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Fatigue in Air Traffic Controllers:

Literature Review

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16. Abstract

Air traffic controllers often experience fatigue on the job, due to shiftwork, workload, and stress. Performance impairment resulting from fatigue is an important concern for system safety and requires countermeasures. This document reviews the literature on the major sources of fatigue and provides potential countermeasures to this problem. The topics surveyed cover fatigue related to shiftwork and schedules, workload and time on task, and automation. Lifestyles, personality, and individual differences that influence how an individual experiences fatigue are also considered. Potential countermeasures include methods of increasing alertness during night shifts, topics for training and education, strategies for reducing fatigue related to sleep loss, recommendations on scheduling, and aspects to consider in the automation process.

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1 INTRODUCTION

Air traffic controllers (ATCs) often experience fatigue on the job due to shiftwork, workload, and stress. Until now, no critical incident has been directly attributed to fatigue, but fatigue is a factor that cannot be easily assessed after the occurrence of an incident. Still, Roske-Hofstrand (1995) observes that 21% of reported incidents in the Aviation Safety Reporting System (ASRS) mention factors related to fatigue (for both pilots and ATCs). The impairment of ATC performance due to fatigue is thus an important concern for system safety and requires the development of countermeasures. The goal of this document is to review the research literature on fatigue among ATCs and to present recommendations with respect to potentially viable countermeasures to reduce the impact of fatigue in air traffic control operations.

2 BACKGROUND

2.1 Sources of Fatigue Among ATCs

Fatigue among ATCs originates from various sources. Roske-Hofstrand (1995), after consulting the ASRS, categorized types of fatigue mentioned by ATCs: **physical fatigue** (related to lack of sleep and sluggishness at start of a shift); **shift/schedules-related fatigue; end of shift and workload fatigue** (related to high and low workload, and time on duty); and **emotional stress** (lack of sleep related to problems with supervisors, co-workers, etc.). Not all authors would agree on this typology; still, a lot of attention has been focussed on fatigue caused by shiftwork, schedules, workload and time on task, and also on factors influencing resistance and vulnerability to fatigue. The following sections describe current, related literature.

2.2 Shiftwork and Schedules

2.2.1 Shiftwork

Many airports have 24-hour-a-day air traffic control operational requirements, thereby requiring some controllers to work overnight. Shiftwork has the potential to disrupt the circadian rhythms of the body and sometimes impair work performance, raising concerns for the safe operation of air traffic control systems (Costa, 1999; Meyer, 1973). In the literature on air traffic control, a great deal of attention has focussed on how shiftwork and schedules result in fatigue, and on how they affect performance, sleep, mood, and health. Authors investigating fatigue among ATCs find that fatigue related to shiftwork is twofold: 1) ATCs working at night are at the nadir of their circadian rhythms, which results in fatigue, sleepiness, and performance decrements; 2) shift schedules often create sleep debt, which reduces alertness and performance, particularly during night shifts and at the beginning of early morning shifts.

The night shift is obviously an important cause of concern when considering shiftwork. Many studies observed that ATCs reported more sleepiness during the night shift, compared to day or evening shifts (Cruz and Della Rocco, 1995b; Della Rocco and Cruz, 1995a; Grandjean et al., 1971; Rhodes et al., 1994; Rhodes et al., 1996), peaking in the early morning hours in some cases (Costa, 1999; Luna, 1997). Low traffic load occurring during night shift contributes to increased fatigue and sleepiness in ATCs (Luna, 1997; Wickens, Mavor, and McGee, 1997). Other authors mentioned that ATCs were experiencing more fatigue, less vigour, and more confusion as the night shift progresses (Costa, 1993; Luna, French, and Mitcha, 1997; Luna, French, Mitcha, and Neville, 1994; Melton, 1985; Saldivar, Hoffman, and Melton, 1977). Luna et al. (1997; 1994) measured activity level for controllers using an actigraph (a monitor recording physical activity) and observed an average of 85 minutes of sleep during night shifts (including naps during breaks), a result three times greater than sleep measured during day and evening shifts. By observing electroencephalogram (EEG) patterns of ATCs working midnight shifts, Rhodes et al. (1996) found corroborating observations of microsleeps and periods of inattention, showing that ATCs had more "difficulty remaining alert during midnight shifts" (p. viii).

The sleepiness and fatigue reported by ATCs can be attributed to the circadian trough occurring at night, but also to sleep deprivation and its associated sleep debt. For the shiftworker, night shifts entail sleeping during the day. Again, because of circadian rhythms, and also because of the diurnal orientation of social life, ATCs working at night get the shortest amount and poorest quality of sleep. Many studies consistently show shortened sleep before a night shift, a phenomenon observed with the use of sleep logs and sleep lab measures (Cruz and Della Rocco, 1995b; Della Rocco and Cruz, 1995b; Della Rocco, Cruz, and Schroeder, 1995; Melton, 1985; Rhodes et al., 1994; Rhodes et al., 1996; Saldivar et al., 1977; Schroeder, Rosa, and Witt, 1995; Stoynev and Minkova, 1998). Also, the quality of sleep ATCs get before a night shift is poor compared to sleep before a day or evening shift, according to subjective reports of ATCs and results obtained with sleep lab measures. In a study by Della Rocco and Cruz (1995b), ATCs rated the sleep before the night shift as the poorest of their schedule. Rhodes et al. (1994) obtained a similar result through a survey of Canadian ATCs and observed corroborating sleep lab measures. In another study from Rhodes et al. (1996), polysomnographic data showed lesser quality sleep for ATCs working night shift and also sleep patterns usual for individuals suffering from sleep deprivation. Comparing physiological indices of stress, Melton, McKenzie, Polis, et al. (1973) noted that day sleep of ATCs was less restful than night sleep. Only Stoynev and Minkova (1998) measured subjective quality of sleep of ATCs and did not observe differences among the three shift types.

Fatigue, sleepiness, circadian trough, sleep deprivation, low traffic load, and low lighting levels were all identified as factors contributing to decreased performance and vigilance at night (Benson, 1970; Costa, 1993; Costa, 1999; Grandjean et al., 1971; Luna, 1997; Rhodes, et al., 1996; Wickens et al., 1997). Studies indicate that the performance decrements on various tests related to air traffic control tasks are particularly pronounced at the end of the night shift (Della Rocco and Cruz 1996; Della Rocco, Cruz, and Schroeder, 1995; Luna, 1997; Rhodes et al., 1994; Rhodes et al., 1996; Schroeder et al., 1995). However, a few of these authors note that, if the decrement reflects the fatigue influence, the performance on these tests might not be parallel to the operational performance of ATCs (Luna, 1997; Rhodes et al., 1994; Schroeder et al., 1995). Still, operational performance is probably affected by fatigue, since more incidents have been observed at night among other groups of workers (Costa, 1999). Considering the potential consequences of errors in ATC tasks, the performance decrements observed during the night shift raise serious concerns about operational safety.

While there is concern about night shifts, day shifts also have their problems. ATCs experience more fatigue before a day shift compared to the evening shift (Melton, 1985). Working day shift entails sleep loss because ATCs do not go to sleep earlier at night before working an early day shift, and get less sleep in the morning (compared to evening shift and days off) due to early rise (Costa, 1999; Cruz and Della Rocco, 1995b; Della Rocco, Cruz, and Schroeder, 1995; Rhodes et al., 1994, 1996; Saldivar et al., 1977). This situation is exacerbated for the numerous controllers who have a long commuting distance. For example, controllers working in the greater Toronto area often have over an hour of driving to get to work, compared to 10 to 15 minutes for ATCs working in Moncton or Gander (Rhodes et al., 1996). Shiftworkers have difficulties compensating for early rise by going to sleep earlier, because there is a period before usual sleep onset when the biological clock seems to prevent sleep (Cruz and Della Rocco, 1995a; Folkard and Barton, 1993).

Compared to performance later in the day, early day shift performance is decreased (Rhodes et al., 1996). Considering the higher frequency of accidents during early morning shifts among other groups of workers (Costa, 1999), operational safety is probably threatened by fatigue and performance decrements experienced at the start of early morning shifts.

2.2.2 Schedules

In addition to the problems inherent in night and day shifts, scheduling the shifts also introduces difficulties. Scheduling is, in fact, a highly emotional topic that creates much tension between air traffic control management and employees (Hopkin, 1982, 1995; Melton and Bartanowicz, 1986). The debate over scheduling issues has been around for almost three decades and a completely satisfactory solution remains elusive.

Table 1 Examples of shift schedules used in air traffic control facilities

Schedule	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Permanent schedule:							
Week 1: 5 days	700-1500	700-1500	700-1500	700-1500	700-1500		
Week 2: 5 days	700-1500	700-1500	700-1500	700-1500	700-1500	off	off
Week 3: 5 days	700-1500	700-1500	700-1500	700-1500	700-1500		
Slow rotation:							
Week 1: 5 days	700-1500	700-1500	700-1500	700-1500	700-1500		
Week 2: 5 evenings	1500-2300	1500-2300	1500-2300	1500-2300	1500-2300	off	off
Week 3: 5 nights	2300-700	2300-700	2300-700	2300-700	2300-700		
Rapid rotation:							
Counterclockwise	1500-2300	1500-2300	700-1500	700-1500	2300-700	off	off
Clockwise	700-1500	700-1500	1500-2300	1500-2300	2300-700	off	off

As can be seen in **Table 1**, various types of shift schedules exist to cover the 24-hour period of operations in air traffic control facilities. **Permanent schedules** involve always working the same shift. The **slow rotation schedule**, a variation of the permanent schedule, involves working five straight days on a specific shift, then rotating to another shift the following week. Other schedules imply **rapid rotation** of shifts during the week. Although the exact configuration may vary, two main kinds of rapid rotation schedules exist: 1) clockwise rotation, and 2) counterclockwise rotation. In the **clockwise rotation** (also called forward or delayed rotation), the work week starts with a day shift, rotating later in the week to an afternoon shift, and finally changing to a night shift. In the **counterclockwise** (backward or advancing rotation), the work week starts with an afternoon shift, then advances to an early day shift, to finally end with a night shift (Luna, 1997; Tepas and Monk, 1987). In **Table 1**, two days off are represented as the weekend, a common situation for ATCs working in the United States.

In Canada, the schedules differ from those used in the United States. The 1999 collective agreement between Nav Canada and the Canadian Air Traffic Control Association (CATCA) established four types of schedule cycles detailed in **Table 2**. According to the agreement, the rest period must be not less than three consecutive days. The agreement also states that each shift should not begin "within 10 hours of the completion of the employee's previous shift" and that a regular shift should not exceed 11 hours (CATCA / Nav Canada, 1999).[1]

Table 2 Schedule cycles of Canadian air traffic controllers

	Schedule #1	Schedule #2	Schedule #3	Schedule #4
First week	6 days on – 4 days off	6 days on – 4 days off	6 days on – 5 days off	6 days on – 3 days off
Second week	6 days on – 4 days off	6 days on – 3 days off	6 days on – 3 days off	6 days on – 3 days off
Third week	5 days on – 3 days off	5 days on – 4 days off	5 days on – 3 days off	5 days on – 5 days off

In air traffic control facilities, various types of schedules exist, including five straight days (rotation of shift from one week to another) and a rapid backward rotation referred to as the 2-2-1. These schedules have been studied and also compared in terms of fatigue, sleep, performance, and stress. These studies are often difficult to conduct and they meet with many methodological difficulties leading to limited statistical analyses associated with small sample sizes and non-equivalent groups or shifts. Nevertheless, the accumulation of data allows us to note some consistent pattern in the results across studies and it is observed that each schedule, as will be reported below, has its own particular weaknesses.

1 Other articles of the Collective Agreement e.g., Overtime, Holidays, and Staffing, may affect actual work schedules. The reader is referred to the Collective Agreement for a more extensive description of conditions influencing work schedules.

The main cause of concern regarding **permanent schedules or slow rotations** is people working consecutive night shifts. Generally, five consecutive night shifts are thought to allow enough time for the circadian rhythms to adapt to nocturnal life. However, this hypothesis is not supported by research. Studies report that the circadian rhythms of night workers in varying operation domains tend to desynchronize and never adjust completely to night work, even after working this schedule for prolonged periods (Benson, 1970; Costa, 1999; Luna, 1997; Tepas and Monk, 1987; Wickens et al., 1997). Working consecutive night shifts is also a major inconvenience in the social life of shiftworkers, and they tend to go back to diurnal life on their time off, hindering the adaptation process (Luna, 1997; Tepas and Monk, 1987).

Consecutive night shifts have another drawback, as observed by Rhodes et al., (1996). In their study, they observed that ATCs working five consecutive night shifts accumulated a sleep debt of more than 10 hours due to a low average of daytime sleep and poor sleep quality. The melatonin levels of these ATCs indicated that their circadian rhythms never adopted a nocturnal pattern. Melton and Bartanowicz (1986) similarly concluded that five consecutive night shifts are not enough to adapt circadian rhythms to a nocturnal pattern, resulting in accumulated fatigue because of inadequate sleep during the day. Moreover, controllers working five consecutive nights report that they need the complete weekend to make up for the loss of sleep, and they tend to go back to work tired at the beginning of the following week (Melton, McKenzie, Smith, et al. 1973; Saldivar et al., 1977). Even if consecutive night shifts allowed adaptation to circadian rhythms, ATCs still experience too many inconveniences, such as loss of proficiency related to low traffic volume at night (Luna, 1997; Luna et al, 1994, 1997; Melton, 1985; Melton and Bartanowicz, 1986); boredom, which creates fatigue and eventually leads to low motivation (Luna et al., 1994); and reduced social contact with family, friends, and colleagues (Melton and Bartanowicz, 1986; Rhodes et al, 1994; Wickens et al., 1997).

As opposed to permanent schedules and slow rotation, during **rapidly rotating shifts**, individuals keep diurnal circadian rhythms, as can be measured by body temperature, melatonin levels, or arterial pressure (Costa, 1993; Luna et al., 1994; Rhodes et al., 1996; Stoynev, Minkova, 1998). Maintaining a diurnal cycle prevents desynchronization between various biological circadian rhythms, and ATCs are at the peak of their circadian rhythms during the day and afternoon shifts when there is an increase in traffic.

In studies pertaining to rotating schedules of ATCs, the 2-2-1 counterclockwise rotation schedule received a lot of attention. The exact configuration of this schedule varies, but it usually involves working two evening shifts, rotating to work two day shifts, followed by a single night shift. This schedule presents the advantage of working only one night shift compared to the consecutive five night shift schedule, a feature appreciated by many ATCs (Schroeder et al., 1995). However, compared to the usual 16 hours off between two consecutive straight shifts, time off on counterclockwise rotation ranges from 14 to 8 hours. Regarding the fatigue issue, these short rest periods raise questions about whether ATCs get enough sleep between their shifts to fully recover. A lack of complete recovery can affect performance.

Research focussing on the sleep of ATCs working 2-2-1 schedules found a constant decline in the quantity of sleep during the work week (Cruz and Della Rocco, 1995b; Della Rocco and Cruz, 1995b; Della Rocco, Cruz, and Schroeder, 1995; Melton, 1985; Melton et al., 1975; Melton, McKenzie, Smith, et al., 1973; Rhodes et al., 1996; Saldivar et al., 1977; Schroeder et al., 1995). This decline is easily explained by the early rise for the day shift, the quick turnaround, and the short day sleep obtained before the night shift (Cruz and Della Rocco, 1995b; Della Rocco and Cruz, 1995b; Della Rocco, Cruz, and Schroeder, 1995; Rhodes et al., 1996; Saldivar et al., 1977; Schroeder et al., 1995). As discussed earlier, sleep before night shifts is reduced and poor, a condition exacerbated for a 2-2-1 schedule where ATCs get less sleep before the night shift compared to the sleep obtained before consecutive night shifts (Melton, et al., 1975; Melton, McKenzie, Smith, et al., 1973; Saldivar et al., 1977). According to Melton, McKenzie, Smith, et al. (1973), some ATCs on a 2-2-1 schedule prefer to take a brief nap prior to a night shift to be just tired enough in the morning to sleep well and readjust to normal day life.

Does the 2-2-1 schedule create more problems related to sleep loss, fatigue, and performance? To investigate this question, some researchers compared the 2-2-1 schedule to other types of schedules. Saldivar et al. (1977) compared a five consecutive shift rotation to the 2-2-1 schedule and observed no differences in the amount of fatigue complaints. Over five work days, ATCs got less sleep on the 2-2-1 schedule, mainly because of shortened sleep before the night shift, but the comparison across seven days was not significant. Della Rocco and Cruz (1995b) obtained a similar result in a laboratory study of sleep/wake cycles. In another study, Melton et al. (1975) observed that ATCs on a 2-2-1 pattern got less sleep than their counterparts on five consecutive days, but the differences were mainly due to the night shift, since on the first four days of the week, ATCs on a 2-2-1 schedule got 30 minutes more sleep than ATCs on consecutive day schedules.

In a field study, Cruz and Della Rocco (1995b) compared a 2-2-1 schedule to a straight day schedule and found no significant differences between these schedules in sleep quantity, sleep quality, and sleepiness ratings before and after the shifts. Melton, McKenzie, Smith, et al. (1973) found that ATCs on 2-2-1 got more sleep than those on five night shifts, but less than those on five-day shifts. In this study, ATCs on 2-2-1 schedules experienced less stress, and no difference in fatigue was observed. Compared to a consecutive shift schedule, the shortened rest period on a quick turnaround contributes to reduced sleep (Cruz and Della Rocco, 1995a). In this study, the authors observed that the amount of sleep before a morning shift was often less than six hours for all shift rotations, an indication that some ATCs might not be able to get to sleep earlier because of their biological clock.

A few studies have evaluated performance in relation to 2-2-1 schedules and to quick turnaround between shifts. Schroeder et al. (1995) and Della Rocco and Cruz (1995b) observed that performance decrements in 2-2-1 schedules were significant only for night shifts. Rhodes et al. (1996) made a similar observation, but they also noticed that performance was poorer following sleep loss resulting from quick changes.

It is difficult to be categorical about fatigue, sleep loss, and performance in relation to 2-2-1 schedules. As Melton and Bartanowicz (1986) argued, 2-2-1 schedules have the advantage of working four of the five shifts within normal waking hours. However, sleep patterns are disrupted by the changing starting times of this schedule (Cruz and Della Rocco, 1995b). Some ATCs may cope better than others with this sleep disruption. One important concern about this schedule is the night shift. As stated earlier, ATCs might have some inappropriate sleeping habits before the night shift, but the longer weekend allows for enough recovery time to eliminate the accumulated sleep debt. In the long run, negative effects are possible since it has been reported that older ATCs have more difficulties dealing with 2-2-1 schedules and this schedule is associated with illness indicators (Rhodes et al., 1994).

Until now, a lot of attention has been focussed on consecutive shifts and 2-2-1 backward rotating shifts. Other schedules are possible for air traffic control operations, like the forward rotating schedule where the shiftworker begins the schedule on a day shift, followed by an evening shift, and finally, to a night shift. As with the backward rapid rotation schedule, forward rapid rotation helps maintain a diurnal circadian cycle (Stoynev and Minkova, 1998). Some authors note that, generally, the clockwise rotating schedules are more consistent with the circadian rhythms, and allow more time to rest between shifts, and would thus be preferable to counterclockwise schedules (Costa, 1999; Barton and Folkard, 1993; Luna, 1997; Tepas and Monk, 1987; Wickens et al., 1997). Few studies of forward rapidly rotating schedules among ATCs exist. According to these studies, night shifts are problematic as well on forward rotating schedules because of reduced sleep quantity, fatigue, increased sleepiness, and microsleep periods (Luna et al., 1994; Stoynev and Minkova, 1998). Also, USAF ATCs on a forward 2-2-2 schedule rotation did not sleep or nap before their first night shift, a possible indication that even though this schedule allows more time to sleep between shifts, ATCs might not be taking full advantage of it (Luna, 1997; Luna et al., 1994). Forward rotation schedules may allow more time to rest between shifts, but they reduce the duration of the weekend (Luna, 1997). Since weekends allow time for recovery from the night shift, a shortened weekend increases the probability of tired ATCs returning to work the following week. This kind of rotation is thus unpopular among ATCs, who prefer backward rotation to obtain increased time for the weekend (Melton, 1985; Melton and Bartanowicz, 1986; Schroeder et al., 1995; Wickens et al., 1997). Comparison of forward and backward rotating schedules for ATCs have not been studied at length, and although forward rotating schedules may appear advantageous, this topic requires further study (Luna, 1997; Stoynev and Minkova 1998).

2.3 Workload and Time on Task

Workload is experienced differently from one ATC to another, depending on experience, skills, motivation, tiredness, and also on their coping skills (Hopkin, 1995; Wickens et al., 1997). Still, high workload related to high traffic volume eventually creates fatigue because of the sustained efforts required (Meyer, 1973). The efforts needed to cope with high workload can only be sustained for a certain period of time and they take their toll on performance. During simulated air traffic control tasks, as time passed, lapses in attention occurred more frequently and reaction times increased for complex monitoring tasks, particularly for high task load conditions (Schroeder, et al., 1994; Stern et al., 1994; Thackray and Touchstone, 1985; Thackray, Touchstone, and Bailey, 1978). The performance decrements and fluctuations of alertness associated with time on task are even worse if the operator is suffering from sleep loss or sleep disruption (Meyer, 1973).

The fact that high traffic periods are associated with high workload is obvious. However, low traffic load can also be demanding. Air traffic control tasks involve a lot of monitoring. Sustaining vigilance for prolonged periods of time is demanding and boring and leads to decreased alertness and low motivation (Luna et al., 1994; Schroeder et al., 1994; Wickens et al., 1997). This has been confirmed by subjective ratings of participants who reported increasing tiredness, boredom, and irritation (Schroeder et al., 1994).

2.4 Workload and Automation

Worldwide air traffic is growing rapidly, putting more pressure on ATCs and increasing their workload. With the development of new technologies, increasing automation in the air traffic control environment has often been considered as a strategy to reduce workload of ATCs and increase traffic capacity of airports (Hopkin, 1995, 1999; Wickens et al., 1997). However, the possible consequences of automation on cognitive processes and ATC performance are not well known (FAA, 1990; Garland, Stein, Muller, 1999). It is often stated that automation of some functions reduces the role of an ATC to a monitoring one (Thackray and Touchstone, 1985; Thackray et al., 1978). Such changes do not necessarily reduce ATC workload, since vigilance tasks are demanding, and fatigue may arise from sustained attention (Hopkin, 1995; Stern et al., 1994; Wickens et al., 1997). Gaines (1993) also noted that reducing the work of ATCs to a monitoring role could result in their “losing the art of controlling” (p.17). Automation can also add to the ATC workload by demanding “increased knowledge and mental effort to understand and interpret system dynamics and outcomes” (FAA, 1990, p. A-57). Thus, automation of the air traffic control environment needs to be carefully evaluated and planned to be fully beneficial.

2.5 Lifestyles, Personality Characteristics, and Individual Differences

Some lifestyle elements have been shown to influence how a person deals with fatigue. For example, ATCs who have healthy habits such as exercising, a balanced diet, good sleep hygiene, and good time management strategies cope more effectively with fatigue (Costa, 1999; Meyer, 1973; Rhodes et al., 1994). It seems that physical fitness reduces fatigue and increases performance on night shifts (Costa, 1999). In contrast, ATC who smoke, who drink too much alcohol and coffee, and who take medication to go to sleep show more illness indicators (Rhodes et al., 1994).

Coping with shiftwork, fatigue, and stress becomes increasingly difficult with age, mainly because older ATCs are less resistant to stress, get less sleep, and their circadian rhythms are more easily disrupted by unstable sleep patterns (Costa, 1999; Costa et al., 1995; Meyer, 1973; Rhodes et al., 1994; Rhodes et al., 1996). While differences exist in relation to age, circadian rhythms are not different for men or women; they are equally vulnerable to fatigue (Costa, 1999).

Personality characteristics and behavioural aspects also influence the impact of fatigue on individuals. Whether ATCs are morning or evening types can influence performance and adaptation to shifts. Morning types prefer to get up early and go to bed early at night, while evening types prefer the opposite. Accordingly, morning-type ATCs have more difficulty coping with night work, but they cope more easily with early morning hours, while evening types, as can be expected, cope more easily with evening and night shifts (Costa, 1999; Costa et al., 1995; Rhodes et al., 1994). Overall, evening types cope better with shiftwork since they show less sleep disruption with shiftwork and also lowered levels in physiological indicators associated with stress (Costa, 1993, 1999). ATCs who have stable circadian rhythms are better able to resist sleep disruptions and experience less fatigue, while those who have rigid sleep habits or are unable to overcome drowsiness, are more vulnerable to fatigue (Costa, 1993; 1999).

3 POTENTIAL COUNTERMEASURES

From the findings described in the previous sections, certain suggestions and recommendations can be made to address the fatigue issue. The measures discussed in the following section include ways to improve alertness during the night shift, training programs on sleep strategies and shiftwork coping, recommendations about shifts and scheduling, and suggestions for increasing automation of the air traffic control environment.

3.1 Increasing Alertness During Night Shifts

Fatigue, sleepiness, and decreased performance on night shifts can be addressed in different ways. Measures oriented toward improving alertness during the night shift could be implemented. Such measures include better lighting of the work site (Costa, 1999; Cruz and Della Rocco, 1995b; Luna, 1997; Luna et al., 1994). The current low ambient illumination contributes to reduced alertness (Luna, 1997; Rhodes et al., 1996). Bright lights help maintain alertness and postpone sleep (Costa, 1999; Luna et al., 1994) while improving vigilance levels (Boivin, 1997). Proper care should be taken to find an adequate level of illumination to allow for easy monitoring of radar screens (Luna, 1997; Hopkin, 1995; Rhodes et al., 1996).

Another strategy geared to increase alertness is napping. Many authors suggest that napping, either before or during the shift, helps prevent sleepiness and preserve alertness through the night shift (Costa, 1993; 1999; Luna, 1997; Luna et al., 1994). Napping in the context of air traffic control operations has not received much attention until recently, but some researchers have become interested in this area. Rhodes et al. (1996) noted the benefits of naps and recommended that napping should be studied in a simulated air traffic control work environment to fully evaluate the effects on alertness and performance. Della Rocco, Cruz, and Schroeder (1995) were planning to investigate the effectiveness of napping on the night shift. In suggesting naps as a means of improving alertness during night shifts, Luna (1997) observed that such a strategy raises the problem of sleep inertia, a transition period where the individual is still sleepy and not completely functional. This issue can be solved by proper timing of naps (before shifts) and by allowing enough time for recovery following a nap.

Several authors suggest that taking melatonin could be helpful for ATCs in coping with night shifts. Melatonin is a pineal hormone thought to be involved in the regulation of sleep and wakefulness (Sanders, Chaturvedi, and Hordinsky, 1998). The ingestion of melatonin prior to sleep helps sleep onset and improves sleep quality while reducing subsequent fatigue and sleepiness (Costa, 1999). Melatonin is a powerful resynchronizer of circadian rhythms and contributes to increased performance of night workers (Luna, 1997). It might be helpful for ATCs working consecutive night shifts, but could have detrimental effects for those working rapid rotation schedules, which are precisely aimed at preventing a phase shift of the circadian cycle (Luna, 1997). There is also the possible risk of residual effects that may cause sleepiness and performance impairment. The administration of melatonin at the right time therefore seems critical for ATCs on shiftwork (Sanders et al., 1998). Although it might look promising as a strategy against fatigue, interest in melatonin is rather recent and there is still much to learn about its efficacy, side effects, and long-term effects on health, as well as its interaction with other medication (Sanders et al., 1998).

Other possible strategies exist to help maintain alertness during night shifts. Drinking coffee, a common strategy, helps maintain alertness and performance, and if taken early enough during the shift, does not disturb sleep onset at the end of the shift (Luna, 1997; Luna, et al., 1994). One should not drink too much coffee, however, because of its negative effects on the digestive system (Costa, 1999). As stated earlier, low traffic levels are frequent during night shifts, demanding high vigilance from ATCs, contributing to boredom and fatigue (Rhodes et al., 1996). A possible solution would be to keep ATCs busy, possibly with simulated traffic operations, as long as that does not interfere with normal operations (Rhodes et al., 1996). Other strategies could consist of exercising on the job with a stationary bicycle or rowing machine, or just engaging in conversation or simple games with colleagues (Luna, 1997; Luna et al., 1994).

3.2 Education

Many ATCs may have improper sleep strategies and may not take full advantage of their time off to rest (Melton, McKenzie, Smith, et al., 1973; Rhodes et al., 1996; Saldivar et al., 1977). Some ATCs on a 2-2-1 schedule prefer just to take a short nap before a night shift to be tired enough to sleep in the morning, while others, before their day shift, go to bed late at night (especially after an evening shift), even though they have to get up early. Sleep loss and fatigue result from these habits. Shiftwork can not be eliminated, so, obviously, better coping strategies should be promoted. As Roske-Hofstrand (1995) stated, there is a need to raise the awareness of staff and supervisors about the fatigue problems among ATCs, since it is too often considered a personal problem rather than a job-related hazard.

Developing training programs on shiftwork countermeasures and on sleep hygiene for ATCs and management could at the same time raise awareness about fatigue and help reduce fatigue by teaching appropriate coping strategies (Della Rocco and Cruz, 1995b; Della Rocco and Cruz, 1996; Della Rocco, Cruz, and Schroeder, 1995; Rhodes et al., 1996). Rhodes et al. (1996) suggest including family members of ATCs in sleep hygiene training to sensitize them to the fatigue problem. One of the important topics to be considered is appropriate sleep strategies: how to create a good environment to sleep, appropriate habits prior to sleeping, appropriate sleeping times of the day, and helpful relaxation techniques before sleeping (Rhodes et al., 1996). This training would also represent a good opportunity to emphasize the importance of healthy habits such as a healthy diet and exercising, and to explain the effects of alcohol and medication. The training could also include information on other topics related to fatigue, such as the effects of circadian rhythms, influence of individual characteristics on the ability to cope with shiftwork (age, morning/evening types, stability of circadian rhythms), and workload management strategies (Gaines, 1993).

3.3 Reducing Fatigue Problems Related to Sleep Loss

Early morning shifts induce sleep loss. ATCs have to get up earlier, while not being able to go to bed earlier because of their biological clock (Cruz and Della Rocco, 1995a; Folkard and Barton, 1993). It might be useful to reschedule the day shift to start later in the morning to avoid shortened sleep before the shift (Cruz and Della Rocco, 1995a; Cruz and Della Rocco, 1995b). Some air traffic control facilities do not operate at night but start early in the morning. Accordingly, it might not be possible for them to start activities later. Also, starting later in the morning entails prolonging the night shift, and thus having tired staff handling the morning rush hour. Alternatively, it can mean that hand-over of traffic from one group to another occurs during peak traffic, possibly increasing operating risks considering that incidents happen more often at the beginning of shifts when ATCs are developing a portrait of the traffic situation (Stager and Hameluck, 1988). Another possible avenue would be to revise the scheduling of the work system, which might not be an easy task (see section 3.4).

3.4 Rescheduling

Scheduling the shifts for air traffic control operations is an emotionally charged issue where staff and management do not always share the same point of view (Hopkin, 1982). Debates over proper schedules have been going on since the early 1970s and scheduling is still an unresolved issue (Melton and Bartanowicz, 1986). Research does not indicate a clear direction either; some results are contradictory and these studies often have methodological problems. Still, certain patterns in the results suggest some guidelines with respect to scheduling.

Considering the data reviewed in previous sections on permanent shift schedules and slow rotation, these schedules have few positive aspects for night shifts and many disadvantages for performance and safe operations. The reason this kind of schedule is used in air traffic control facilities should be questioned regarding safe operations, and evidence suggests considering other types of schedules for ATCs. Considering fatigue, sleep loss, disruption of circadian rhythms, loss of proficiency related to low traffic, and reduced social interaction, the number of consecutive night shifts should be reduced as much as staffing allows (Costa, 1999; Hopkin, 1995; Melton and Bartanowicz, 1986; Rhodes et al., 1994; Rhodes et al., 1996; Wickens et al., 1997).

Rapid rotating schedules are alternatives to the previous permanent or slow rotating schedules. They involve working fewer night shifts, only one or two at the end of the week. Such schedules, the 2-2-1 backward rotation in particular, have inconveniences; they compress the work week and reduce time off between shifts, particularly with a quick turnaround, resulting in sleep loss and performance decrements (Della Rocco and Cruz, 1995b; Rhodes et al., 1996; Schroeder et al., 1995). Any strategy geared to reducing sleep loss and increasing alertness would be advisable for this schedule. While some authors argue that clockwise schedules are preferable to counterclockwise to allow more time to rest between shifts, Cruz and Della Rocco (1995a) observed that the direction of the rotation might not be as important as the scheduled time off between shifts. Thus, redesigning schedules to allow longer rest periods, 10 to 13 hours instead of 8 hours on the quick turnaround, would reduce sleep loss and improve performance.

The direction of the rotation is a delicate matter. Clockwise rotation would be preferable to counterclockwise because of the dynamics of the circadian cycle (Costa, 1999; Luna, 1997; Tepas and Monk, 1987). However, these schedules compress the weekend, an unpopular consequence for most ATCs. In reality, very few clockwise rotation schedules exist (Luna, 1997; Melton and Bartanowicz, 1986). If clockwise rotations were considered, for ATCs to accept them, it would be necessary to find a way to keep a reasonable time off for the weekend period (Melton and Bartanowicz, 1986).

As the preceding idea suggests, many ATCs appreciate counterclockwise rotations because of extended weekends (Luna, 1997; Melton, 1985; Melton and Bartanowicz, 1986; Hopkin, 1982, 1995; Wickens et al., 1997). Still, as observed by Della Rocco and Cruz (1995b), some ATCs resent counterclockwise schedules like the 2-2-1, possibly because they cope less effectively than others with changing sleep patterns and sleep loss. This suggests that, when possible, work systems should include different schedules to fit individual ATC preferences. Some authors argue that ATCs should be consulted and should have some control over the assignment of schedules. It is a matter of job satisfaction: ATCs are more motivated and more able to cope with the fatigue and stress related to a schedule they have chosen (Hopkin, 1982, 1995; Melton, 1985; Melton and Bartanowicz, 1986; Meyer, 1973). In fact, Hopkin (1982) noted that some ATCs will adapt to any schedule as long as it is “acceptable” to them. Thus, in the process of designing and assigning schedules, all previously mentioned considerations regarding sleep, circadian rhythms, and health are important. Melton and Bartanowicz (1986) made some convincing recommendations, suggesting that in designing schedules, operational requirements and safety must come first and schedules should be reasonable and manageable, an idea promoted as well by Hopkin (1995) and by Wickens et al. (1997). After that, employees’ desires and needs can be taken into account. When this is possible, the work environment can be more pleasant and less stressful, with less tension between management and staff.

A related topic to scheduling concerns breaks. While they work, ATCs should take breaks. As discussed earlier, their tasks require sustained vigilance. Since vigilance decreases over time while feelings of fatigue increase, a break every two hours of continuous work should be allowed (Hopkin, 1995; Roske-Hofstrand, 1995). During their breaks, ATCs should have time to walk away from their station, go to the bathroom, spend time in relaxation facilities at the workplace, where they can have something to drink or chat with colleagues (Hopkin, 1995; Meyer, 1973; Roske-Hofstrand, 1995). Taking a break is very important during night shifts since low traffic levels induce fatigue resulting from efforts to counter boredom. Unfortunately, too often during night shifts, reduced staff makes it difficult for ATCs to take a break (Rhodes et al., 1994; Roske-Hofstrand, 1995). Staff planning should take breaks into consideration, especially during night shifts (Rhodes et al., 1996).

Other authors suggest that night shifts should include breaks long enough for naps. Costa (1993) studied Italian ATCs on a 1-1-1 backward rotating schedule with a night shift including a four-hour rest period. Apparently, this kind of schedule facilitated psychophysiological adaptation and helped compensate for sleep loss. This is only one example of many possible night shift schedules that would include a break long enough for napping. Break periods could also be shorter for naps of 20-40 minutes. As discussed earlier, research is ongoing to determine the ideal length of a nap. It is important to note that a night shift with a napping break would be longer and would require changes to existing schedules. Prolonging the night shift could allow for a later start in the morning, resolving the problem of sleep loss associated with an early start. Night shifts could be longer; 8 to 10 hours is still an acceptable shift length if periods of standby are included (Hopkin, 1995). However, staff may not appreciate a change to longer shifts and they may resist such a change. Thus, prior to modifying schedules to include longer breaks during night shifts, more information is needed on naps and their frequency within the shift.

3.5 Increasing Automation

Within certain boundaries, automation can be useful to reduce workload. Carefully designed systems would increase the efficiency of the air traffic control system where the human operator "can perform successfully and with satisfaction" (FAA, 1990, p. A-59). New automated systems should be flexible to allow ATCs to choose their level of workload: reduced workload results in boredom, whereas moderate levels of workload are motivating (Hopkin, 1995). Flexible computer aids should focus on data collection, leaving ATCs in charge of more interesting tasks requiring information processing and decision-making (Hopkin, 1995; Wickens et al., 1997). Therefore, new automated systems have important potential benefits for air traffic control operations, but their impact and usability by human operators should be carefully evaluated (Cabon et al., 1997).

4 CONCLUSION

This report has reviewed the research literature on fatigue among ATCs. It appears that night shifts, shiftwork, and workload are important variables related to fatigue in ATCs. Automation and personal characteristics can also influence their experience of fatigue. Some potential countermeasures have been discussed. They include ways to increase alertness during the night shifts, topics for health training programs for ATCs, means of reducing sleep loss, suggestions for rescheduling shifts to reduce sleep loss and fatigue, and recommendations for future automation of the air traffic control environment.

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