Songklanakarin J. Sci. Technol.
40 (1), 47-52, Jan. - Feb. 2018

http://www.sjst.psu.ac.th

Original Article

Phases of time, mental workload and pilot age; A case study: Indonesian civilian pilot

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Received: 22 July 2016; Revised: 18 September 2016; Revised: 2 October 2016

Abstract

Each activity or work performed by a worker will always contain a workload. Such workloads include both physical and mental workloads arising from the work environment. Different work time conditions are also deemed to affect the mental condition of a pilot. The aim of this study is to measuring the value of pilot mental workload in terms of difference pilot age to operate the aircraft based on the difference in phases of time. Subjective Workload Assessment Technique (SWAT) method is used to measure mental workload value, this method consists of three dimensions with their levels, there are: time, mental effort, and psychological stress load. The results of this study indicate that the conditions with the highest mental workload for the group one consisting of 26 pilot respondents (aged <30 years) were at the time flights were made in the morning (06:00 to 11:59 am), during weekends, and during peak seasons. While the results for group two (pilot age ≥51 years), indicating that the conditions with the highest mental workload were at the time flights were made in the early morning (00:00 to 05:59 am), during weekends, and during peak seasons. This study also showed that the time dimension factor (T) significantly affects the mental workload of pilots, indicating that they put more emphasis on this factor when they are considering workloads.

Keywords: mental workload, pilot, age, phases of time, SWAT

1. Introduction

Each activity or work performed by a worker will always contain a workload. Such workloads include both physical and mental workloads arising from the work environment. These workloads are designed in accordance with both physical and mental capabilities and limitations of workers. Their work performance may decrease if workers have excessive workloads, which in turn may affect occupational safety. This is because huge workloads may create tension that can affect emotions, ways of thinking, and occupational health conditions. In relation to activities or work with a high stress level and requiring great concentration and attention, in this case operating aircrafts, the mental workload is more dominant and it should be a matter of concern.

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Different work time conditions are also deemed to affect the mental condition of a pilot. Regardless of the habitual factor, the human body has its own time to work and rest and this will influence the physical condition, and ultimately the mental state and vice versa (Saputra *et al.*, 2014). Flight crew shifts result in a desynchronization of circadian rhythm, including oscillations in core body temperature, hormone secretion, sleep, and alertness (Wright & McGown, 2004). Airborne crews may present sleepiness because they are working during the circadian cycle low point, corresponding to the lowest body temperatures. All this condition can be a signs of fatigue. A pilot who experiences fatigue his level of vigilance in performing flight tasks may decrease and this may lead to an aircraft accident. This fatigue can be caused by excessive physical and mental activities. Both in terms of their responsibilities and moral, mental activities are definitely heavier and of a higher level compared with physical activities because mental activities will always involve elements such as perception, interpretation and mental processes of particular information received by the sensory organs so that a decision can be made or the process to remember such information. Considering this phenomenon, it is necessary to measure mental workloads in order to determine the extent of mental workloads of a pilot. However, there are considerable individual differences in the extent to which fatigue caused by mental workload affects performance. These differences include the effects of sleep loss, nighttime work, and considerations of individual sleep needs and recovery time. Differences between individuals may vary depending on age, sleep need, experience, overall state of health and other factors (Gander *et al.,* 1993).

There is much interest in determining the relationship between flight crew shifts (schedules) and their association with aviation accidents/incidents caused by fatigue (Goode, 2003), since accident/incident inquiries are crucially important for aircraft safety. Based on the foregoing, this research was developed with a view to determine if there is a difference in mental workloads between pilots with different phases of time in operating an aircraft viewed from their age difference using the SWAT method.

2. Materials and Methods

2.1 Methods

This study uses Subjective Workload Assessment Technique (SWAT) for solve the problem and also answer the research question in this study. SWAT has been developed in response to a need for workload measure with known metric properties that is useful in operational or "real-world" environments. Maximum effort has been expended to keep the SWAT data collection as less intrusive as possible. The principal way this has been accomplished is through the application of a scaling procedure known as conjoint scaling. This approach allows responses to be made in the operational setting using only three factors that have been used to operationally define workload, there are: Time, Effort, and Psychological Stress load. Each of the three dimensions has a verbal description of the three levels associated with the "low", "medium", and "high" values possible for the ratings (Corwin, 1992). This approach also minimizes the amount of time required to make response responses by keeping down the number and complexity that an operator must memorize (Reid, 1989).

SWAT is divided into two distinct phases: (a) scale development and (b) event scoring. The scale development phase is used to train on the use of the descriptors and to obtain data concerning how these dimensions combine to create each individual's personal impressions of workload. As part of the scale development process, each rater must rank in order (sort a stack of cards containing) the verbal descriptions of the 27 workload combinations possible from the orthogonal combination of the three levels of each three dimensions. The principal reason for completing the card sort is to generate data that are used to produce a scaling solution tailored to the groups or individuals perception of workload. This is one aspect of SWAT which is different from most other subjective workload assessment approaches (Reid, 1989). A between rater comparison of the card sort is conduct to determine if a common prototype solution exits for the raters as a group and to determine if axiom occur with respect to the rank ordering of three dimensions. The prototype scale solution that is developed then allows for the mapping of actual event scores "low", "medium" and "high" ratings on the dimensions of Time (T) load, Mental Effort (E) load, and Psychological Stress (S) load, to be assigned a value on a 0 to 100 overall workload value (Corwin, 1992).

2.2. Flight scenarios

The purpose of the various flights was to manipulate systematically task in order to influence pilot workload. In this research, the 'phases of time' factor was divided into eight conditions, namely: Condition 1: Flights were made in the morning (06:00 to 11:59 am), Condition 2: Flights were made in the afternoon (12:00 to 17:59 pm), Condition 3: Flights were made at night (18:00 to 23:59 pm), Condition 4: Flights were made in the early morning (00:00 to 05:59 am), Condition 5: Flights were made during weekends (Saturday to Sunday), Condition 6: Flights were made during weekdays (Monday to Friday), Condition 7: Flights were made in the period of peak seasons (Eid Mubarak and summer holiday), and Condition 8: Flights were made in the period of non-peak seasons.

2.3. Subjects

The research data were obtained directly using SWAT questionnaires distributed to respondents. The research respondents were Indonesian civilian aircraft pilot that operate a scheduled aircraft or aircraft register type is AOC (Aircraft Operations Certificated) 121. The research subjects taken as the sample consisted of 52 respondents, i.e. 26 respondents (aged <30 years) and 26 respondents (aged ≥51 years). All the participants in this study are a man. The survey was conducted by distributing SWAT questionnaires to be filled by pilots and it was carried out at the time they were off-duty.

3. Results and Discussion

The SWAT analysis began with collecting SWAT data using the cards of mental workload combination, i.e. in the form of pieces of paper specifically made to support data collection processes. After that, the respondents, i.e. the pilots, were asked to sort the cards based on their own perception regarding the level of the workload from the lowest to the highest one and to do this, there were no rules specifying which order was true and which one was wrong. There were a total of 27 cards to arrange, each of which was a combination of the three SWAT dimension levels, namely time load (T), mental effort load (E), and psychological stress load (S). Results of the SWAT questionnaire application were used as an input to the SWAT software for scale development and event scoring which are the procedures for SWAT method application. In this study, phases of time is divided into eight periods condition, there are: morning (06:00 to 11:59 am), afternoon (12:00 to 17:59 pm), night (18:00 to 23:59 pm), early morning (00:00 to 5:59 am), weekend (Saturday to Sunday, weekdays (Monday to Friday), peak season (Eid Mubarak and summer holiday), and non-peak season.

At the stage of scale development, the value of Kendall's coefficient of concordance (W) was generated to determine the scaling to be done, if the value of Kendall's coefficient is <0.75, it implies that the data are too heterogeneous and the mental workload measurement will be done per individual respondent both based on the prototyped scaling solution (PSS) and the individual scaling solution (ISS), where the results cannot be said to represent the mental workload value of the whole respondents, and if the value of the Kendall's coefficient is ≥0.75, it implies that the whole respondents of the research have the same characteristics, then the group scale solution (GSS) will be undertaken. The SWAT software results in this research generated a value of Kendall's coefficient (W) of each 'phases of time' condition (conditions 1 to 8) for the group one consisting of 26 pilot respondents (aged <30 years) which was greater than 0.75, thus it can be said that the index of agreement in the card arrangement between the respondents is relatively similar and homogeneous. Similarly, the group two consisting of 26 respondents (aged ≥51 years) generated a value of Kendall's coefficient which is greater than 0.75. If the value of Kendall's coefficient is <0.75, it implies that the data are too heterogeneous. However, although the data are processed as a group, the value of each individual can still be presented.

After obtained Kendal coefficient value (W), the next step was prototyping. Prototyping is a process of stratification respondents in homogeneous groups based on the perception of the relative importance of the three main dimensions in SWAT, there are: Time (T), Mental Effort (E), and Psychological Stress (S) Load (Wignjoesoebroto & Zaini, 2007). The prototype screen displays the results of how the individual subjects prototype. A subject who prototypes "time" would considers the time load dimension to contribute the heaviest to his perception of workload. A subject who prototypes "stress" would consider the psychological stress load dimension to contribute the heaviest. Data analysis results showed that the highest level of those dimension for both groups are a time dimension, thus all the subjects had an agreement and assumed that the time load factor was the most important factor in determining the level of mental workload of a pilot, where the time load dimension depends on the availability of time and the ability to overstep in an activity. It is closely related to whether the subjects can complete their task within specified periods of time.

After the SWAT scale had been obtained, event scoring could be performed later to determine the mental workload, i.e. by converting the SWAT score indicated by the respondents to the SWAT scale, based on this conversion it can be seen whether the activities the respondents did classified as light, moderate or heavy. The event scoring data or the measurement of pilots' mental workload if viewed from the 'phases of time' factor after processed using the SWAT software are presented in Table 1 for the group one and in Table 2 for the group two. The mean column presents the value of pilots' mental workload.

Table 1. SWAT scale for group one (age <30 years).

Pilot	Phases of Time							
	Hour Period				Day Period		Season Period	
	Morning	Afternoon	Night	Early morning	Weekend	Weekday	Peak season	Non-peak season
1	28.2	48.8	51.5	63.6	54.8	15.1	100	38.9
2	91.3	48.8	100	63.6	66.2	51	100	22.4
3	100	48.8	51.5	63.6	99.4	51	100	52.2
4	100	48.8	51.5	23.4	99.4	51	100	52.2
5	100	48.8	17.4	0	99.4	15.1	100	22.4
6	58.5	48.8	100	63.6	99.4	51	100	52.2
7	100	26.7	65.9	40.2	99.4	51	100	22.4
8	100	48.8	0	63.6	99.4	51	100	52.2
9	100	48.8	65.9	40.2	99.4	51	100	52.2
10	100	48.8	34.1	63.6	99.4	51	100	52.2
11	28.2	48.8	94.7	63.6	54.8	15.1	100	9.1
12	65.1	48.8	51.5	63.6	54.2	15.1	100	22.4
13	65.1	48.8	0	0	54.8	51	100	9.1
14	28.2	48.8	51.5	100	87.4	15.1	100	9.1
15	65.1	48.8	51.5	63.6	54.8	51	100	9.1
16	100	48.8	51.5	63.6	99.4	42.5	100	52.2
17	65.1	48.8	17.4	51.2	99.4	51	100	38.9
18	91.3	26.7	51.5	63.6	99.4	8.5	100	22.4
19	100	48.8	51.5	63.6	99.4	51	100	52.2
20	100	48.8	65.9	63.6	99.4	51	100	9.1
21	73.8	48.8	51.5	87.7	99.4	51	100	22.4
22	58.5	0	100	82.3	54.8	51	64.7	9.1
23	73.8	48.8	51.5	12.4	99.4	51	100	22.4
24	100	48.8	90.9	58.1	99.4	51	100	52.2
25	100	48.8	100	63.6	99.4	42.5	100	22.4
26	58.5	48.8	94.7	58.1	87.4	15.1	100	9.1
Mean	78.9	45.2	58.2	55.5	86.8	40.4	98.6	30.4

Source: Results of SWAT software

Table 2. SWAT scale for group two (age ≥51 years).

Pilot	Phases of Time							
	Hour Period				Day Period		Season Period	
	Morning	Afternoon	Night	Early morning	Weekend	Weekday	Peak season	Non-peak season
1	83.9	54.7	87.7	91.6	89.9	52.1	100	67.3
2	100	54.7	71.8	91.6	89.9	41	72.4	17
3	93.5	54.7	100	84.3	89.4	52.1	89.3	53.4
4	100	65.3	100	100	89.9	52.1	79.2	53.4
5	48.8	54.7	50.7	55.7	54.7	52.1	51.6	53.4
6	48.8	54.7	50.7	55.7	54.7	52.1	51.6	53.4
7	93.5	54.7	87.7	100	100	54.8	89.9	42.4
8	93.5	44.8	87.7	100	100	58.4	89.9	42.4
9	100	55.2	87.7	100	100	54.8	72.4	53.4
10	100	54.7	59.5	63	100	61.1	100	67.3
11	17.1	54.9	23.9	100	54.7	13.8	48.6	42.4
12	48.8	54.7	50.7	100	54.7	52.1	51.6	53.4
13	64.9	0	50.7	0	54.7	0	51.6	0
14	0	54.7	50.7	55.7	0	0	0	0
15	83.9	54.7	15.1	84.3	89.9	52.1	89.3	10.8
16	93.5	54.7	87.7	35.1	54.7	52.1	89.9	53.4
17	70.8	44.8	62.9	91.6	89.4	91	51.6	53.4
18	83.9	54.7	47.4	44.9	54.7	52.1	61.7	42.4
19	0	54.7	50.7	100	30.1	52.1	15.5	17
20	48.8	54.7	50.7	8.6	54.7	52.1	100	53.4
21	17.1	20	15.1	19.4	20	11.1	15.5	17
22	17.1	0	71.8	71.4	89.4	52.1	100	17
23	48.8	54.7	50.7	64	54.7	52.1	51.6	53.4
24	31.7	20	15.1	35.1	20	58.4	61.7	17
25	48.8	54.7	50.7	55.7	54.7	52.1	51.6	53.4
26	93.5	99.5	78.9	84.3	89.9	52.1	72.4	53.4
Mean	62.7	49.2	59.9	68.9	66.7	47.2	65.7	40

Source: Results of SWAT software

Table 3. Highest mental workload value.

	Flight condition	Mean of mental workload value (age <30 years)	Mean of mental workload value (age ≥51 years)
Hour Period	Morning (6:00 am - 11:59 am)	78.9 *	62.7
	Afternoon (12:00 - 17:59 pm)	45.2	49.2
	Night (18:00 - 23:59 pm)	58.2	59.9
	Early Morning (0:00 – 5:59 am)	55.5	68.9 *
Day Period	Weekend (Saturday to Sunday)	86.8 *	66.7 *
	Weekday (Monday to Friday)	40.4	47.2
Season Period	Peak season (Eid Mubarak and Summer holiday)	98.6 *	65.7 *
	Non-peak season	30.4	40

Based on the results of the SWAT analysis (Table 3), figures marked with an asterisk (*) indicate the levels with the highest mental workload for each condition. From the table, it can be concluded that for the group one consisting of 26 pilot respondents (aged <30 years), the conditions with the highest mental workload value were at the time flights were made in the morning (6:00 to 11:59 am), during weekends, and during peak seasons; and for the group two consisting of 26 pilot respondents (aged ≥ 51 years), the conditions with the highest mental workload value were, for the dimension of the phases of time, the highest mental workload value of the pilots viewed from the hour period was at the time flights were made in the early morning (00:00 to 5:59 am), whereas if viewed from the day period the greatest mental workload took place at the time flights were made during weekends, while for the season period, the highest mental workload occurred during peak seasons. Based on the SWAT value, it is revealed that in relation to the dimension of phases of time, if seen from the hour period, there were differences in the value of the highest mental workload between the group one and the groups two. For the group one consisting of 26 pilot respondents (aged <30 years), the condition with the greatest mental workload was at the time flights were made in the morning (6:00 to 11:59 am), which is the peak traffic hour/golden time and is the rush hour for the air traffic in Indonesia. This is because these range of age, the pilot still has a limited flight hours and dominant still qualified as a SIC (second in command) or a copilot, thus if confronted with the aspect of busy air traffic, this may make a pilot increasingly busy and have greater load whilst performing tasks and work that may affect the psychological consideration of how to maintain work processes in good psychological conditions, and if it is neglected it will result in fatigue both physically and psychologically among the pilots in this age group.

Meanwhile, for the group two consisting of 26 pilot respondents (aged ≥ 51 years), it is revealed that the greatest mental workload of the pilots was at the time flights were made in the early morning (00:00 to 05:59 am) because at this age pilots have a lot of experience in flight hours and most of them are qualified as a PIC (pilot in command) or a captain on a flight so that the flight operator can trust them to carry out long haul flights which usually takes a long time and begin at night. A study conducted by De Mello et.al. (2008) also found that the risk of errors increased by almost 50% in the early morning relative to the morning period (ratio of 1:1.46) for the period of the afternoon, the ratio was 1:1.04 and for the night a ratio of 1:1.05 was found. These results showed that the period of the early morning represented a greater risk of attention problems and fatigue. If flight is conduct in this period, it can effect to the pilot condition, night or early morning work requires the pilot to perform tasks at a time when the organism should be resting instead of working. This is because humans are naturally born to be a day creature not a nocturnal creature. It is means that at noon with the presence of the sun causing the environment to be bright, people tend to have an instinct to work and perform activities, and vice versa because of absence of sunlight (dark nights) people tend to have an instinct to rest or sleep at night. This life follows a rhythm of biological life called the circadian rhythm, when the rhythm is disturbed as a result of changes in working hours in which the body is supposed to be in a phase of rest are required to work, causing the loss of sleep time. Such a condition may bring adverse effects both physically and psychologically and these may affect the mental workload of a pilot. Although in modern society artificial lighting makes it possible to have light for the whole 24 hours span, body function (hormonal, metabolic, digestive, cardiovascular, mental etc.) are still influenced mainly by the natural light/dark cycle, showing periodic oscillations that have, in general, peaks (acrophases) during the day time and troughs at night (Costa, 1999). On night flight schedule, in particular, pilot must change their normal sleep or wake pattern and adjust their body functions to inverted rest or activity periods, having to work when they should sleep and sleep when they should stay awake. It is common knowledge that work efficiency during the night is not the same as during the day. There is in fact clear evidence that it can be significantly influenced by the time of day in which the task is performed, owning to the interaction between the homeostatic (time since awake) and circadian process that regulate sleep and wakefulness (Turek & Zee, 1999). The results study from Krauchi and Wirz (1994) also shows that operating long haul flights during the night (whether or not they are transmeridional) frequently conflicts with human circadian regulation and severely affects physiologic and psychological functions in-flight performance. Body temperature drops most during the early morning, reaching its minimum at about 05:00 am (Van Dongen, 2006), which is suggests that this factor may affect crew member performance, due to the low level of physical and cognitive aspects during this period. However, it must emphasize that temperature by itself, cannot be regarded as a warning, which is influenced by other biological mechanism. Thus, the biological rhythms reflect the contributions, to a greater or lesser degree, of endogenous components and masking effect (Minor & Waterhouse, 1987). A study conducted by Goode (2003) suggests that setting limits to hours worked by commercial pilot would reduce the risk of accident caused by pilot fatigue.

Meanwhile, if viewed from the day period and season periods, the highest mental workload value of the group one and that of the group two were the same, i.e. the pilots felt the highest mental workload at the time they had to fly during weekends and peak seasons because in the world of aviation, especially in Indonesia, there is a term called the passenger flow cycle, i.e. a season with an abundant number of passenger (*peak season*), which usually occurs during school holidays, year-end holidays, Eid holidays or weekend. Moreover, at his period extra flights are also offered by the flight operator to anticipate the increasing number of passengers. This increasing number of flights is directly proportional to the increase in the air traffic, especially in Indonesia, all of which may affect the performance of pilots in carrying out their task.

Based on the analysis above, the overall pilot mental workload categorized in the high workload (overload), when faced with flight conditions conducted in the morning (06:00 to 11:59 am) for group one, early morning (00.00 to 05:59 am) for groups two, during weekend and entered a period of peak season. The highest mental workload will lead the error that conduct by human. Human errors are result from physiological and psychological limitation and causes include fatigue and fear as well as cognitive overload, poor interpersonal communications, imperfect information processing and flawed decision making (Helmreich & Merrit, 1998). The abilities of a pilot in making judgments and decisions are vital in aviation safety. Decision-making is one of the important and primary links in whilst flying especially to cope with emergency and dangerous situations. In the state of fatigue, a pilot tends to feel oppressed to make a decision and action, and unable to carefully observe a variety of the safest alternative actions to do (Mustopo, 2012). A pilot experiencing fatigue tends to have a lower level of vigilance whilst performing his job which eventually may contribute to the occurrence of aircraft accidents.

The results of this study suggested a relationship between phases of time and higher mental workload during flight. Aircraft operator should develop strategies for pilot who works in different phases of time in order to minimize fatigue that caused by highest mental workload in an attempt to help reduce errors from pilot that can influence to the aircraft accident.

4. Conclusions

The results of this study indicate that the conditions with the highest mental workload for the group one consisting of 26 pilot respondents (aged <30 years) were at the time flights were made in the morning (06:00 to 11:59 am), during weekends, and during peak seasons. While the results for group two (pilot age ≥51 years), indicating that the conditions with the highest mental workload were at the time flights were made in the early morning (00:00 to 05:59 am), during weekends, and during peak seasons. This study also showed that the time dimension factor (T) significantly affects the mental workload of pilots, indicating that they put more emphasis on this factor when they are considering workloads.

References

Corwin, W. H. (1992). In flight and post flight assessment of pilot workload in commercial transport aircraft using the subjective workload assessment technique. *The International Journal of Aviation Psychology, 2*(2), 77-93.

Costa, G. (1999). *Handbook of aviation human factors.* London, England: Erlbaum.

De Mello, M. T., Esteves, A. M., Pires, M. L. N., Santos, D. C., Bittencourt, L. R. A, Silva, R. S., & Tufik, S. (2008). Relationship between Brazilian airline pilot errors and time of day. *Brazilian Journal of Medical and Biological Research, 41*(12), 1129-1131.

Gander, P. H., Nguyen, D., Roekind, M. R., & Connel, L. J. (1993). Age circadian rhythms, and sleep loss in flight crews. *Aviation Space Environment Medicine, 64,* 189-195.

Goode, J. H. (2003). Are pilots at risk of accident due to fatigue. *Journal of Safety Research, 34,* 309-313.

Helmreich, R. L., & Merrit, A. C. (1998). Culture at work: National, organizational, and professional influences. Aldershot, England: Ashagete.

Krauchi, K., & Wirz, A. J. (1994). Circadian rhythm of heat production, heart rate, and skin and core temperature under un-masking conditions in men. *American Journal Psychology, 287,* R819-R829.

Minor, D., & Waterhouse, J. M. (1987). The problem of masking and some ways to deal with it, In G. Hilderbrandt, R. Moog, F. (Eds.). *Chronibiology and chronomedicine* (pp. 119-135). Frankfurt, Germany: Peter Lang.

Mustopo, W. I. (2012, April 23). Faktor Psikologi Pada Fatigue dan Konsekuensinya Terhadap Keselamatan Penerbangan. Retreived from: http://psikologipenerbangan.blogspot.com/2011/07/faktor-psikologi-pada-fatigue-dan.html

Reid, G. B. (1989). *Subjective workload assessment technique (SWAT): A user's guide (U). Amstrong aerospace medical research laboratory.* Ohio, OH: Wright-Patterson Air Force Base.

Saputra, A. D., Priyanto, S., Muthohar, I., & Etsem, M. B. (2014). Analisis pengaruh waktu terbang (phases of time) terhadap beban kerja mental pilot pesawat terbang dengan menggunakan metode subjective workload asessment technique (SWAT). *Prosiding FSTPT, 2*(1), 1335-1349.

Turek, F. W., & Zee, P. C. (1999). *Regulation of sleep and circadian rhythms.* Basel, Switzerland: Marcel Dekker.

Van Dongen, H. P. (2006). Shift work and inter-individual differences in sleep and sleepiness. *Chronobiology International, 23,* 1139-1147.

Wignjosoebroto, S., & Zaini, P. (2007). *Studi aplikasi ergonomi kognitif untuk beban kerja mental pilot dalam pelaksanaan prosedur pengendalian pesawat dengan metode "SWAT".* Surabaya, Indonesia: Laboratorium Ergonomi dan Perancangan Sistem Kerja Jurusan Teknik Industri. Surabaya. Institut Teknologi Sepuluh Nopember.

Wright, N., & McGown, A. (2004). Involuntary sleep during civil air operations; Wrist activity and the prevention of sleep. *Aviation Space Environment Medicine, 75,* 37-45