Independence and constituted one of the colonists' grievances against King George III. This passage reads: "He has called together legislative bodies at places unusual, uncomfortable, and distant . . . for the sole purpose of fatiguing them. . . ." People traditionally have been very sensitive to, and resistant to, alterations in their cycles of sleep and wakefulness. Rural people have been inclined to maintain these cycles in phase with sunset and sunrise. They tend to arise earlier in the summer, when sunrise is earlier, than they do in the winter. The first published suggestion that great economies could be effected by instituting what was later to be called "daylight saving time" appeared in 1784 in the *Journal of Paris*; the author was Benjamin Franklin. From the fact that the suggestion was not followed until the 20th century, we see how the human being clings to his customary sleep-wake cycle[2].

II. DISCUSSION

Time Zones

Prior to 18 November 1883, no standard time zones existed[3]. Individual towns estimated noon as best they could by trying to determine when the sun was most directly overhead. Thus, each town had its own time, and there were more than 100 different time zones in the United States. The state of Michigan had 27 time zones. The U.S. railroads, needing a more uniform system as a basis for establishing train schedules, led in the informal adoption of four standard time zones, in 1883. The United States, in the Standard Time Act of March 19, 1918, gave legal sanction to the railroads' four-zone system.

Twenty-Four-Hour Physiological Cycles

The importance of the periodicity of the earth's rotation as a factor in the rhythm of biological functions is demonstrated by the 24-hour variations manifested by most forms of terrestrial life. √Two forms of biological periodicity have been distinguished: (1) An exogenous periodicity, which exists as long as the environmental factors change periodically, fading like a "damped oscillation" when the environmental conditions are kept constant, and (2) an endogenous periodicity, which functions like a biological clock after a certain time pattern has been established[4]. In this second form of periodicity the oscillation has its own natural period. which depends on the organism; the environment merely influences the frequency of the phase.

√ In exogenous periodicity the periodic changes of the surroundings play the role of "*Zeitgeber*" ("time-givers"), or clues and synchronizers to which the organism responds. Time-savers can be either environmental factors, such as light or darkness, temperature, and tidal and other geophysical forces, or regularly repeated physiologic processes such as going to sleep, eating, exerting body wastes, and so on. Changes in the hours of daylight and variations in environmental temperature are the most effective time-givers[5].

Periodicities such as the diurnal cycles of light and temperature do not force an oscillation on the living system but "entrain" an oscillation. Under normal conditions the time-givers play the role of regulators by keeping the frequencies or oscillations of the organism in step with the external stimuli. It is well known that the daily fluctuations of physiological and psychological functions show maxima and minima at certain times of the 24-hour day. This is of practical importance since there is evidence that these rhythms are associated with temporal fluctuations in efficiency and performance. For example, it is known that there are diurnal variations in efficiency in the performance of various types of tasks, such as sentry duty, automobile driving, radar observation, problem solving of all kinds, and other mental and psycho-motor tasks[6].

Investigations of circadian rhythms have demonstrated that the biological clockwork is composed of a multitude of oscillating subsystems, which are properly timed through mutual coupling. If the system is uncoupled from the time-giver or if the subsystems become asynchronous, the internal clock imprecisely times the functions and the periods may vary from 20 to 28 hours. However, the functions can then become locked upon another periodic system. This is the case when an individual adapts to a somewhat different timetable—for example, from normal time to daylight saving time or to another local time during travel. Since a natural day has two different phases—the light period and the dark period—which, outside the tropics, may differ considerably in length, especially at high latitudes, animals migrating from north to south and vice versa have to make adjustments to changes in the light-dark ratio. The markedly affects their activity pattern. When the time-givers, such as the light-dark or the temperature phase, are modified, the organism does not immediately follow the new pattern; it may not do so for a few days or even weeks. If the exogenous and endogenous periods are similar, the entrainment process adjusts the inner clock to the environmental cycle by establishing a definite phase relation between the oscillations of the organism and the exogenous periodicity[7]. We know, of course, that not all biological functions have a 24-hour cycle, and, furthermore, we know that the phase of biological periodicities can be modified or resynchronized. However, there are still many unsolved problems concerning the application of the theoretical "models" to practical life situations; the limits of permissible phase shifts; the changes associated with the direction of geographical dislocations; and the interactions between time-givers and activity patterns. Also, the medical implications of desynchronization of the circadian system have not been fully assessed.

Effects of Shifts of Light-Dark Ratio

Some early observations of the effects of changes of the light-dark ratio concerned the physiological functions of workers on alternating work shifts. In a recent study[8] the diurnal rhythm of body temperature of workers on alternating day and night shifts was recorded. Body temperature usually shows a peak during the day and a drop at night. While the body temperature of these workers followed the normal diurnal time course during the 1-week day shift, during the 5-week night shift it showed a different pattern at times of work or sleep, but, for the time between 4 and 10 p.m., which was a period of leisure on both shifts, it showed a pattern very similar to that for the day shift. The three workers used as subjects in this study responded quite differently to the changes in work shift. One individual adjusted almost immediately to the switchover, in either direction, whereas the second needed several days to make the adjustment. The third man never adapted completely to the night-shift routine. This individual variation in ease of adapting to time changes and in ease of establishing new habit patterns has been observed many times.

Since the metabolic structure is closely related to the temporal parameters which determine the physiological-function cycle[9], the diurnal variations in urinary excretion of the 17 ketogenic steroids, the catecholamines, sodium, potassium, calcium, and inorganic phosphate were measured during artificial shifts of the day-night cycle. The catecholamine rhythm and, in particular, the adrenaline (epinephrine) cycle, which normally shows a peak during ordinary daytime activity, shifted rapidly—but not entirely—during nighttime work. The excretory maximum occurred when the physical and mental demands of the night shift were greatest[10].

Another way of studying the effects of changing light-dark ratios is to observe men living (temporarily or permanently) at high latitudes. Natives of the arctic region, where the normal stimuli of sunrise and sunset are absent for a considerable portion of the year, showed a certain decrease in the amplitude of all components of the 24–hour urinary excretion cycle; during the extremes of the season these rhythms sometinues even disappeared completely[11]. These fluctuations seem to indicate, not an entrainment of the rhythms by the changing light-dark ratio, but rather a damping effect on the naturally occurring cycle.

The effects of long periods of abnormal work and abnormal time routines on physiological functions in man were studied in a series of experiments conducted in Troms (Norway) and Spitzbergen. Groups of subjects lived and worked on 21–hour, 24–hour, and 27–hour schedules[12]. The body temperature cycle of these men adapted almost immediately to the abnormal routines[13]. The urinary excretion cycle was disturbed only in the early daylight period and was reestablished after about 2 weeks. In contrast, the potassium excretion cycle adhered more closely to its normal 24–hour pattern throughout the entire period[14]. The excretion cycles of the 17-hydroxycorticosteroids and electrolytes adjusted to the changed routines within 5 weeks or more. The adaptation was delayed when the experimental "days" fell within periods which corresponded to deep sleep periods at home[15].

Several laboratory studies have been made by various investigations under controlled conditions in order to determine the effects of changes of the light-dark ratio on the body's circadian rhythms and, as a corollary, to ascertain the effect of desynchronization on human performance[16]. The test subjects in these studies were isolated singly or in groups for various periods. In one study at Baylor University, Houston, Texas, the subjects lived for 1 week on a schedule of light and darkness comparable to that of a normal day. During the next 6 days, the "sunrise" was advanced 30 minutes each day, so that by the 6th day it was at 3 a.m. and "sunset" was at 7:00 p.m. This schedule was continued for 3 days. Then, beginning on the 17th day, the light was kept on for the rest of the 30–day test period. In this study the following physiological measurements were taken: body temperature, blood pressure, pulse rate, volume and osmolarity of urine, and urinary content of epinephrine, norepinephrine, corticosteroids, creatinine, sodium, potassium, and chloride. Psychological and perceptual tests were also administered, and electroencephalograms were taken at certain intervals.

The most significant finding of the Baylor experiment was the discovery that, while the circadian periodicity shifted gradually with a gradual shift of the light-dark ratio, an abrupt change to constant illumination resulted in a severe disruption in the biological rhythm pattern, which became grossly distorted. The performance of discrete and sensitive motor and sensory tasks was impaired as a result of this disruption, but gross motor functions were unaffected. The affected functions were reentrained after about 3 days of constant light, but the cycle was slightly longer than 24 hours. Extremely long periods of isolation (6 monthes and longer) resulted in a relatively stable body temperature and sleep-wake rhythm but in a desynchronization of the activity cycle. The subjective concept of time became distorted; specifically, subjective estimates of time increased considerably in the course of these experiments. The dissociation of certain functions and the effect of the shifts of the light-dark ratio on psychophysiological processes indicate that the light-dark ratio and the individual's work schedule, degree and kind of activity, social habits, and sleep pattern interact in ways yet to be clarified.

The Air Traveler and Circadian-Rhythm √Desynchronization

Circadian rhythms became a matter of importance to travelers with the evolution of the airplane and the feasibility of long-distance flights. Wiley Post, the record-setting global flier of the 1930's, was the first to recognize the adverse effects of time-zone displacement on the sleeping and eating cycles of air travelers[17]. Prior to his 8–day global flight of 1931 and his 7–day solo global flight of 1933, Post determined the effects of altered sleep-wake cycles on his flying proficiency. He also experimented with an irregular schedule of meals and worked out a conditioning program designed to break his habitual sleeping and eating patterns. As indicated in his book[17], Post felt that the time-zone effects were significant and that the steps he took to adjust to them were beneficial.

The next published discussion of time-zone effects in global flying is a 1952 report by Strughold[18]. Since then, and especially since jet-powered air transports were introduced in the late 1950's, the literature on aerospace medicine has contained many papers on "jet age" time-zone effects. Crew members and passengers have repeatedly reported adverse physiological and psychological consequences of rapid long-distance flights—of east-to-west or west-to-east flights in particular.

In recent years, several studies have been made of passengers and crew members under real flight conditions and of volunteer subjects under stimulated flight conditions, in an attempt to assess the immediate and delayed effects of diurnal rhythm desynchronization. Several of these studies are reviewed here. Almost all countries that have aircraft making long transcontinental and intercontinental flights are investigating time-zone effects[19]. Although the "ultimate" study has not yet been made, several investigations have provided enough data to make possible certain travel-policy decisions.

British scientists at the Royal Aircraft Establishment in Farnborough, England, made biomedical studies on pilots of planes making intercontinental flights; these studies encompassed the flight phase and periods immediately preceding and following the flights[20]. They showed that the pilot's heart rate varied directly with (1) the flight workload; (2) the type of airplane (the rate for a pilot landing the Boeing 707 was 128 beats per minute; that for one landing the VC–10, 100 beats per minute); (3) the nature of the approach aids and airports (when aids were limited and the airport poor, the heart rate was higher); and (4) the weather.

These physiologic responses are super-imposed upon the circadian rhythms and upon the time-zone desynchronization. An algebraic summation, for a particular flight, of (1) workload stresses, (2) circadian rhythm nadir, and (3) time-zone desynchronization may, for a particular crew member, lead to a potentially dangerous impairment in performance. Recognizing this, the United Kingdom issued new guidance information on flight-time limitations[21]. This reads in part as follows:

> Article 47 of the Air Navigation Order . . . is designed to ensure that no crew member of a British-registered aircraft which is either engaged on a flight for the purpose of public transport or is being operated by an air transport undertaking is subjected to excessive fatigue. It requires the aircraft operator, after taking into account the particular circumstances of his operations, to include in his operations manuals or comparable documents details of his limitation on flight times and flight duty periods, and of the minimum rest periods he has established.

The guidance information then recommends that "long-haul operators should ensure that their crews are properly briefed on the physiological effects of time zone changes so that they can adjust their sleeping pattersn accordingly, and should bear this factor in mind when scheduling rest periods between flights." The recommendation is made that "in the event of there being a time zone change of four or more hours between the place of departure and the place where the duty ends, the subsequent rest period should not be less than twelve hours."

Aeromedical specialists at the Institut fur Flugmedizin in Bad Godesberg, Germany, used a battery of nine psychophysiological tests and a questionnaire to determine the stress of flight and of time-zone changes on Lufthansa pilots on the North Atlantic route[22]. After having established the rhythmicity of the psychological and physiological functions in base-line studies, they determined the shifts in peak that occurred during actual flights. The investigators found the following relationship: the greater the interval between the time of departure and the time of maximum activity or efficiency of the pilot, the greater the stress experienced by the crew. They also concluded that performance failures (and probably accidents) are more likely to occur during the hours of lowered resistance to stress. As a result of these studies it was recommended that intercontinental flight crews be rescheduled, consideration being given to departure time, flight duration, and multiple landings.

French scientists studied the responses of Air France pilots on flights extending through five time zones on the Paris-New York route[32]. They reported that younger pilots suffered less from fatigue than older pilots, and that pilots should receive more flight credit for hours of flight from east to west or from west to east than for the same number of hours on a north-south route. When the trips were extended to Anchorage, Alaska, the analysis of some hormonal reactions yielded evidence of pronounced and stable circadian variations in excretion of the 17–OH corticosteroids; the other functions studied were not appreciably modified during a stopover in Anchorage. However, after 5 days the pilot's renal and plasma hormonal cycles were fully adapted to local time, and different from the cycles observed before the departure from Paris.

Table 1. Departure and arrival time coeffcients used ✓ in the ICAO formula (see text).

Period	Departure time coefficient	Arrival time coefficient
0800–1159 hours	0	4
1200–1759 hours	1	2
1800–2159 hours	3	0
2200–0059 hours	4	1
0100–0759 hours	3	3

French aeromedical specialists responsible for an operational area which extends through the international dateline and some distance north and south of the equator, studied groups of subjects in a first attempt to develop a geographical map of circadian functions in relation to local time[24]. They found a 4–hour shift in the rhythm of several basic biological functions after a 5–hour change in time, but no dissociation of normally associated functions. The functions appeared to drift from the base rhythm after a 10-hour shift from local time; this shift, reportedly, was physiologically more disconcerting than two 5-hour shifts.

Dutch scientists recorded the diurnal rhythm in the excretion of water, chloride, sodium, and potassium for subjects during flights from Amsterdam to New York and back. The experiment lasted 5 days, with a stay of 4 days in New York and return flight on the 5th day. In a second experiment, the subjects were returned to Amsterdam after a stay of only 2½ hours in New York[25]. When the subjects arrived in New York the maxima of their excretion cycles were unchanged. Those who stayed in New York did not adapt to the New York time cycle, and the amplitude of the rhythms for excretion of water and electrolytes decreased. In subjects who had flown from Amsterdam to Anchorage[26], the maxima of the excretion cycles shifted by the 6th day after arrival. However, the amplitudes of the rhythms were depressed, and in subjects who flew on to Tokyo, the rhythm disappeared completely. In addition to some desynchronization in rhythm pattern, the amounts of water and electrolytes excreted deviated temporarily from normal values. These deviations, which were thought to be caused by the stresses involved in air travel, seemed not to affect the process of adaptation, however.

Only recently have Japanese scientists studied physiological responses to the time shifts associated with long-distance flights[27]. They recorded the diurnal pattern of body temperature of travelers after an eastbound flight that involved a time shift of 10 hours. This time shift disrupted the normal temperature cycles; these were gradually reestablished after approximately 13 days (during this time the maximum of the cycle shifted by 40 to 50 minutes per day).

✓Russian scientists have studied the effects of rapid time-zone changes on their pilots flying through 11 time zones on routes within the U.S.S.R. These studies are, of course, conducted without the need for passports and all the other complications of international travel which are encountered by scientists of other countries making similar studies. In preparation for the direct New York-Moscow air link, there was an exchange of information between U.S. and Soviet aviation personnel, which included familiarization with the flight equipment, operational procedures, and regulations of the other country. The Soviet Ministry of Civil Aviation revealed in 1967 that studies of responses to time-zone shifts have been made along the Moscow-Khabarovsk-Moscow route[28]. Flights over this route require 8 to 9 hours of flying time. The Russians observed changes in certain physiologic variables, in visual factors, in electroencephalograph and electrocardiograph recordings, and in blood pressures. They also reported subjective symptoms of fatigue in individual pilots, which they attributed to "the difference in astronomic time between the geographical points." Also, disturbances were found in the relaxation, sleep, and feeding schedules of the crew members, which had a disturbing effect upon their preflight condition. It took these disturbances longer to disappear.

√In the United States, experiments have been made by Federal Aviation Administration personnel on the effects of time-zone shifts on body temperature, heart rate, respiratory rate, loss of water by evaporation from the palms of the hands, urinary output, reaction time, decision time, and critical flicker fusion. Assessments have been made of subjective fatigue, of subjective wellbeing, and of intellectual facility of travelers before, during, and after intercontinental flights in east-west, west-east, and north-south directions[29]. It was found that rectal-temperature cycles adjusted to local time in 3 to 5 days after a flight from Oklahoma City to Tokyo, and readjusted to normal in 1 day after the return to Oklahoma City. Reaction time, decision-making time, and subjective fatigue scores were adversely affected during the transition period in Tokyo and, to a lesser degree, shortly after the return to the point of origin. The differences among individuals were found to be marked. In a second east-west journey, from Oklahoma City to Manila, phase shifts occurred in rectal temperature and heart rate (in 4 days) and in evaporative water loss (in 8 days). As for the psychological functions, reaction time and subjective fatigue were significantly increased in Manila, but, in contrast to the time lags of the physiologic phase shifts, the duration of these psychologic effects was very short. By the second day following the arrival in Manila, normal psychologic functions had apparently been restored. The return to Oklahoma City caused less transitory impairment of the physiologic and psychologic functions.

A flight from Oklahoma City to Rome was made to investigate possible bidirectional differences in phase shift. The time lags of the primary shifts were greater than those associated with the flight from Oklahoma City to Manila—namely, 6 days for rectal temperature, 8 days for heart rate, and even longer for evaporative water loss. While the phase shifts that occurred in Manila maintained the relations of the original cycles, those that occurred in Rome were unrelated. In contrast to the physiologic functions tested on the Rome trip, the psychomotor functions tested showed no impairment after the west-east translocation. However, there was significant increase in subjective fatigue. After the return from Rome to Oklahoma City, the rectal-temperature and heart-rate cycles did not completely readjust during the 5–day post-flight test period. During the north-south flights, only subjective fatigue showed a significant increase.

Similar results, in regard to the physiologic phase shifts, were obtained in experiments by Halberg[30]. Cycles of sleep-wakefulness, oral temperature, and renal excretion of 17–OH corticosteroids, 17–corticosteroids, sodium, and potassium were studied in a healthy human subject during a 12–day stay in isolation before departure for Europe by air. Data were obtained during the subject's stay overseas and during 56 days of isolation after his return to the United States. The six cycles became desynchronized during the subject's isolation, and the phase shifts were found to occur more slowly after west-east than after east-west dislocation. The latter phenomenon was

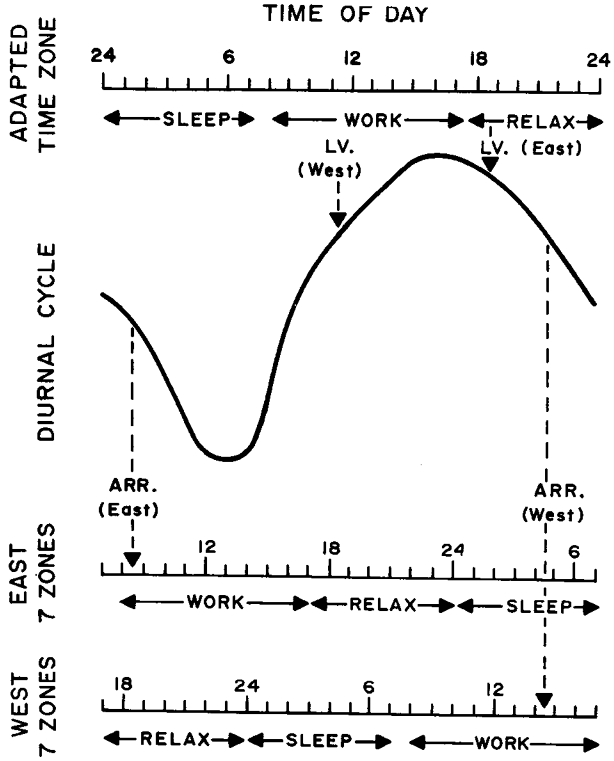

Figure 1. Representative diurnal curve such as might be recorded for body temperature, heart rate, activity, and other cycles. (Scale at top) Time of day for the time zone to which the individual is adapted; (scale immediately below curve) the corresponding time of day seven time zones to the east of the zone to which the individual is adapted; (scale at bottom) the corresponding time of day seven time zones to the west of the zone to which the individual is adapted (see text).

observed for several physiological parameters during flights from the United States to Japan. These findings are supported by results of animal experiments, which also indicate that it is much easier to delay the circadian rhythm than to advance it[31]. The physiological "advance-delay" phase differences in these cases apparently override any psychological effect of displacement as opposed to the return home.

In contrast, the results obtained by Aschoff and Wever in Germany point in the opposite direction[32]. After experiments with birds had showed that reentrainment occurs more quickly after a single shortening of the *Zeitgeber* period than after a lengthening of that period, an experiment with a human subject was conducted in an air-raid shelter in Munich. On the 6th day of isolation the artificial night was shortened by 6 hours, in simulation of a west-to-east flight; on the 13th day the night was lengthened by 6 hours, in simulation of the return flight. After the "eastward flight" the subject's body temperature was immediately in phase with the periods of light and darkness, but after the "westward flight" it took about 3 days for the activity cycle, and 5 days for the body-temperature cycle, to shift back to normal. These data are in line with Wever's mathematical model, which predicts that reentrainment should be accomplished in a shorter time after west-to-east than after east-to-west flight.

The findings by some investigators that flights from a given location to a point farther west are more disruptive of diurnal rhythms than the opposite case are in contrast to conclusions drawn by other investigators. The resolution of these differences is of scientific interest and also has practical implications. The following questions arise: (1) Can the effects of time-zone shifts be realistically simulated in laboratory experiments? (2) Is the entrainment model truly applicable to the conditions that exist in geographic dislocations? (3) Do bidirectional or even tridirectional differences truly exist? (4) How serious are the physiological and psychological effects of time-zone shifts on airplane crew members and passengers? (5) Does circadian desynchronization impose such stress on the human organism as to significantly impair efficiency? (6) What measures can be taken to attenuate or compensate for the deleterious effects of time-zone shifts if they degrade performance?

Time-Zone Nomograph

Figure 1 shows a representative diurnal curve (such as might be recorded for body temperature, heart rate, performance, or other cycles). Above the curve is a time scale for a time zone to which an individual is adapted. Below the curve are times scales for zones 7 hours to the east and 7 hours to the west.

If a traveler leaves on a nonstop flight from New York to Rome (a 7–hour flight, crossing seven time zones) at 1830 hours, he will arrive at 0830 hours local time, which is 0130 hours New York time. He is thus biologically ready to sleep, and not hungry. However, with sufficient conscious effort, he can immediately engage in business meetings, tours, meals, and social functions, but probably at less than peak efficiency for the first 24 hours.

The return flight, after the traveler has become fully adapted to the local time, leaves Rome at 1100 hours and arrives in New York at 1415 hours, after a 10–hour flight. Sleep, which is "due" in 2 or 3 hours, may be delayed for a while, but the "biologic clock" starts its awakening process by late evening, and sound sleep, once attained, is hard to maintain. The traveler cannot achieve sleep by the conscious effort which permitted him to perform acceptably after his arrival in Rome. Moreover, the stomach is very time-conscious, and hunger for breakfast, which is "due" at 0100 hours, may further add to his discomfort. Adaptation after westward flights can thus be expected to take longer than adaptation after eastward flights of the same length.

These are but two examples, given in general terms. There are obviously many variables which govern the symptoms an individual experiences. These include times of departure and arrival, length of flight, direction of flight, layovers, travel experience, stress, age, physical condition, food and liquor consumed during flight, sleep during flight, climatic changes, and the new social environment. The normal diurnal curves for temperature and heart rate can be affected by the social environment. With the supersonic transport it might be possible to arrange for crews to make a round trip in one day, thus keeping them adapted to one time zone. Except in the case of longer trips with fewer layovers, the effects of supersonic travel on passengers should not be significantly more (or less) disrupting than present jet travel.

Applications of Data on Circadian Rhythm

The International Civil Aviation Organization (ICAO) has its headquarters in Montreal and has a membership of 116 countries. Because its staff members travel frequently from country to country, ICAO has evolved a travel-time formula to help insure that disturbance in circadian rhythm neither works a hardship nor impairs cerebral function on trips to distant places. Enlightened policies of this type are being adopted by the management of other progressive organizations and corporations, insuring optimum efficiency on the part of their traveling representatives. The immediate and long-range benefits to the parent organization may not be apparent at first, but they have a sound biological basis. The benefit to the traveler—in terms of lessening of fatigue—of the use of formulas such as that used by ICAO is obvious.

The ICAO formula is as follows:

$$\text{Rest period (in tenths of days)} = \frac{\text{Travel time (in hours)}}{2} + \text{Time zones in excess of 4} + \text{Departure time coefficient (local time)} + \text{Arrival time coefficient (local time)}$$

The departure and arrival time coefficients are given in Table 1.

Lloyd Buley, chief of ICAO's Medical Section, states that, in general, adherence to the ICAO formula has had the desired results. The increased weighting given the later hours for departures helps compensate for the effects of loss of sleep. Also, the high arrival-time coefficient for the period 0800 to 1159 hours (Table 1) helps compensate for the disruptions experienced during early morning flights plus the effect of arriving at the beginning of a workday without sufficient rephasing of the circadian rhythms. The amount of phase difference is accounted for in the formula by the term "time zones in excess of 4."

In applying the formula, the following rules are observed by ICAO.

(1.) The value obtained for rest period, in tenths of days, is to be rounded to the nearest higher half day. However, rest stops that add up to less than a day before rounding will not be scheduled unless the journey involves an overnight flight on mission travel.

(2.) "Travel time, in hours" means the number of hours of elapsed time required for the journey, in accordance with the published schedules of the airline, rounded off to the nearest hour.

(3.) "Time zones" are computed in increments of 15 degrees of longitude from Greenwich.

(4.) "Departure time" and "arrival time" are local times.

The computation (according to the formula) for determining the rest periods for flights from Montreal to London and back could be as follows. For the west-to-east flight, $(6/2)+1+3+3=10/10$ day, or 1 day; thus 1 day of rest would be allowed in London. For the return trip, the figures might be $(7/2)+1+1+2=7.5/10$; no extra day of rest would be given in Montreal since overnight flight was not involved (see rule 1).

The computation for flights from Montreal to Karachi and back could be as follows. For the west-to-east flight, $(26/2)+5+4+3=25/10$; thus, 2½ days of rest would be allowed in Karachi. For the return trip, the figures might be $(26/2)+5+4+2=24/10$; thus 2½ days of rest would be allowed in Montreal.

For the north-to-south flight from Montreal to Mexico, the computation could be as follows: $(7/2)+0+1+0=4.5/10$; thus, no day of rest would be given. However, the computation for a flight from Montreal to Lima might be $(15/2)+0+1+4=12.5/10$, and 1½ days of rest would be given. Some flights might involve north-south travel across several time zones. The computation for a flight from Montreal to Sydney might be $(31/2)+5+0+3=23.5/10$; thus 2½ days of rest would be given in Sydney. The International Radiation Commission, with headquarters in Vienna, utilizes the ICAO formula in planning long trips for its staff.

There is another possibility: Can the critical circadian rhythms be readjusted prior to departure to be in phase with the time of the city of destination? The sleep cycle—the most obvious, and posibly the most critical, of the rhythms—can be modified within limits. The Deparment of Psychiatry and the Brain Research Institute at the University of California, Los Angeles, held a symposium in May 1968, entitled "Physiology and Pathology of Sleep," at which various reports of successful alterations of sleep patterns were given. Differing techniques were cited, including tests with a new drug, flurazepam hydrochloride, which, unlike most hypnotics, is reported to induce sleep with no adverse effect on the rapid-eye movement (REM) phase of sleep now known to be essential to optimum mood and efficiency during wakefulness[33]; (see also Kleitman's classical work[34]). Pilots have reported many informal means of inducing sleep between flights, including moderate exercise (walking) and warm baths.

III. Conclusions

The scientific literature of many countries reports circadian rhythms which influence the behavior of biological systems. In the modern aviation environment man is exposed rather abruptly to disruptions of these rhythms, particularly during long east-to-west and west-to-east flights. It is still an open question whether eastward or westward flights from the point of origin pose a higher stress on the air traveler.

Experimental evidence obtained on animals and man is still inconclusive; in the case of man, the individual differences between "early risers" and "early sleepers" may mask to some extent the transmeridianal time-shift effect. As to the latitudinal displacements, the flight experiments conducted so far did not last long enough to determine whether pronounced shifts of the light-dark ratio would affect the circadian oscillator. In any case, the methods of lessening the effects of desynchronization of circadian periodicities are similar to those that are used for crew members and travelers on long-distance flights. They specifically include the following:

(1.) Keeping the clock time and the environmental factors at the destination the "same" as those at the point of origin through simulation (this approach is often not practical, for obvious reasons).

(2.) Scheduling flight time and rest time according to a formula that takes into account the number of time zones traversed, departure time, state of rest at time of departure, and arrival time, so that there is as much rephasing of the critical circadian rhythms as is felt necessary in the light of demands made on the individual before, during, and after the trip.

(3.) Pacing activities during the initial period of rephasing so that superimposed stress (in particular, heavy eating and drinking)are kept to a minimum.

(4.) To avoid the necessity of taking traditional hypnotics, with consequent loss of REM sleep, inducing sleep by moderate exercise and a warm bath.

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