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HUMAN CIRCADIAN RHYTHMS AND THE SHIFT WORK PRACTICES OF AIR TRAFFIC CONTROLLERS

Raymon M. McAdaragh

This research investigates human circadian rhythms and describes how they are affected by different types of shift work rotation patterns. Past studies have indicated that air traffic controllers prefer to work the type of rotation patterns that induce the negative result of circadian dysrhythmia. It has been established that workers experience decrements in performance from this condition. Recently, an alternate work schedule has allowed controllers to work new various rotation patterns, some of which disrupt circadian processes even more than previously preferred schedules. A descriptive analysis of controller work schedules from randomly selected facilities indicates that 16% of controllers are working the most disruptive type of schedules and that another 29% are working other dysrhythmia-inducing shift rotations. It is concluded that performance deficiencies are highly probable among these controllers and that tests should be conducted to determine the significance of the effect.

INTRODUCTION

The purpose of this study was to determine what type of shift work patterns were being practiced by air traffic controllers. Studies have indicated that night work and certain types of shift work rotation patterns subject workers to adverse physiological and psychological effects. These adverse effects are the product of internal disassociation, a condition experienced by those individuals whose circadian (24-hour) rhythms have lost phase relation to one another. Research has demonstrated that subjects affected by circadian dysrhythmia experience subjective sleepiness, reduced performance ability, insomnia, increased health risks, and a potential for accidents and uncontrolled manifest sleep at work (Akerstedt, 1988).

Statement of Problem

The air traffic control profession carries a great responsibility, in terms of life and property, which is dependent on the controllers' alertness and performance ability. The working hours of controllers are governed by federal regulations to a limited degree but these regulations may be overridden by union-management agreements. Controllers work a variety of shift work schedules, but some studies by the Civil Aeromedical Institute (CAMI) in the 1970s and 1980s indicated a controller preference for the type of rotation patterns that are now known to induce circadian dysrhythmia (Melton, 1985). These studies also indicated that controllers were actually experiencing some of the adverse effects characteristic of internal disassociation (Melton, 1985; Melton et al., 1973; Melton et al., 1975; Saldivar, Hoffman, & Melton, 1977).

Other studies (Hawkins, 1987) also were conducted to try to find solutions to the problem of circadian dysrhythmia, and in 1982 the results of one study described a type of shift work rotation pattern designed to account for circadian rhythms and reduce the onset of internal disassociation (Czeisler, 1982). In recent years, however, agreements between the Federal Aviation Administration (FAA) management and controller unions have allowed controllers the option of working an alternate work schedule (AWS) consisting of various combinations of rotations and daily work hours. One of the options included is a 10-hour, four-day compressed work week. This type of work schedule and some of the other AWS shift work patterns now available run contrary to the recommendations made by the 1982 study to improve schedules.

Review of Related Literature

It has been determined that most biological processes consist of sequences of events in a rhythmic nature, most of which are controlled by the hypothalamus of the brain. From the hypothalamus, the rhythmic processes of the body's internal organs are influenced (Romer, 1971). Some other cycles, however, such as the body's temperature cycle, which influences the sleeping cycle, are controlled elsewhere (Hawkins, 1987).

Body rhythms occurring on a daily basis are known as circadian rhythms and are centered on subjective midnight (Kronauer, Jewett, & Czeisler, 1991). The cycle of light and darkness is the strongest entraining agent. Normally, the circadian clock is set when daylight enters the brain (Chollar, 1989). But instead of simply resetting the clock, the light exposure terminates all rhythmicity so that the cycles may start again (Winfree, 1991).

Other entraining agents, such as meal time, physical activity, and sleep also influence the body's oscillatory functions. The brain, which is supported by the timing of these processes, demonstrates a rhythm that is reflected in measured performance (Hawkins, 1987).

In 1975, CAMI demonstrated that a shift in routine causes performance deficiences. It was concluded that individuals making a 12-hour alteration in routine should not perform critical tasks during the first awake period following the alteration, and that they should not work for more than eight hours continuously for the next several days (Higgins et al., 1975). It was later determined that as much as 82% of performance decrements experienced after a change in routine are associated with circadian dysrhythmia as opposed to sleep loss (Rankin, Latham, Peters, & Penetar, 1989).

Studies have demonstrated that circadian rhythms take several days to realign and that a very consistent pattern of symptoms is present until resynchronism occurs (Monk, Moline, & Graebar, 1988). It also has been determined that resynchronism occurs at a different rate depending on whether the phase must be delayed or advanced (Hawkins, 1987). A state of internal disassociation associated with impairments in mood and performance proficiency has been used to describe the effects of circadian dysrhythmia (Monk, Moline, & Graebar, 1988).

At the 1989 meeting of the American Association for the Advancement of Science, researchers reported the following:

> Police officers, nuclear-power-plant operators, medical interns, and many others who work night perform more poorly and are involved in more on-the-job accidents than their daytime counterparts. This is particularly true for those who rotate between daytime and night work, and thus have their sleep schedules constantly disrupted. (Chollar, 1989, p. 26)

Shift work also has been shown to have a negative effect on the well-being of individuals. Sleep loss and circadian dysrhythmia have a negative influence on each other (Akerstedt, 1988). The term shift work insomnia has been used to describe this condition (Akerstedt & Kecklund, 1991).

And, when considering heart disease, cancer, stroke, or all causes combined, it has been demonstrated that individuals sleeping six hours or less or nine hours or more have a higher death rate than individuals sleeping seven or eight hours whatever the cause including shift work insomnia (Wingard & Berkman, 1983). It also has been shown that there is an earlier occurrence of gastrointestinal disease in three-shift workers and that cardiovascular disease in general is rated to the amount of shift work (Akerstedt, 1988).

Sleepiness in individuals has been measured in many studies through the Multiple Sleep Latency Test (MSLT), which uses the electroencephalogram (EEG) and electrooculogram (EOG) to measure alpha and theta signs of sleepiness. Torsvall and Akerstedt (1989) showed that train drivers with no social contacts indicated strong signs of sleepiness during night drives and even missed traffic signals while dozing off. Akerstedt, Kecklund, and Knutsson (1991) demonstrated that industrial workers who were allowed social contacts only indicated signs of sleepiness in the early morning hours during dozing episodes. Earlier, Lille and Chefiout (1982) demonstrated that busy air traffic controllers did not indicate signs of sleepiness (Akerstedt, 1988). From the results of these studies it is now suggested that EEG monitoring only monitors manifest (expressed) sleep and not latent (concealed, dormant) sleepiness. If latent sleep surfaces abruptly during a reduction in activity, it might pose a

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threat to safety (Akerstedt, Kecklund, & Knutsson, 1991).

CAMI conducted several studies between 1971 and 1985 to determine the effects of shift work on air traffic controllers. These studies compared stress levels, mood variations, subjective sleepiness, and the sleep logs of controllers on different shift rotation patterns to determine whether certain schedules caused problems for them. The results of these studies showed that, generally, there was no significant difference between the controllers' stress levels on different shifts, but night work caused highly rated subjective sleepiness and reduced hours of sleep during the work week (Melton, 1985; Melton et al., 1973; Melton et al., 1975; Saldivar, Hoffmann, & Melton, 1977; Smith, Melton, & McKenzie, 1971).

Akerstedt and Kecklund (1991) demonstrated that shift workers never overcome the negative effects of shift work and that shift work insomnia is a persistent problem for those who are afflicted with it. This inability to adapt appears to be due to the constant conflict within the endogenous timing system that drives circadian rhythms (Cauter & Turek, 1990).

Study results clearly show that shift work is associated with increased subjective, behavioral, and physiological sleepiness.

> These effects are particularly pronounced during the night shift, and may terminate in actual incidents of falling asleep at work. In some occupations this clearly constitutes a hazard that may endanger lives and have large economic consequences.
>
> Furthermore, since night shift sleepiness affects a large majority of individuals engaged in it, the threat is quite real and has probably been underestimated in the past. (Akerstedt, 1988, p. 30)

Controller Work Schedules

Air traffic controllers work a variety of shift work schedules. In some facilities, controllers are allowed to design their own shifts as long as they meet facility needs and the standards listed in the FAA's Facility Operations and Administration manual. This manual states:

> Facility Air Traffic Managers shall ensure that Air Traffic Control Specialists (ATCSs) assigned to a position of operation:
> 1. Do not work more than 6 consecutive days.
> 2. Do not work more than a 10-hour day.
> 3. Have an off-duty period of at least 8 hours between watches. (Facility Operations and Administration, 1991, p. 2-4-1)

FAA regulations may, however, be superseded by union agreements. The current agreements between the FAA and the two controller unions, the National Association of Air Traffic Specialists (NAATS) and the National Air Traffic Controllers Association (NATCA), have similar statements. The NAATS agreement, for example, states: "Any provision of this agreement shall be determined a valid exception to and shall supersede any existing agency rules, regulations, orders and practices which are in conflict with the agreement" (NAATS/FAA Agreement, 1988).

The most widely preferred rotational schedule that has been used by ATCSs is the 2-2-1 (two evenings, two days, and one midshift) phase-advanced, compressed schedule. A rotation in the opposite direction is considered a phase-delayed schedule. The five-day phase-advanced schedule also has been common among controllers. Adaptation to phase-delayed schedules is easier than with phase-advanced schedules for the same reason that east-to-west transmeridian flight causes fewer jet lag symptoms than does west-to-east transmeridian flight (Melton, 1986).

Czeisler (1982) therefore recommends a clockwise rotation (morning-afternoon-night) or phase-delayed rotation for rotating shift workers. The human free-running period of the sleep-wake cycle averages 25 hours; consequently, only a small phase advance with respect to the environment is allowed, but a two- to three-hour phase delay is required. Work schedules should be designed to account for this. Czeisler has demonstrated that a phase-delayed rotation with a 21-day period between shift changes improves production and well-being in three-shift workers (Akerstedt, 1988).

Earlier, Folkard (1980) found that permanent shifts are good for occupations requiring simple perceptual motor tasks, but that rapid rotating schedules are preferred for more cognitive, memory-loaded tasks provided that circadian rhythms are not adjusting. Folkard cautioned that further research was needed.

Controllers tend to prefer phase-advanced schedules because of the longer breaks they provide between work weeks. By compressing the work week, the longer break is realized at the expense of shortened intervals between work sessions. Work schedules are generally voted on by union members and presented to facility management by the facility union representative for approval.

Controllers generally do not work steady, nonrotating shift work because the FAA discourages this practice. Traffic is generally light on the midwatch and it is felt that controllers permanently on this shift would experience a deterioration of proficiency in handling heavier work loads, should they be called on to do so. Also, social isolation from professional colleagues would keep these controllers from attending training, briefings, and conferences (Melton, 1985).

On Jan. 23, 1991, and on May 21, 1991, memorandums of understanding were issued between the FAA and the two controller unions. These agreements allow the usage of an alternate work schedule by the controller work force. On a voluntary basis only, the AWS allows controllers to work many varieties and combinations of schedules and hours, including a rotating schedule that further compresses the work week into four 10-hour days. Controllers nationwide may be taking advantage of this opportunity to have even longer breaks between work weeks by using this schedule in a phase-advanced, compressed rotation pattern. If this is the case, internal disassociation and the adverse consequences associated with it can be expected to affect these controllers even more than previously favored schedules have done in the past.

As noted earlier, FAA regulations can be superseded by agreements between the FAA and controller unions. It is now possible for controllers on the AWS to be held over or called in early for up to two hours of overtime. For example, a local union-management agreement at one Automated Flight Service Station (AFSS) allows controllers on the AWS to work up to 12 consecutive hours with a minimum of eight hours between shifts when overtime is involved.

Research Question

The responsibilities of air traffic controllers may be greater than those of individuals in most other occupations. Considering the results of previous studies on human circadian rhythms, including those studies by the the FAA's CAMI that indicated a controller preference for compressed work schedules, it appears to be important to determine whether air traffic controllers have amended their shift work practices to take into account the probable consequences of the different types of shift rotation patterns.

The results of the CAMI study of 1975 indicated that persons on shift work should not work more than eight hours continuously following a 12-hour shift in the wake-sleep cycle or performance decrements will result. It also indicated that the first work period after the shift in routine should not be worked at critical tasks for this same reason. In light of these findings it would be expected that new shift work policies would have been implemented for controllers. But in recent years a new alternate work schedule with an even more compressed work week and extended daily work hours has been made available to the controller work force. The question to be answered by this study is: What type of shift work rotation patterns are currently being worked by ATC specialists at full-time operational facilities?

METHOD

Subjects

In order to provide a sample of subjects that is representative of the entire air traffic control work force, a sample of work schedules was randomly selected from the three types of air traffic control facilities in the country: Air Route Traffic Control Center (ARTCC), Air Traffic Control Tower (ATCT), and Flight Service Station (FSS), which are now mostly automated AFSSs. The only condition applied was that the facilities selected for the study include only full-time operational facilities (24 hours per day).

If the samples were to include schedules from part-time facilities, erroneous results would be obtained considering shift work rotation patterns.

By far, most controllers work at full-time operational facilities, and controllers at part-time facilities generally are not expected to be affected by

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circadian dysrhythmia.

In order to obtain the necessary type of sample for the study, the facilities were selected from the FAA's Administrator's Fact Book (Aug. 1992). This publication lists the 21 ARTCCs, and the 50 busiest ATCTs and FSSs in the country. Only a few of the facilities on this list are not full-time facilities, and they could easily be eliminated. Also, busier facilities have more controllers.

To make the sample selection, each facility was assigned a consecutive number (0-120), and arbitrary numbers were then selected from a list of 10,000 random numbers. From the facility lists the following were randomly selected: Two ARTCCs, Memphis (MEM) and Jacksonville (JAX); five ATCTs, Memphis (MEM), Los Angeles (LAX), Phoenix (PHX), Nashville (BNA), and Miami (MIA); and five FSSs, McAlester (MLC), St. Petersburg (PIE), Terre Haute (HUF), Bridgeport (BDR), and Fort Dodge (FOD).

To obtain the required controller work schedules for the sample, each of the selected ATC facilities was contacted to request a copy of its controller's 1992 watch schedule with the names of the controllers removed for the purpose of anonymity.

The names of the controllers were not needed for the study, and it was felt that anonymity would help in obtaining the schedules more easily. This selection method provided about a 10% sample of controllers from the busiest full-time ATC facilities in the country, or about 6% (997) of the 16,762 operational controllers in 1992. All ARTCC and ATCT specialists are governed by NATCA/FAA agreements and all FSS specialists are governed by NAATS/FAA agreements. All air traffic controllers are governed by the same FAA work-hour regulations.

PROCEDURES

Once the required sample of controller work schedules was obtained, the shift work patterns of all working developmental and journeyman controllers were analyzed and categorized into seven categories based on their disruption to circadian rhythms:

1. Phase-advanced, compressed work-week schedules of greater than eight hours per shift (AWS). According to research, this type of schedule should have the most disruptive physiological and psychological effects.

2. Phase-advanced, compressed work-week schedules (2-2-1, and variations of it) that work all shifts each week and straight night shifts. According to studies, these are the shift work patterns that disrupt circadian rhythms continuously.

3. Phase-delayed schedules (1-2-2, and variations of it) that work all shifts each week. These schedules are slightly better than the phase-advanced compressed work week in that they allow more rest between shift rotations.

4. Phase-advanced or phase-delayed straight shift schedules (five-day to nine-day) that rotate on a weekly basis or up to every nine days. Research has demonstrated that desynchronized rhythms require approximately nine days for resynchronization to occur. The week of midshifts will require at least that long for the resychronization process to be completed.

5. Phase-delayed straight shift schedules (10-day or more) that rotate on a greater than nine-day basis. According to research this is the type of schedule recommended for workers who must rotate shifts (ideally on a 21-day rotation).

6. Straight day or evening shifts, or day and evening shifts with no midnight shifts. These shifts allow for a steady sleep-wake pattern and only differ in the daily routine of work and free time.

7. All combination-type shifts, including the many variations of the AWS. These varying work schedules will have too many variables to make valid assumptions for this level of study.

Many of these work schedules may be very disruptive to circadian systems but some may be less disruptive. Categories 1 and 2 may be considered the most disruptive types of schedules, while Categories 3 and 4 are less disruptive for schedules that rotate.

Category 5 is the type of schedule recommended by Czeisler for workers who must rotate shifts, and Category 6 includes no midnight shifts and, thus, little or no disruption to circadian rhythms.

Category 7 includes any schedules that could not be placed within the scope of this study.

In order to qualify for the rapid rotation categories (1, 2, and 3), a schedule was only considered if the midnight shift was included in it at least every other

Table 1
ATC Work Schedule Dispersion by Category Type

CATEGORIES								
ATC Facilities	1	2	3	4	5	6	7	No. ATCSs
MEM ARTCC	21	124				29	69	243
JAX ARTCC	94	22				47	98	261
MLC AFSS	14	8				7	16	45
PIE AFSS		16				31	14	61
HUF AFSS		5				14	24	43
BDR AFSS						42	16	58
FOD AFSS	2	7				8	26	43
MEM ATCT	7	35				17	7	66
LAX ATCT		21				16		37
PHX ATCT	12	13				1		26
BNA ATCT	12	4				14	15	45
MIA ATCT	2	35				11	21	69
Total	164	290				237	306	997
Percent	16%	29%				24%	31%	

Categories 1-7 represent the following schedule types:
1. Phase-advanced, compressed-week schedules (>8 hour shifts).
2. Phase-advanced, compressed-week schedules (2-2-1)/straight mids.
3. Phase-delayed schedules (1-2-2 variety).
4. Phase-advanced or delayed schedules (5- to 9-day rotations).
5. Phase-delayed schedules (> 9-day rotation intervals).
6. Straight day or evening schedules (no mids).
7. Randomly-rotating schedules (not consistent on a weekly basis).

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Table 2
Work Schedule Category Percentages by ATC Facility Type

	CATEGORIES						
Type of Facility	1	2	3	4	5	6	7
ARTCC	23%	29%				15%	33%
AFSS	6%	14%				41%	39%
ATCT	14%	44%				24%	18%

week, or 50% of the time. For instance, most 2-2-1 schedules did not work the midshift every week. If the midshift did not show up on that type of schedule at least every other week, the schedule was assigned to Category 7.

RESULTS

Of the three-shift, rapid-rotating type sample schedules assigned to categories that are within the scope of this study (Categories 1-6), 100% were assigned to the categories that disrupt circadian rhythms the most (Categories 1 and 2). This amounts to 45% of the entire sample (see **Table 1**).

Category 1 (the most disruptive AWS with a compressed work week) included 16% of the sample (164 controllers), while the traditional 2-2-1 and straight-mids category (Category 2) included 29% (290 controllers). None of the sample schedules was assigned to the two less disruptive rotating shift categories (Categories 3 and 4) or to the category recommended by Czeisler (Category 5). Of the entire sample, 24% (237 controllers) had schedules without any midnight work and were assigned to Category 6, while 31% (306 controllers) indicated individualized randomly rotating schedules that could not be categorized within the scope of this study (Category 7).

Table 2 displays the schedule category coverages by ATC facility type. This table seems to indicate that the ARTCC/ATCT specialists generally work more of the disruptive-type schedules than do the AFSS specialists. A look at Table 1, however, reveals that MLC AFSS is an exception to that observation in that nearly half of its schedules are assigned to Categories 1 and 2, indicating that this is not a characteristic that applies to all AFSSs.

DISCUSSION

If the test sample in this study is representative of the entire controller population working at full-time ATC facilities, it can be expected that a large number of controllers may now be working historically favored schedules that are disruptive to circadian rhythms, and that many of the other controllers have opted to work a phase-advanced alternate work schedule that further compresses the work week and increases the probability of negative effects on their circadian rhythms. If this is the case, most controllers can be expected to be working these types of rotational schedules. It is important to mention again that controllers choose these schedules and are willing to work fatigue-inducing rotational patterns in order to obtain greater breaks between work weeks. By contrast, a large number of controllers may now be working schedules that do not disrupt circadian rhythms, while many controllers could be working individualized schedules that are not of a standard repetitive nature, or are some variation of the AWS.

The results of this study also indicate that none of the sample's schedules fell under the traditionally favored weekly rotation category (Category 4). This finding may be due to the fact that 24% of the sample were assigned to Category 6 (straight day and evening work). With 45% of the controllers now working midshifts in Categories 1 and 2, and many controllers in Category 7 working midshifts as well, more controllers are now able to design schedules that do not include midshifts. The introduction of the AWS has now made it possible for many controllers to design and work individualized schedules rather than work the traditional facility-wide schedules of the past.

Czeisler's recommended rotating shift pattern (Category 5) also was undetected in the sample. This finding tends to indicate that controllers do not prefer this type of schedule and that the FAA has not made any requirements governing controller work schedules beyond the regulations that have been observed in the past. Considering the results of studies that relate to circadian dysrhythmia, including the FAA's own CAMI study (Higgins et al., 1975) that demonstrated performance deficiencies associated with shifts in routine, this is quite surprising. Other studies cited in this paper (Akerstedt 1988; Folkard, 1980; Monk et al., 1988; Rankin et al., 1989) also describe performance deficiencies associated with circadian dysrhythmia and all have been available for consideration.

Because the work schedules assigned to Categories 1 and 2 are assigned based on the occurence of the midshift at least 50% of the time, assuming a valid sampling, it may be possible that at least 45% of all controllers working at full-time ATC facilities are afflicted with circadian dysrhythmia at least 50% of the time. These controllers could be expected to suffer from internal disassociation and, as a result, experience subjective sleepiness, reduced performance ability, insomnia, increased health risks, and a potential for accidents and uncontrolled manifest sleep at work. In view of this possibility, it appears to be imperative, and is therefore recommended, that studies be conducted to determine what levels of dysrhythmia-induced deficiencies, particularly those concerning performance ability, are present among the suspect controllers. This appears to be even more important than most of the earlier studies conducted by CAMI that focused primarily on controller stress levels. These studies mostly indicated that stress is not related to dysrhythmia.□

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