Compatibility between Shift Work and Chronotype in Indonesian Air Traffic Control’ Workers: View of Performance and Mental Workload

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Abstract. Shift work is commonly found in modern industries. Shift work arrangement is problematic since working in the out of normal work is giving negative consequences. Therefore, attempts have been made to optimize shift work arrangement and to minimize the negative consequences. One approach that has been used as a base in arrange shift work is chronotype, defined as individual preferences about their sleepiness work and is partially determined by clock genes. This present study aimed to observe the effect of chronotype on shift work arrangement, from the view of performance and mental workload. 25 Air Traffic Control/ATC workers work in three shift involve in this study. Chronotype was assessed once work by Munich Chronotype Questionnaire. The performance was assessed based on sleepiness (using Karolinska Sleepiness scale) and alertness (using alertometer) in the end of each shift for every ATC worker. Separate mixed ANOVA was applied in analyzing the result. This study reveals that people work in a shift work that is compatible with the chronotype perceive significant lower mental workload, slightly better alertness and slightly lower sleepiness than people work in a shift work that is not compatible with the chronotype. The implication of the result is discussed.

1. Introduction
Shift work is commonly defined as an employment practice designed to make a product or provide service all 24 hours of the clock each day of the week. The shift work typically sees the day divided into shifts, set periods of work during which different groups of workers perform their duties.

In developed countries, the number of workers in shift work has been increased in a very significant way and shift work has been pointed out as a major risk factor of worker health problem and work related accident for example in European Union countries [2]). In the USA, the Center for Disease Control and Prevention also report that more worker engaged in long hours work and shift work which has been associated with health and safety risks. In global number, the number of shift worker is about 20% of the workforce [3]).

Similar pictures have been found in developing countries. Ong and Kogi4) have been reported a few studies on shift work in countries of Asia and South America. According to Ong and Kogi, the developing countries need a different approach to managing shift work from those used in developed nations--one that concentrates more on the social consequences of shift work, particularly for the large proportion of female workers engaged in permanent night work. Talking about consequences of the shift work, not only fatigue and accident, Juda [2]) listed negative consequences of the shift work, started...
from psychological distress (i.e., increased depression, anxiety, stress, and neuroticism, see [5,6]) for examples); physical health problem (i.e., digestive problem and cardio-vascular disorders [7]); metabolic problems [8]); and reproductive problems [9]). Even worse, shift work also correlates with cancer risk [10]).

Shift work studies have come a long way. Any options to solve the problem of shift work and effort to reduce the consequences must be considered, in particular, individual differences in adapting, tolerating, and coping shift work. The fact that shift work is problematic and give negative consequences mentioned above might because shift workers cannot adjust the demand of the work to their capacity to fulfill the task demand in particular, relates to work of work. Wittmann et al. [11]) and Gamble et al. [12]) hypothesized that there is a significant discrepancy between social schedule and biological work of worker, therefore maladaptation and unhealthiness arise. Talking about shift work and biological work, one aspect of the individual differences that gain attention in shift work arrangement is the internal timing of the body, which has been known as chronotype.

Chronotype is defined as individual preferences about their sleepiness work and is partially determined by clock genes [13]). Individuals can be classified based on their preference concerning sleep work and habits according to their chronotype: morning/early types and evening/late types [14,15]). Morning types show the highest activity in the early hours of the day. In contrast, evening types shift their activity to the later hours of the day and the start of sleep towards the evening. Some research state that chronotype must be considered in work design as it might lead to stress, frustration, and low performance[16]).

In the context of shift work, research on the correlation between chronotype and shift work have been conducted recently. Recent knowledge about chronotype and shift work is so extensive. However, mixed result has been found. For examples, Fernandes et al. [17]) observe the relation between chronotype and shift work in train drivers and found no significant correlation between chronotype and performance as well as chronotype and fatigue. However, evening types tend to score worse in sleep and quality of life. In hospital workers, Antunes [18]) found no correlation between shift work and chronotype. However, in their study on the perception of the workers considering their chronotype in shift work arrangement, Guimareas et al. [16]) show that people working in shifts that are not compatible with their chronotype felt more stress and less satisfaction with the work condition. In Indonesia, one of emerging developing countries, shift work workers has been reported increase as well. Some studies have been conducted in Indonesia in relation to shift worker such as in particular, in a hospital [19]) and in the manufacturing industry. The research also underline consequence of shift work in fatigue and quality of services of the particular industries. Another industry having a problem with shift work is Air Traffic Control/ATC [20]).

ATC workers, along with pilot are often blamed for Indonesian flight accident. In fact, Indonesia still has more than three works the global average rate of fatal air crashes and the country averages more than one flight accident a year. In the past few years, Indonesia has redoubled efforts to improve that record, but the challenges are enormous. Therefore some effort has been made in order to improve the performance of both ATC workers and pilot. In the context of ATC workers, since ATC officer work on shift, shift work also a crucial issue in improving the performance of ATC officer [21]).

This study, therefore, aimed to analyze shift work arrangement in ATC workers that is ATC officer in Jakarta’s Soekarno-Hatta airport, the ninth-busiest in the world and serving a metropolis of nearly 30 million people. Like many airports in the country, Soekarno-Hatta is struggling to cope with Asia’s boom in air travel and traffic density is quite high. Any effort to minimize negative consequences of shift work of ATC is expected. This study also observes the benefits of arranging shift work according to their chronotype. This proposed study gives novelty in the criterion of compatibility between chronotype and shift work that is both performance criterion as well as mental workload. The term ‘workload’ is used to describe the difference between the resources demanded by the job and the resources available to the worker [22]). This study also observes the influence of compatibility between shift work-chronotype with performance and mental workload.
2. Methodology

2.1. Participant

Twenty five Air Traffic Control (ATC) workers were participating voluntarily in this study (mean age= 26.96 years, SD=1.97 year, 11 female) and they work in three shift work: morning (06.00-14.00), afternoon (14.00-20.00 WIB), and night shift (20.00-06.00 WIB). Flight density level in particular task demand in those three shift work is considered to be equal based on an interview with ATC supervisor.

2.2. Measures

Chronotype was assessed using Munich ChronoType Questionnaire (MCTQ [23,24]) that assesses chronotype using self-reported individual sleep phases. The MCTQ asks questions about sleep and activity works separately for work and free days. Chronotype is calculated based on the midpoint between sleep onset and wake up (mid-sleep), which is set as the phase reference point for sleep on free days, i.e., days with no work or social obligations. The MCTQ provides population-specific continuous distributions, with early and late chronotypes falling on either tail of the distribution. In overview, people more active in the morning is categorized as morning type/early type and people more active in the night is categorized as night type/late type. There is a type between both of them that is intermediate type. The MCTQ was adapted into Indonesian following back translate procedure (see [25,26,27] for review).

Mental workload was assessed using the raw NASATLX [28,29]). The NASA-TLX consist of 6 subscales that are mental demand, physical demand, temporal demand, performance, effort, and frustration level. Subjects were instructed to give a rating on each subscale ranging from 0 to 100.

Sleepiness level was observed using Karolinska Sleepiness Scale [30,31]). This scale measures the subjective level of sleepiness at a particular work during the day. On this scale, subjects indicate which level best reflects the psycho-physical state experienced in the last 10 minute. The KSS is a measure of situational sleepiness.

The performance was assessed using smartphone-based alertometer [32]). Respondents were given a number of stimuli in the form of four images that are in between two transverse rotating. Respondents were asked to assess whether the four images are similar or not. Alertometer will record the reaction work and accuracy of the responses given by the respondents, then it calculates the two became a value. Respondents were asked to do six sets of stimuli. The first five sets made to obtain a baseline value that a comparison value alertometer sixth and generate value ratio which indicates the level of alertness alertometer ATC personnel on a particular shift. The higher the alertness of participants, the higher score of the alertometer. Procedure Within-subject quasi-experiment was applied in the study. Subjects were doing their normal activities during their work in three different shifts. Chronotype was assessed once in the beginning of the study. Whereas measurement of mental workload, sleepiness, and alertness is conducted at the end of every shift work for every ATC workers.

2.3. Procedure

Within-subject quasi-experiment was applied in the study. Subjects were doing their normal activities during their work in three different shift. Chronotype was assessed once in the beginning of the study. Whereas measurement of mental workload, sleepiness, and alertness is conducted at the end of every shift work for every ATC workers.

3. Result

Differences among three shift work in mental workload, sleepiness, and alertness

ANOVA shows there are no significant differences among the three shift work for mental workload, sleepiness, and alertness. However, as expected, there is a tendency of increasing score of mental workload and sleepiness from morning shift to night shift. Moreover, a tendency of decreasing alertness score from morning to night shift was found as well as can be seen in Figure 1.
Incorporating chronotype in analysis of mental workload, sleepiness, and alertness among the three shifts

Among 25 ATC participants, there are 9 participants have an early type, 16 participants have an intermediate type, and 6 participants have a late type. Mental workload measures for the three shift work based on chronotype can be seen in Figure 2.

![Figure 1. Mental workload (a), sleepiness (b), and alertness (c) as a function of shift work](image1)

![Figure 2. The NASA-TLX as a function of shift work and chronotype](image2)

For the analysis of mental workload, separate mixed ANOVAs with chronotype (early, intermediate, late type) as a between subjects factor and shift work (morning, afternoon, and night shift) as a within subjects factor were carried out on the NASA-TLX ratings and the ratings for each of the sub-scales of the NASA-TLX. The effect of chronotype was not significant for the NASA-TLX and all subscale of the NASA-TLX. The effect of shift work was not significant for the NASA-TLX and all subscales of the NASA-TLX except for Frustration level (F(2, 44) = 3.79, p < 0.05, MSE = 171.26). Most importantly, the chronotype x shift work interaction was significant for the NASA-TLX (F(4, 44) = 3.59, p < 0.05, MSE = 71.21). The interaction is expected and it tells that the shift work gives a different effect on the NASA-TLX depending on the chronotype.

3.2.2 Sleepiness as a function of chronotype and shift work

Sleepiness that was measured using KSS can be seen in Figure 3.
For the analysis of sleepiness, separate mixed ANOVAs with chronotype (early, intermediate, late type) as a between subjects factor and shift work (morning, afternoon, and night shift) as a within subjects factor were carried out on the Karolinska sleepiness scale. The effect of chronotype was significant ($F(2, 22) = 9.89, p < 0.05, \text{MSE} = 2.61$). The effect of shift work was significant ($F(2, 44) = 3.91, p < 0.05, \text{MSE} = 1.98$). The chronotype x shift work interaction was not significant.

For the analysis of alertness, separate mixed ANOVAs with chronotype (early, intermediate, late type) as a between subjects factor and shift work (morning, afternoon, and night shift) as a within subjects factor were carried out on the Alertometer scale. The effect of chronotype, shift work, as well the chronotype x shift work interaction was not significant.

4. Discussion
This study aimed to analyze shift work arrangement of ATC based on chronotype, in which mental workload, sleepiness, and alertness were observed as criteria. In general, mental workload and sleepiness are slightly increasing whereas alertness is slightly decreasing from morning shift to night shift. This result is not surprising since morning shift is a normal shift of the worker commonly. The result of this study is in line with the result of the previous study such as [11] who found the influence of chronotype in shift work of the nurse, in which morning shift perform better than afternoon or night shift.

In-depth mental workload analysis by incorporating chronotype reveals that the shift work gives a different effect on the mental workload depending on the chronotype. Workers in shift work that compatible with their chronotypes (i.e., early type workers work in the morning shift, intermediate type workers in afternoon shift, and late type workers in night shift) perceive mental workload lowest.
compare to other shift work. Comparison with the previous study could not be conducted since as far as acknowledge by authors, the present study is the first study involving mental workload in the analysis of shift work and chronotype. However, this present study support Guimaraes et al. [16]) who underlined preference and satisfaction of workers to have shift work compatible with their chronotype.

This result can be explained based on the definition of subjective mental workload measures itself. Since subjective mental workload is defined as perceived mental workload, the subjectivity of respondents plays an important role. Working in the shift rather than normal shift (i.e., morning shift) indeed perceived harder than other shift. The view of mental workload in the analysis of compatibility between shift work and chronotype will give new perspective will enrich the analysis of chronotype and shift work.

Analysis of sleepiness shows that both early and intermediate chronotype fell increasing sleepiness from morning to night shift. In contrast, no trend was found for late chronotype. The irregular trend for late chronotype can be explained by a study conducted by Boudreau [33]). According to Boudreau, adaptation to night shift work is difficult and unique and is associated with different health indices. Therefore changes in biological condition in human including sleepiness could be found. Furthermore, the mix result on the sleepiness trend among different shift is in line with Gamble et al. [12]) who reviewed that only a few studies have observed the influence of chronotype on the ability to cope with shift work schedules and the results have been inconsistent. Moreover, Juda [2]) stated the importance of mediator’s variable such as duration and quality of sleep and psychological well-being and is needed.

The fact that there was no significant effect of both chronotype and shift work in alertness was not surprising. This result is in line with the result of the previous studies such as Fernandes et al. [17]) who found non-significant differences in the psychomotor vigilance task score of the Brazilian train driver in different shift work based on their chronotype.

There are limitations of the study worth noting. First, the number of participants are limited due to a limited number of ATC workers and limitation of the permit from ATC manager for safety reason. There are also unbalance number between male and female and unbalance number among different chronotypes due to the similar reason. Further research in different ATC with a larger number of participants might enrich the analysis. Other limitations are related with the disadvantages of field studies. Unlike controlled experimental studies, field studies are often difficult to compare due to heterogeneity in settings, conditions, participants etc.

5. Conclusion
In practical, the result of this study can be used as a basis of improvement in shift work arrangement of Indonesian ATC workers. Since workers with a compatibility between shift work-chronotype reveal significant lower mental workload and slightly lower sleepiness and higher alertness than workers with noncompatible of shift work-chronotype, management of ATC should consider chronotype in the arrangement of shift work of ATC workers. The potential result of the consideration vary: healthier employees, more productivity, and last but not least reduce incident and accident rate involving ATC workers.

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