THE EFFECTS OF JET-LAG ON HAND-EYE COORDINATION

by

JACOB ALAN MYERS

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Approved by:

Charles B. Corbin
Major Professor

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CHAPTER I

INTRODUCTION

Man in adapting to his environment and daily routine establishes his physiological functions into regular patterns called circadian rhythms. Circadian upset or jet lag occurs when one changes time zones in a short period of time. In such a situation the body's rhythms tend to retain the established patterns of the home time zone. For example, the man flying from Paris to New York experiences a change of six time zones during a flight of six hours. He will leave a six p.m. Paris time and will arrive at six p.m. New York time. His body is physiologically on London time, 12 midnight, but his senses and environment say it is still six p.m. Consequently his sleep-awake cycle, hunger and thirst needs, and hormone secretions which trigger these and other functions of the body are out of phase.

Circadian upset has been a problem to man throughout time. However, in the past decade the tremendous increase in jet travel has intensified this problem and has come to be termed jet lag. Everyone who has traveled across time zones rapidly has experienced the uncomfortable situation they find themselves in at their destination. After crossing several time zones in a short period of time, as in jet flight, the body metabolism becomes desynchronized for the time period of adjustment to the new time zone. Travelers often falsely blame food or beverages they consumed enroute. In actuality the traveler must adjust to a different day-night and thus change his body functions to meet his new environment. The best medicine for this ailment is time, the same thing that brought it on.

Statement of the Problem

The problem of this study was to determine the effects of jet lag on hand-eye coordination.

Statement of the Purpose

The purpose of this study was to determine if jet lag reduces hand-eye coordination as evidenced by free throw percentages of professional basketball teams.

Rationale of the Study

In 1957, Drs. Edmund B. Flink and Richard T. Doe at the University of Minnesota, looked at adrenal hormones and electrolytes in urine after east-west flights (Flink, Doe, 1957). One investigator flew from Minneapolis to Toyko and on to Seoul, Korea, taking urine samples every three hours. It took nine to eleven days before the urinary steroid and electrolyte rhythms adjusted to Seoul time - an adaptation rate of about an hour a day.

Since rapid travel has become a way of life for a sizeable population, it would seem urgent to learn how to accelerate resynchronization. Drs. F. Gerritzen, of the Netherlands, T. Strengers and S. Esser attempted to abbreviate the adaptation time on a test flight from Amsterdam to Alaska and Toyko, by exposing the seven volunteers to an inverse lighting schedule (Gerritzen, Strengers, Esser, 1969). However, the passengers did not adapt according to expectation, and it was conjectured that their excretion of androsterone, dehydroisoandrosterone, and to some extent, etiocholanolone, (hormones secreted by the Leydig cells for the development of male sex characters located between the seminiferous tubules of the testes) had increased by the stress of the flight itself.

The Syntax Corporation has undertaken research expected to result in a drug that would phase-shift endocrine rhythms. Hormone therapy for travelers may be a future prospect although the mechanisms involved in circadian rhythms are not yet understood enough to allow a predictable manipulation of rhythmic functions.

Meanwhile, the British airlines have approved extended rest periods for crews, and a number of companies - among them Timken Roller Bearing Company, Phillips Petroleum, Continental Oil - are beginning to worry that traveling executives will make business blunders far exceeding the cost of an extra day or two for rest. These companies insist upon a 24-hour rest period after coast-to-coast or international flight. An international Civil Aviation Organization, based in Montreal, now has 116 member nations to evolve policies for sane international travel schedules.

In view of above discussion it would seem that jet lag could also have an adverse effect on athletic performance through impaired coordination. If this is the case, scheduling could be a critical factor in efforts to improve performance after time zone travel.

Therefore, the lack of investigation of circadian upset in sports coupled with extensive use of air travel to meet season schedules gives adequate support for pursuit of this study.

Based on the preceeding rationale the following hypotheses were investigated;

1. Jet lag would reduce hand-eye coordination as evidenced by free throw performance.

2. The reduction of hand-eye coordination as evidenced by free throw performance would increase with the number of time zones crossed.

3. There would be a differences between home games and away game free throw performance in favor of the home game situation when jet lag was not a factor.

Limitations of Study

This study on the effects of jet lag on hand-eye coordination was limited to the free throw performance from the 1970-1971 regular season of five teams from the National Basketball Association.

A questionnaire was sent to all professional basketball teams in the American Basketball Association and the National Basketball Association, but due to a lack of cooperation, data was gathered for all but 36 games out of 408 from the box scores appearing in The New York Times. A copy of the letter sent to the professional teams is included in the Appendix. Those teams were; the Buffalo Braves, the Philadelphia 76ers, the Boston Celtics, the Baltimore Bullets, and the New York Knickerbockers, all located in the eastern time zone.

Definitions of Terms Used

Acrophase. The time of the peak on the best-fitting sine curve.

Circadian. From the Latin circa dies, referring to a period of approximately 24 hours but ranging from 20 to 28 hours.

Endogenous. Rhythms which may be supposed to originate within the animal.

Exogenous. Rhythms which may be wholly dependent upon some external periodicity.

Nychthermeral. Alteration of night and day.

Phase of a periodicity. Refers to any particular point in the cycle, perhaps the maximum, or the minimum, or the point where the value rises past the mean.

Phase-shift. The periodicity, while remaining the same in form, is somewhat advanced or retarded.

Ultradian rhythms. Extreme fluctuations in circadian rhythms.

Chapter II

REVIEW OF LITERATURE

Introduction

Most men live in a world dominated by a single periodicity, the alternation of light and darkness. The day may be longer in summer, shorter in winter, but the alternation of light and darkness adheres closely to a period of 24 hours, and all our social life is geared to it. We wake and sleep, work and rest, eat and fast, drink and abstain, in a pattern which conforms to this alternation of light and darkness, and even night workers usually revert to the more customary habits at week-ends, and are in any case inevitably aware that their working and sleeping habits are out of phase with the general pattern of the community. Only in the Arctic, where day and night alternate only at the equinoxes, where summer is a period of continuous daylight and winter of continuous darkness, does man live for much of his life outside this regular 24 hour alternation, and even in many Arctic communities the social pattern still fits itself to a twenty-four hour clock. All foms of life which are in any way dependent upon sunlight, whether for vision, warmth, or photosynthesis, are to a varying extent constrained by this periodicity. Furthermore, different organisms are in a multitude of ways interdependent, even those which do not themselves make profitable use of sunlight may be similarly constrained by the habits of their neighbours. Therefor, many mammals are nocturnal, not because darkness is itself an advantage, but because it renders them less visible and hence safer from predators. Likewise, predatory animals may be active by night simply because the forms of life upon which they prey are themselves nocturnal in their attempt to elude observation. There are, of course, many other geophysical rhythms with periods different from twenty-four hours, upon which some organisms are to varying extents dependent. The annual alternation of summer and winter in temperate lattitudes dominates the reproductive behavior of plants and hence often the habits of animals dependent upon plants for their food. The tidal rhythm is of great importance for animals living in the intertidal zone as for others which prey upon them. In addition, some animals are dependent upon the lunar period governing the occurrence of unusually high tides. For man, however, the alternation of light and darkness is of primary importance, and there is some doubt whether he can even detect or be affected by other geophysical periodicities such as that in the Earth's magnetic field or in barometric pressure which have periods slightly different from 24 hours.

The chief consequence of technological advance, with the easy availability of artificial heat and light, has been that men have tended to go to bed later and rise later while still adhering to the twenty-four hour period. Apart from Arctic dwellers, men have only escaped from this pervasive twenty-four hour period by staying underground for long spells, or on submarine cruises, but this will be the natural condition of space travelers who escape from the earth's shadow. A much more common disturbance is a sudden change in phase, such as occurs whenever one flies some substantial distance around the world. This is now common enough activity to raise practical problems, as well as providing much material for students of rhythms. Material which may help to provide an eventual solution to the problems of night workers, shift workers, and workers in industries such as transport where irregular hours may be neccessary.

Invisible rhythms underlie most of what we assume to be constant in ourselves and the world around us. Life is in continual flux, but the change is not chaotic. The rhythmic nature of earth life is, perhaps, its most usual yet overlooked property. Though we can neither see nor feel them, we are nevertheless surrounded by rhythms of gravity, electromagnetic fields, light waves, air pressure, and sound. Each day, as Earth turns on its axis, we experience the alternation of light and darkness. The moon's revolution, too, pulls our atmosphere into a cycle of change.

In concert with the turning earth, plants and animals exhibit a very pronounced daily rhythm. Often external cues synchronize living organisms into an exact tempo. However, when men or animals are isolated from their usual time cues, they do not keep to a precise solar day (24 hours) nor even a precise lunar cycle (24.8 hours). Nonetheless, isolated creatures do show rhythms that do not deviate very much from the 24 hours. This daily rhythm is denoted by the popular term "circadian."

Mollusks, fish, cats, marigolds, baboons, men - indeed, most living organisms show a circadian rhythm of activity and rest. Time-lapse photography has captured the circadian dance of plant life, showing how leaves lift and drop, open and close every 24 hours. Man, no exception to this daily ebb and flow, may be unaware that his body temperature, blood pressure, and pulse, respiration, blood sugar, hemoglobin levels, and amino acid levels are changing in a circadian rhythm. So, too, do the levels of adrenal hormones in his blood and concentrations of essential biochemicals throughout his circadian cycle. We excrete rhythmically, not merely according to the time of liquid intake. As a decade of laboratory researches has disclosed, there is a rhythmic fluctuation in the contents of the urine, along with almost every physiological function, from the deposition of fat or sugar in the liver to the rate at which cells are dividing.

In health we have an appearance of stability that cloaks a host of rhythms, hormonal tides, intermeshed with surges of enzyme activity, production of blood cells, and other multitudinous necessities for integration among these circadian production lines, and they in turn may act as timekeepers for us, guiding us in our periods of energetic endeavor, or rest, acting as distributors of our dreams and the tidal motions underlying our ever-shifting moods. Although we appear constant from the outside, we can feel inside that we are not really the same from one hour of the day to the next.

The corollary of all this circadian change is very dramatic, for a creature's strength and weakness also vary, depending upon biological time of day. Life and death may hang in the balance of timing. Mortality has been decided, experimentally, not by the amount, but by the time of day that a rodent received X-rays or was injected with pneumonia virus, bacteria, or drugs. Exposure to loud noise affects a rodent little during his period of rest, but may hurtle him into a frenzy, into convulvions, and even death if it occurs during his activity period. A volume of anecdotal literature attests that man, too, must be biologically different at different times of day. Now, these casual observations are being researched. People do perform differently on psychological and physiological tests at different hours. It may soon be learned why more pregnant women go into labor during the night or early morning hours than afternoon, and why doctors receive so many of their calls from patients with coronaries during these same hours. Deaths and symptoms of diseases do not seem to be distributed evenly around the clock. The pain of glaucoma and symptoms of certain allergies or of asthma seem to occur mostly at certain hours. As should be expected, drugs also affect man differently according to biological time of day. Biological time of day does not necessarily coincide with the local clock time. For example, a person who works at night and sleeps by day is likely to be 180 degrees out of phase with the daytime workers of the world. He sleeps when they are awake. His temperature is falling as theirs is rising. His adrenal steroid levels are low when theirs are high. The positions of various body functions indicate "time of day" in the body biological time of day.

Subjectively, people do notice that they are changing during the 24 hours of the day. Some people express this by their preference for afternoon or morning work, or may notice that they are emotionally resilient at certain hours and irritable at others. Like mechanical clocks, we synchronize our activity with the imperatives of society around us, and squeeze ourselves into the 24-hour schedule of modern life. But unlike mechanical clocks, our bodies will not instantly adjust. Jet travel has forced many of us to realize that internal time must be respected. A person is not the same at four a.m. as at four p.m., a fact that is unpleasantly palpable to the traveler who flies from Moscow to New York and finds himself trying to make mid-afternoon conversation in an office, while his body feels that it is not quite dawn. Two weeks later, long after he feels adjusted to local time, his body may be showing signs that adjustment is still not complete.

Related Research

The term "circadian" (derived from the Latin circa dies, about a day) was introduced by Halberg in 1959 (Mills, 1966). It refers to a time period which imprecisely approximates 24 hours in duration, ranging from 20 to 28 hours (Halberg, 1960). It is commonly applied to rhythmic ciologic functions which are geared to 1) an internal "biologic clock" (endogenous rhythm), 2) the intrinsic sleep-wake cycle, and/or, 3) exogenous influences (the solar day-night cycle, temperature, social environment, etc.). Examples of circadian rhythms are diurnal variations in body temperature, heart rate, performance, adrenocortical secretions, eosinophils (Halberg, 1964), and evaporative water loss (Hauty, 1965).

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 affected by instituting what was later to be called "daylight savings time" appeared in 1784 in the Journal of Paris; the author, Benjamin Franklin (Franklin, 1784). From the fact that the suggestion was not followed until the 20th century, it is seen how the human being clings to his customary sleep-wake cycle.

One of the grievances against the King contained in the Declaration of Independence, July 4, 1776, reads; "He has called together legislative bodies at places unusual, uncomfortable, and distant . . . for the sole purpose of fatiguing them . . ." Thus, the adverse effects of time and odd hour schedules on the subjective and physical state of individuals may have helped bring about the Revolution.

Prior to November 18, 1883, there were no standard time zones (Corliss, 1949). More than one hundred different time zones existed in the United States, based on "sun" time in individual towns as determined by the best local estimate of "noon." Michigan had as many as 27 local times. Scheduling coordination problems led the United States railroads to spearhead the adoption of standard time zones in 1883. The United Stated Government gave a legal sanction to the time zone principle by passing the Standard Time Act on March 19, 1918, adopting the "four-zone" system of the railroads.

In 1952, Strughold described the desynchronization of diurnal rhythms relative to air travel through many time zones (Strughold, 1952). Twenty-one years earlier, Wiley Post reported his anticipation of time zone physiological problems due to lon-distance flights (Post, Gatty, 1931). This is the first recorded instance of time zone effects relative to air travel. Mr. Post's successful record-breaking, globe-girdling flights appear to have been successful, in part, due to his recognition of the adverse effects of diurnal rhythm disruption on flight performance. He spent months learning how to eat and sleep at varying times in order to break his regular habits. In 1933 Mr. Post set a new around-the-world record flying alone in his single engine Lockhead Vega, the Winnie Mae. He had readjusted his "biologic clock" so his body was out of phase when he completed one half of his journey over Russia. Because of this, he claims he was able to stay alert without stimulants.

Air transportation has highlighted the relationship of circadian rhythms to the subjective and physical well-being of travelers, especially when they rapidly traverse more than four time zones. One country is currently proposing to amend its air crew flight time limitations as follows: "In the event of there being a time zone change of four or more hours between the place of departure and the place where duty ends, the subsequent rest period should be not less than twelve hours (Board of Trade, Great Britain, 1967).

Pincus first described a diurnal periodicity for the excretion of urinary 17-ketosteroids (Pincus, 1943). Adrenocortical secretions begin to enter the blood stream just prior to waking and serve to arouse the sleeper. The plasma cortisol level begins to rise about 0400, reaches a peak at about 0800, and declines to about one-half this level by late evening. These plasma cortisol levels are reflected in increased urinary 17-hydroxycorticosteroid, 17-ketosteroids, aldosterone, potassium, and water excretion two to four hours later.

There are diurnal variations in body temperature. The lowest values occur about four hours after midnight during sleep and are thought to result from variations in cutaneous blood flow (as a heat loss mechanism) and body metabolism, which decreases with sleep (Pincus, 1943).

Breathing rates change on a circadian basis (diminishing in amplitude and rate during sleep); the vital capacity diminishes after midnight, possibly due to an increased blood volume in the pulmonary vessels. The heart rate generally reaches a daily peak during the 1500-1800 period (Pincus, 1943).

Diurnal changes in human performance have also been noted. Halberg has reported a 70% increase in errors in reading gas meters after midnight (Halberg, 1964). Chiles has found cycling in performance in several studies (Chiles). Walsh and Misiak have reported diurnal variation of critical flicker frequency (Walsh, Misiak, 1966). The effects of shift rotation upon manual dexterity and mental capability have been observed in industry.

Since the disruption of circadian rhythms may adversely affect human performance, a number of studies have been conducted in an attempt to determine the point at which airline pilots become imparied to an unsafe degree. German scientists have determined, from psycho-physiologic studies of transatlantic airline pilots, that the greater the interval between the flight departure time and the pilots' "activity peak", the greater the strain of flying (Klein, Bruner, Ruff, 1966). They infer from their data that performance failures and accidents are more likely to occur during the "hour of lowest resistence."

French aeromedical physicians have reviewed responses of airline pilots undertaking flights through six time zones (Paris to New York) and found that 1) younger pilots suffered less than older pilots, and 2) that the hours of flight from east to west or vice versa should be weighed with an incremental coefficient that would give pilots more credit than for hours flown in a north-south direction (Lavernhe, Lafontaine, Laplane, 1965).

British aeromedical scientists have accomplished biomedical studies on transoceanic pilots prior to, during, and after their flights (Howitt, 1965; Howitt, 1966). The investigators found that heart rates varied directly with 1) work load during flight, 2) the specific airplane, 3) the nature of the approach aids and airfields, and 4) the weather. These data, when coupled with circadian rhythm disruption, have obvious implications governing scheduling in relation to departure times and recovery periods after flight across several time zones.

Studies conducted by the Federal Aviation Agency have indicated that several days are required for complete resynchronization of the biological rhythms after flights through several time zones; disruption did not occur on north-south flight (Hauty, Adams, 1965). Subjective fatigue was reported initially after all flights. Impaired psychological performance was demonstrated only after the long east-west flight. Re-adaptation to the "home" time zone was more rapid in most cases. The Federal Aviation Agency has been conducting fatigue studies relative to pilots since 1935 (Whitehead, 1935), but only since the jet age of the past decade have time zone effects become of major importance. With the supersonic transport, it should be possible to schedule crews for round trips the same day and keep them adapted for one time zone. Except for possible longer trips with less lay-overs, the effects of supersonic travel on passengers should not be significantly more (or less) disrupting than present jet travel.

There are many variables which effect any individual's experienced symptoms. These include times of departure and arrival, length of flight, direction of flight, lay-overs, travel experience, stress, age, physical condition, food and liquor consumed in flight, sleep in-flight, climate changes, and the new social environment. The normal temperature and heart rate diurnal curves can be affected by the social environment

(Mohler, Dille, Gibbons, 1968).

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. This markedly affects their activity pattern. When the time-variables, 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 oscilations of the organism and the exogenous periodicity (Hoffman, 1967).

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 five days, with a stay of four days in New York and return to Amsterdam after a stay of two and one-half hours in New York (Gerritzen, 1962). 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.

More recently, Japanese scientists have studied physiological responses to the time shifts associated with long-distance flights (Sasaki, 1964). 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 re-established after approximately 13 days (during this time the maximum of the cycle shifted by 40 to 50 minutes per day).

Hauty and Adams assessed subjects three days prior to a test flight to Tokyo for the purpose of obtaining a reference of biological time set to Central Standard Time. Subjects enplaned at 08.10 (CST) for a jet flight to Tokyo. After 18 total elapsed hours, they arrived at 17.00 (Tokyo time) and remained at Tokyo for a period of 10 days. During this period, biological assessments were repeated on alternate days beginning with the first full day in Tokyo. On the 11th day, subjects departed Tokyo at 09.30 (Tokyo time) on a jet flight and, 17 1/2 total elapsed hours, arrived back at Oklahoma City at 11.00 (CST). Here they were subjected to three consecutive days of biological assessment (postflight) beginning with the first full day of their return (Hauty, Adams, 1965). Rectal temperatures were out of phase about four or five hours (early) with Tokyo time. Reaction time was much slower on arrival in Tokyo, although, it had become closer to normal the third day in Tokyo (Hauty, Adams, 1965).

After the return flight to Oklahoma City, as compared to the baseline curve of rectal temperatures, they seemed to be in phase or very nearly so with Oklahoma City time suggesting that the lag time of the back shift is much less than for the primary shift. Reaction time increased on the first day back in Oklahoma City and then decreased on the second day. The increment in this case, however, is less than that which occurred in Tokyo (Hauty, Adams, 1965).

In a study by Hartman and Cantrell conducted as part of a special Military Airlift Command crew duty time test on the C-141, two squadrons were given forms on which to report their activities in half-hour blocks around the clock for 20 successive days. Out of 61 who completed the form without error, ten were alerted and went into predeparture crew rest, flew a mission to the Far East, returned, and completed their post-mission crew rest prior to the end of the study (Hartman, Cantrell, 1968). They had therefore gone through the entire cycle involved in an extended mission. These were used in a detailed analysis of daily patterns.

First, a model mission was empirically derived by obtaining model times for eating, sleeping, and flying on each successive day. Intervals between these activities were alloted to functions such as "crew rest", "on the flight line", "clearing operations" and similar aircrew duties arranged in the appropriate sequence. The resulting model was cross-checked against mean times for each activity obtained from the entire 61 aircraft commanders. Then, eating times, sleeping times, and flying times reported by the 10 pilots selected for detailed analysis were sorted into two groups, at home or on temporary duty (TDY) away from home, converted to percentages, and plotted on a time scale (Hartman, Cantrell, 1968).

Meal times and sleep lacked the pattern characteristic of normal schedules. In-transit meals showed peaks at two a.m. and four p.m. home base time; a complete reversal was observed in the TDY meals. (Hartman, Cantrell, 1968).

The difference between sleep onset at home and in transit is quite striking. Two-thirds of the sleep periods at home begin between 10 p.m. and two a.m. Sleep onset times while flying an extended mission are scattered around the clock. However, sleep durations are quite similar at home and on TDY (Hartman, Cantrell, 1968).

It appears that both the model mission and the raw data from the 10 aircraft commanders indicate the same thing: a pilot going out on an extended mission enters into an unpatterned schedule of living and working (Hartman, Cantrell, 1968).

In one of the most extensive studies reported, Klein, Wegman, and Bruner studied circadian rhythms in relation to physical fitness and stress resistence. In a control group they found the metabolic functions, the cardiovascular system, and adrenal activity to be especially rhythmic. They also found that psychological functions such as reaction time and ability to perform a complex psychomotor task were circadian with the best performance levels occuring between two and four o'clock in the afternoon and the worst performance levels occuring between two and four in the morning. Using Astrand's method for figuring maximal oxygen up-take they reported these functions to be circadian with the high from three to five in the afternoon and the low from three to five in the morning. There was approximately an eleven per cent difference in the two levels. The Schneider Physical Fitness Index was used as an index of fitness and they reported a 36% difference in the high and low in this measure. The authors emphasized, however, that these were indices of fitness, they doubt that the changes measured were indicative of changes in fitness levels. The largest differences recorded during the course of the study were 100% differences found in 17-hydroxycorticosteroid levels. The overall results of the study point to a rhythmic functioning of the human body with daily highs and nightly lows (Klein, Wegman, Bruner, 1968).

As statistical observations in lon-distance flights have shown, the majority of people are sensitive to this phase shift and experience some discomfort. They became hungry, got sleepy, or were awake at the wrong time. But it should be emphasized that this "phase shift syndrome" is not a pathological condition; it is merely the result of the time disharmony between the biological and the new local geographic clock. As a general rule, most travelers adjust themselves to a new circadian cycle at a rate of nearly one hour per day. This delay in time zone adaptation can be significant in many aspects (Strughold, 1969).

Professionally, circadian cycle desynchronization may have some significance for international conferences. The morning hours, during the first few days after long-distance, eastbound flights, and the late afternoon hours after westbound flights, are not the best times for important negotiations. During these days, the individual who has crossed a number of time zones, may be in a somewhat handicapped position due to his desynchronization condition. It also has been observed that actors, athletes, and race horses are not at their intellectual or physical best the first few days after arriving from a region four or more time zones away (Strughold, 1969).

The problem of cycle desynchrony is especially important for those who for occupational reasons have to cross and recross a number of time zones several times a month. Pilots and stewardesses on long-distance air routes are in this category; their physiological clock requires special attention, a need which is well recognized and taken care of by the pilot associations and the mental directors of the airlines (Strughold, 1969).

The question therefore arises: What can be done to minimize the time zone effects upon the biological clock?

First, a traveler could fly to his destination several days in advance, so that he will be adjusted to the new local time - postflight local preadaptation (Strughold, 1969).

Second, a synchronization of the physiological with the physical day-night clcle can be attained by presetting the physiological clock, i. e., by adapting gradually, several days in advance of the trip, a sleep and wakefulness pattern which corresponds to the physical day-night cycle of the place of destination - preflight adaptation, or preflight synchronization (Strughold, 1969).

Third, the use of mild pharmaca taken at the proper time might accelerate, as a kind of biochemical synchronizer, the physiological adjustment to the new geographic day-night cycle. A better method might be physical synchronizing by means of exercise and warm baths (Strughold, 1969), or, for the purpose of this study, a basketball game and shower.

In summary, several pertinent conclusions can be reached from the literature.

1. Many physiological and psychological functions are circadian in nature.

2. Phase shifts in these rhythms can be incurred through shifting the time cues artificially or by transition through time zones.

3. The adaptation fo the functions to new time zones or time cues is an individual matter. However, physiological functions generally take one day per time zone changed for adequate adaptation.

4. The adjustment can be facilitated through some pre-flight adjustments.

CHAPTER III

METHOD OF STUDY

The basketball free throw was used as an example of hand-eye coordination. Free throw data (free throws attempted and free throws made) were collected for the Baltimore Bullets, the Boston Celtics, the Buffalo Braves, the Philadelphia 76ers, and the New York Knickerbockers over the 1970-1971 regular season by means of box scores appearing in the New York Times. Team schedules were taken from the Official 1970-1971 National Basketball Association Guide.

The data was then categorized by time zone changes. For example, if a team traveled from its home time zone (Eastern Time Zone) to the Pacific Time Zone the change was considered a three time zone change (3TZC). The amount of time spent in a particular time zone was also considered as a period of adjustment. Thus, if a team from the Eastern Time Zone spends three days in the Pacific Time Zone, the team is considered to be adjusted to its new environment (one day adjustment for each time zone change). If a team travels from the Pacific Time Zone back to its home time zone (the Eastern Time Zone), this is also considered a three time zone change (3TZC). If a team travels from the Pacific Time Zone (after complete adjustment to the Central Time Zone, a two time zone change (2TZC) was recorded.

The data from home time zone away games was used as a theoretical base for comparison. This eliminated any chance of there being a home court advantage and also ruled out differences due to travel. The theoretical base was compared to games involving one, two, and three time zone changes. Comparisons were also made concerning differences between one time zone change and two time zone changes, one time zone change and three time zone changes, and between games involving two time zone changes and games with three time zone changes. For identification a test was also made between games played on the home court with no time zone changes involved and those games played away from home but in the home time zone (Eastern Time Zone) with no time zone changes involved.

A two-way analysis of variance technique was used to determine if differences existed between teams and/or time zones, and the Fisher Least Significance Difference test was used to define where the differences occurred. Critical F value was set at the 0.05 level of significance.

Computations were performed by the Computer Center of Kansas State University.

For purposes of computer identification, numbers were assigned to the basketball teams and the time zone changes as follows:

Team 1 (T_1)	Buffalo Braves
Team 2 (T_2)	Philadelphia 76ers
Team 3 (T_3)	Boston Celtics
Team 4 (T_4)	Baltimore Bullets
Team 5 (T_5)	New York Knickerbockers

Zone 0	games away in home time zone--no time zone change (HTZA)
Zone 1	games involving one time zone change (1TZC)
Zone 2	games involving two time zone changes (2TZC)
Zone 3	games involving three time zone changes (3TZC)
Zone 10	games at home in home time zone--no time zone change (HTZA)

CHAPTER IV

DATA ANALYSIS AND RESULTS

The experimental hypotheses proposed that jet lag would adversely effect hand-eye coordination as evidenced by free throw performance of professional basketball teams.

Table I illustrates the statistical results of the analysis of variance examination of the free throw data comparing the individual teams and also different time zone changes concerning free throw percentage (performance). The computer program used for this analysis was programmed to print actual probabilities with the F statistic. In Table I the F = .40 shows an 80 percent probability of being due to chance.

Table I

Analysis of Variance for Free Throw Percentage

Source	D.F.	Sums of Squares	Mean Squares	F	Prob.
Team	4	222.45	55.61	0.40	0.81
Zone	4	492.53	123.13	0.89	0.47
Team by Zone	16	1025.77	64.11	0.46	0.96
Residual	287	39752.46	138.51		

As the reader can see, there was no significant difference in free throw performance by time zone change or by individual team. This is further illustrated by Table II and Table III. Therefore, the hypotheses that (1) jet

Table II

Free Throw Percentages by Time Zone Change

	HTZA	1TZC	2TZC	3TZC	HTZH
Zone	0	1	2	3	10
Percent	75[a]*	74[a]	71[a]	79[a]	76[a]

*Items with same superscript not significantly different

lag would reduce hand-eye coordination as evidenced by free performance, (2) the reduction of hand-eye coordination would increase with the number of time zone changes, and (3) there would be a difference between home game and away

Table III

Free Throw Percentages by Team
(Theoretical Base)

Team	1	2	3	4	5
Percent	74[a]*	72[a]	76[a]	76[a]	76[a]

*Items with same superscript not significantly different

game free throw performance in favor of the home game situation when jet lag was not a variable were all rejected. For complete information consult Table III in Appendix.

Tables IV and V show the results of the analysis of variance examination

Table IV

Analysis of Variance for Free Throws Attempted

Source	D.F.	Sums of Squares	Means Squares	F	Prob.
Team	4	345.84	86.46	1.28	0.28
Zone	4	903.95	225.99	3.36	0.01
Team by Zone	16	963.17	60.20	0.89	0.58
Residual	287	19329.20	67.35		

of differences between time zone changes and individual teams of free throws attempted and free throws made respectively.

In Table IV the F value 3.36 for attempts by zones shows an actual probability of 0.01 and therefore has a less than one percent chance error.

Table V

Analysis of Variance for Free Throws Made

Source	D.F.	Sums of Squares	Mean Squares	F	Prob.
Team	4	100.37	25.09	0.54	0.71
Zone	4	533.78	133.45	2.86	0.02
Team by Zone	16	585.75	36.61	0.79	0.70
Residual	287	13381.63	46.63		

In Table V the F value 2.86 for free throws made by zones shows an actual probability of 0.02 and therefore has a less than two percent chance error.

A descrepancy was noted in the number of free throws attempted and the number of free throws made, Tables IV and V. These differences are further defined in Tables VI and VII and the related discussion following each table.

Table VI

Attempted Free Throws by Team
(Theoretical Base)

Team	1	2	3	4	5
Mean	30.71[a]*	32.29[a]	30.50[a]	28.53[a]	27.36[a]

*Items with same superscript not significantly different

No significant differences appeared in the number of attempted free throws between teams (Table VI), but significant differences were revealed between time zone changes (Table VII).

Table VII

Attempted Free Throws by Time Zone Change
(Theoretical Base)

	HTZA	HTZH	1TZC	2TZC	3TZC
Zone	0	10	1	2	3
Mean	33.58	31.86[a]*	31.17[a]	27.04[b]	25.73[b]

*Items with same superscript not significantly different

Differences noted in free throws attempted were; (1) between zone item 0 and between zone items 10, 1, 2, and 3; (2) between zone items 10 and 1 and between items 2 and 3. Zone items 10 and 1 were statistically the same as were 2 and 3. For complete information consult Table I in Appendix.

Table VIII shows there was no significant difference between the individual teams, but Table IX revealed that significant differences did exist in the number of free throws made between the time zone changes.

Table VIII

Free Throws Made by Team
(Theoretical Base)

Team	1	2	3	4	5
Mean	22.46[a]*	23.43[a]	22.93[a]	21.46[a]	20.89[a]

*Items with same superscript not significantly different

In Table IX differences recorded were; (1) between time zone item 0 and 10 and items 1, 2, and 3; (2) between zone items 10 and 1 and items 2 and 3.

Table IX

Free Throws Made for a Given Time Zone Change

	HTZA	HTZH	1TZC	2TZC	3TZC
Zone	0	10	1	2	3

Table IX (Cont'd)

	HTZA	HTZH	1TZC	2TZC	3TZC
Mean	24.96[a*]	24.11[ab]	22.89[b]	19.18[c]	20.03[c]

*Items with same superscript not significantly different

There was no significant difference between (1) home time zone away games and home time zone home games; (2) home time zone home games and one time zone change games; and (3) two time zone change games and those involving three time zone changes. For complete information consult Table II in Appendix.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

Free throw data from five National Basketball Association teams was recorded in categories of free throw percentages, free throws made, free throws attempted, and observations or games from which free throw data was taken. The data was then subjected to statistical analysis.

Since the statistical analysis identifies that there was no significant difference in free throw performance either between teams or time zone changes, it is concluded that;

1. Jet lag has no effect on hand-eye coordination as evidenced by free throw performance of professional basketball teams.

2. No "home court advantage" exists in free throw shooting among the subjects involved in this study.

3. Free throw accuracy does not seem to be affected by extraneous variables.

It is thought that since the subjects involved in this study were professionals, and have been participating in basketball a great number of years, that the free throw has become a routine procedure and is less effected by extraneous variables than, for example, the personal foul.

The statistical analysis did, however, reveal that the mean number of attempted free throws grew smaller as more time zone changes became involved. This can be attributed to the fact that the traveling team was fouled less frequently as more time zone changes became involved.

The lack of effect on hand-eye coordination as evidenced by free throws attempted in games involving three time zone changes might be explained by the fact that the visiting team had not been in that particular time zone long enough to become aware of the jet lag effect. For example, Team X travels from the Eastern Time Zone to the Pacific Time Zone for a four game series in four days. Team X arrives in Team Y's city only an hour before tip-off for the first game and had not had time enough to become aware of their desynchronization by their new environment. But in 24 hours, at the time of the second game, they are aware of their desynchronization.

The number of free throws made also decreased as more time zone changes became involved. Since there was no significant difference in free throw percentages across time zones, fewer free throws made can be attributed to the fact that the number of free throws made decreased accordingly with the number of free throws attempted.

The limits of this study may have been too stringent to consider realistically the economic factors of the effects of jet lag on hand-eye coordination as evidenced by free throw performance. Significant differences at the 0.05 level may be omitted factors that could be very important to coaches, players, and all personnel concerned with professional athletics.

Therefore, the following recommendations are submitted:

1. In view of the background research for this study, very close attention should be paid to time zone travel in scheduling when and/or if it becomes involved.

2. Considering the background research, pre-flight adjustment might be employed whenever practical.

3. Further study should be conducted using the personal foul as an example of coordination.

4. Further study should be conducted using a higher level of chance error. The rejection of all original hypotheses suggests that the level of significance was too stringent. Jet lag has been proven to effect human performance adversely (background research). Thus, a professional organization, such as basketball, should know at what point jet lag effects coordination.

5. Further studies in this area should include a wider range of subjects and more teams from all regions of the nation.

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APPENDIX

TABLES OF FREE THROW DATA

Table I

Attempted Free Throws

Time Zone	T_1 Mean	T_2 Mean	T_3 Mean	T_4 Mean	T_5 Mean	Total Mean
0	34.99	38.84	32.43	31.72	29.91	33.58
1	33.12	34.77	31.75	32.22	23.99	31.17^{a*}
2	26.20	24.99	27.50	26.50	29.99	27.04^{b}
3	30.67	25.99	26.67	20.99	24.33	25.73^{b}
10	28.54	36.86	34.14	31.19	28.57	31.86^{a}
Mean Total	30.71^{c}	32.29^{c}	30.50^{c}	28.53^{c}	27.36^{c}	

*Items with same superscript not significantly different

Table II

Free Throws Made

Time Zone	T_1 Mean	T_2 Mean	T3 Mean	T_4 Mean	T_5 Mean	Total Mean
0	25.31	29.26	23.87	23.72	22.64	24.96[a*]
1	23.99	25.38	24.25	22.67	18.17	22.89[b]
2	20.20	15.99	18.99	19.50	21.20	19.18[c]
3	21.99	18.50	21.67	17.99	19.99	20.03[c]
10	20.79	27.99	25.86	23.42	22.47	24.11[ab]
Mean Total	22.46[d]	23.43[d]	22.93[d]	21.46[d]	20.89[d]	

*Items with same superscript not significantly different

Table III

Free Throw Percentage

Time Zone	T_1 Mean	T_2 Mean	T_3 Mean	T_4 Mean	T_5 Mean	Total Mean
0	73.91	75.13	73.57	74.99	76.25	74.77[a*]
1	73.06	73.27	77.31	69.63	74.58	73.57[a]
2	76.68	63.99	70.23	75.44	68.91	71.05[a]
3	71.77	71.23	80.93	85.71	82.41	78.51[a]
10	73.44	77.03	75.88	75.61	77.52	75.90[a]
Total Mean	73.77[b]	72.23[b]	75.58[b]	76.28[b]	75.93[b]	

*Items with same superscript not significantly different

Table IV

Observations

Time Zone	T_1	T_2	T_3	T_4	T_5	Total
0	16	19	16	18	22	91
1	8	13	12	9	6	48
2	5	1	2	2	5	15
3	3	2	3	1	3	12
10	28	28	29	31	30	146
Total	60	63	62	61	66	

Dear Coach;

A major disadvantage of jet travel today is the phenomena termed jet-lag, or circadian upset.

With today's jet age, long flights across time zones expand and condense days and nights until mind and body, the circadian rhythms, get out of sync with their surroundings. After a long flight one may function at his destination but as well as when the body gets a chance to catch up, which takes about one day for each time zone crossed.

It is generally thought that circadian upsets are mainly factors of west to east or east to west flights.

Research with airline pilots and studies conducted by the Air Force shows that there is a definite effect on the human body by immediate time zone change. It also seems that the delicate hand-eye coordination would be detrimentally affected, but never has any research been conducted in a sports setting.

For a Masters Thesis at Kansas State University in Physical Education, I would like to determine if hand-eye coordination in a sports setting is affected by jet travel.

To do this I would like to compare free throw percentages of professional basketball players. Therefore I am seeking your help and asking for a game by game free throw record of your players for the 1970-71 regular season and a schedule of games so I may determine the time zone changes and time spent in each time zone.

If traveling does have a marked influence on the hand-eye coordination of the players, this study will be a valuable asset to you in planning your away from home schedule in the coming years.

I have enclosed a stamped, self-addressed envelope for your mailing convenience.

The results of this study will be mailed to you immediately upon completion.

Thank you very much for your help and cooperation.

Sincerely,

Jake Myers

Jake Myers

THE EFFECTS OF JET LAG ON HAND-EYE COORDINATION

by

JACOB ALAN MYERS

B. S., Kansas State University, 1970

AN ABSTRACT OF A MASTER'S THESIS

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KANSAS STATE UNIVERSITY
Manhattan, Kansas

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Data from five teams of the National Basketball Association was subjected to a two-way analysis of variance test to determine if jet lag had an adverse effect on hand-eye coordination. As an example of hand-eye coordinations, the basketball free throw was employed. Free throw performance data was tested comparing the individual teams and by one, two, and three time zone changes. As a theoretical base, the home time zone away games where no time zone changes were involved was used for comparison with the other variables including home time zone home games with not time zone changes involved. Data was investigated at the 0.05 level of significance.

The statistical analysis revealed that (1) jet lag had no significant effect on free throw performance, (2) no "home court advantage" existed, (3) the effect of jet lag on free throw performance was not linear, and (4) there was no significant differences in free throw performance between individual teams. Therefore, all original hypotheses were rejected.

The statistical analysis did, however, reveal a significant difference in free throws attempted between time zone changes that was not consistant with the teams involved. The difference in attempts by time zone changes was explained by the fact that the traveling team seemed to commit more personal fouls as more time zone changes were involved. It appeared that the difference in number of attempted free throws could have been a result of jet lag.

It was concluded that the significant difference in free throws attempted as a result of more personal fouls committed as more time zone changes became involved was sufficient reason to warrant further study in the area of the effects of jet lag on coordination.