CHAPTER II

LITERATURE SURVEY

Definitions

To understand the contents of this thesis, an explanation of the meanings of some technical terms is necessary. These terms are as follows:

1. Circadian Rhythms (Eichner, 1988)

Circadian rhythms are physiological rhythms which follow their 24-hour cycle repeatedly. The rhythms are found not only in human beings but also in animals and plants. They have influences over almost all biological functions, including metabolism, urinary excretion, and hormonal output. Moreover, they control the heart rate, body temperature and blood pressure. Even strength and alertness or the state of inactivity such as sleep are influenced by these rhythms.

2. Critical Flicker Fusion Frequency (CFF)
(Marek and Noworol, 1986)

The critical flicker fusion frequency (threshold) is the frequency at which the light is the border line separating a flickering light from a constantly shining light.

3. Fatigue (Grandjean, 1979)

Fatigue is classified into physical and mental fatigue.

3.1 Physical fatigue is an acutely painful phenomenon,

which occurs in overstressed muscles.

3.2 Mental fatigue is a diffuse sensation which is accompanied by indolence and a decrease in working efficiency.

4. Fuzzy Set Theory (Karwowski, 1982)

The basic definitions of fuzzy sets are as follows:

Let X = {x} be a collection of objects denoted by x. A fuzzy set A in X is a set of ordered pairs:

$$A = \{ (x, f_A(x)) / x \in X \}$$

where $f_A(x)$ represents the grade of membership of x in A, and $f_A : X \rightarrow I$ is a function from X to space I, called the membership space. When I contains only two points, 0 and 1, set A is nonfuzzy and its membership function becomes identical with the characteristic function of a non-fuzzy set. It is assumed that I is in the interval [0,1], with 0 and 1 representing, respectively, the lowest and the highest grades of membership. Thus a fuzzy set A can be precisely defined by associating with each object x a number between 0 and 1, which represents its grade of membership in A.

As an example, let N be a set of natural numbers: N = (0, 1 , 2, ...), and consider the fuzzy set A (subset of N) of small natural numbers:

$$A = \{ (0/1), (1/0.8), (2/0.4) \}$$

According to the format of the fuzzy sets, the slash is used to separate two figures in the parenthesis. The first figure is considered an element of the set and the second figure is used to

indicate the grade of membership of the first figure. The number 0 is thus a member of the set A with its grade of membership of 1.

5. Reaction Time (Rosa and Colligan, 1988)

The reaction time indicates the response of a human body to different stimuli. The simple reaction timer is the instrument which displays only one kind of stimulus. The choice reaction timer is operated with the use of various stimului such as sound, light, smell, taste, etc.

6. Repetitive Work (Eastman Kodak Co., 1986)

A period of time used to complete one unit of assembly or to inspect one item is called a cycle. An activity will usually be viewed as repetitive if the cycle time is two minutes or less and it is repeated throughout the work shift. Highly repetitive work has a cycle time of 30 seconds or less. Such work is usually performed with the muscles of fingers, arms, shoulders, or feet. Many of the operations are done while workers are in a sitting position.

Mental Fatigue in General

Mental fatigue is a state which everyone learns of through experience. It is caused by various kinds of stress. The important stresses can be seen in the following figure.

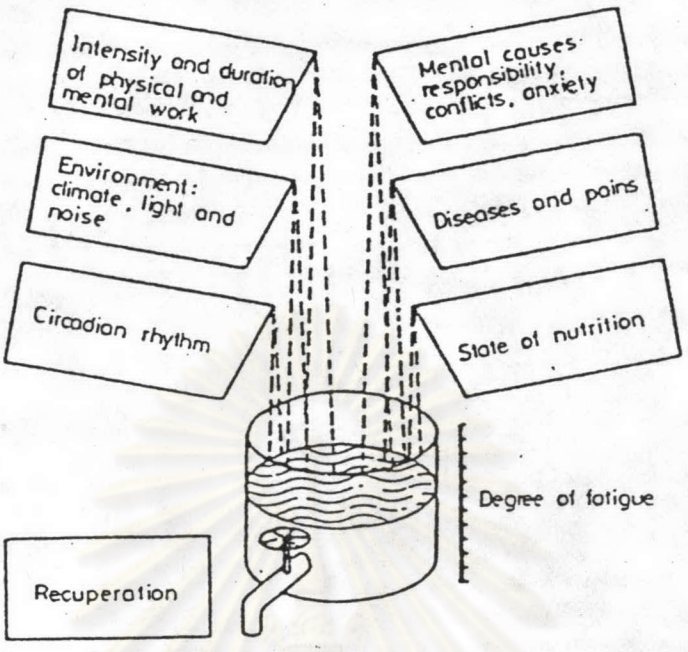

Figure 2.1 A model of the causes of mental fatigue

(Grandjean, 1979)

Figure 2.1 shows that the degree of mental fatigue is determined by different stresses in everyday life. More stresses will bring about mental fatigue of a higher level. The rate of recuperation (outflow) must balance the rate of fatigue (inflow) in order to maintain health and efficiency. In addition, physical fatigue is one of the causes of mental fatigue (see Figure 2.2). Physical fatigue is usually followed by mental fatigue.

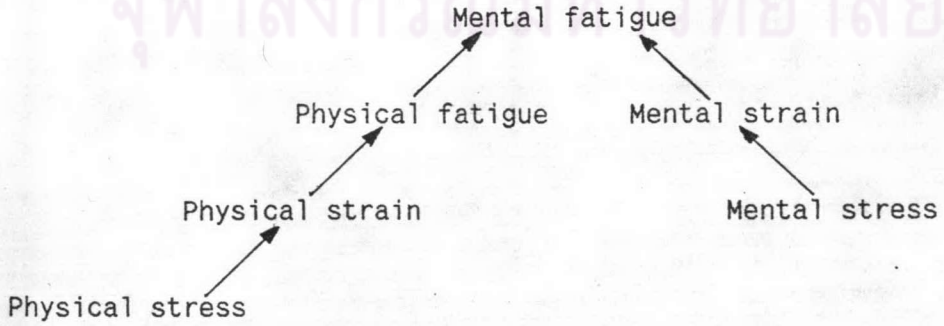

Figure 2.2 Relationship between physical and mental fatigue

The effects of mental fatigue lead to various problems such as decrease in efficiency, increasing errors, absenteeism, turnover and accidents. Fatigued people show unwillingness to work, weariness, somnolence, faintness, and distaste for work. Grandjean (1971) pointed out that these symptoms are related to the mechanism of the nervous system.

The nervous system consists of three parts: central nervous system (CNS), autonomic nervous system and peripheral nervous system. The function of the system is to control the overall mechanism of the body such as heart rate, body movement, and blood circulation.

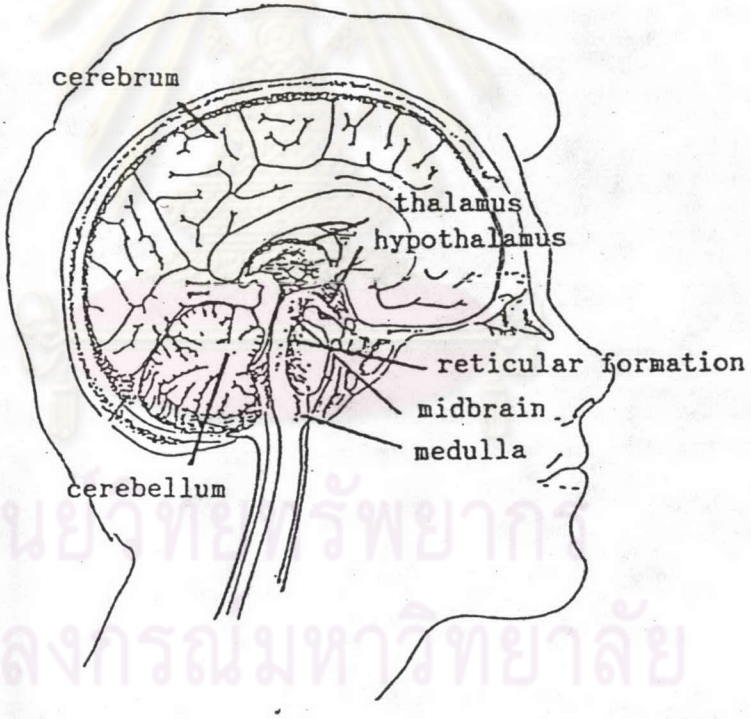

Figure 2.3 Structure of CNS (Tortora, 1986)

The structure of CNS is illustrated in Figure 2.3. This system consists of cerebrum, cerebellum, and the brain stem. The brain stem is divided into the thalamus, hypothalamus, midbrain, medulla and reticular formation. Each part has different functions. The reticular

formation has control over the level of activation of the cerebral cortex. According to neurophysiology, there are, in reticular formation, two systems working in opposite directions: an activating system and an inhibiting system. To carry out their functions, the two systems are stimulated by afferent signals from the cerebral cortex and sensory system. If the activating system predominates, the level of activation of the cerebral cortex will increase. This is a cause of alertness and eagerness. On the other hand, if the activating system is suppressed by the inhibiting system, which becomes more influential, the level of activation will decrease, thereby bringing about fatigue.

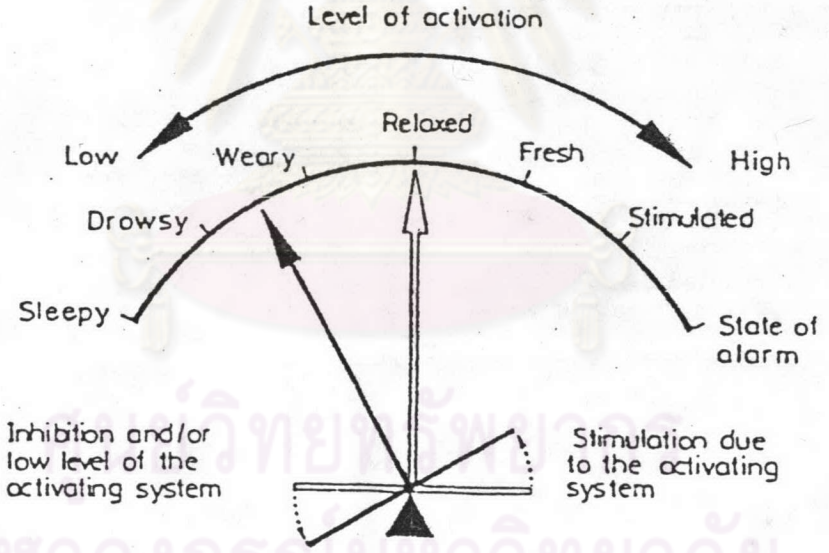

Figure 2.4 The level of activation of cerebral cortex

(Grandjean, 1979)

In this paragraph, the process in the formation of mental fatigue is explained. When the body is stimulated, a stream of impulses from sensory organs will be carried into the reticular formation. The reticular activating system then arouses the cerebral

cortex through the thalamic pathway; as a result, the impulses are sent back along the nerve tracts from the cortex to the reticular activating system and down to other systems such as the motor system and visceral system. By this mechanism, the entire body becomes alert. If the body remains in a state of fatigue; the activating system, which is located in the upper part of the reticular formation, will be inhibited and the inhibiting system in the lower part of the reticular formation will be activated. This will bring about the inhibition of the cerebal cortex and also lead to decline in performance.

Changes of the critical flicker fusion frequency (CFF) values and reaction time are significant indicators used to measure mental fatigue. Much research indicates that the decrease in the CFF values is associated with the deactivation of the cerebral cortex, as a sign of mental fatigue. The changes of the CFF values depend on types of work. Mental work usually makes these values decrease distinctly. For instance, the value is lower in visual workers than in office workers. Because of the increase in fatigue, the reaction of the human body, which is measured by reaction time, will be slower after work. The questionnaire is widely used as the subjective method to assess mental fatigue. Since it is important to know the data on human state of fatigue in a particular situation, the questionnaire is designed to be able to give quantitive values of fatigue.

Literature Reviews

Some of the following studies are focused on the problem of mental fatigue. There are several methods of fatigue testing: critical flicker fusion frequency, reaction time and self-scaling questionnaire.

Grandjean (1958) studied the effects of fatigue on 15 female

telephone operators and 14 office workers. The subjects were tested twice a day: before work in the early afternoon and after work in the evening. The results of the test on the female telephone operators were:

- A 10% increase in visual reaction time
- A decrease of 0.6 Hz in critical flicker fusion frequency

As for the office workers, there was no significant change of the fatigue-indicating values.

Haider (1961) studied fatigue among 337 female workers in textile factories. The first group of 207 employees worked on a moving production line, while the other group of 130 labourers worked at their own speed. Haider assessed the feelings of these workers by using a self-assessment card, with twelve pairs of contrasting states. The results of the experiment with the two groups of workers were different. The production line workers were more tense, bored, and sleepy than those who worked at their own speed. The percentage of weary and tense workers who worked on the production line was as high as 20-25%.

Haider (1963) studied the physiological symptoms of boredom and fatigue from a selected group of electronic workers who took charge in monotonous work. At work, these female workers were subjected to light signals at irregular intervals on the protective shield of their machine. When they noticed a flash of light, they were required to press a pedal. This was a possible way to monitor their speed of response and their level of alertness throughout the day. Haider found out that, during the working period, the alertness of the twenty-nine female workers diminished whereas their reaction time increased.

Saito, Kishida and Endo (1972) carried out important research in the food industry. Workers studied were engaged in the visual control of bottles and their contents. The bottles moved very quickly. The job was considered arduous and monotonous. After a short time at work, the number of rejected bottles became distinctly less than usual. This indicated diminishing alertness. Concurrently, a distinctive fall in the critical flicker fusion frequency could be recorded. The fall was also accompanied by increasing fatigue symptoms. The fall in the critical flicker fusion frequency was greatest during the period when the workers were observed to talk less to others, and to tend to doze or even to fall asleep. The time-scale was as follows:

first hour - little change;

2nd-4th hours - strongly affected;

final hour before lunch break - workers felt better and worked more efficiently.

Weber, Jermini and Grandjean (1975) showed that critical flicker fusion frequency value (CFF) was particularly related to the self-scaling questionnaire which was based on the scale stretched between eight opposite designations. These designations were refreshed-tired ($r = 0.809$), strong-weak ($r = 0.833$), awake-sleepy ($r = 0.976$) and vigorous-exhausted ($r = 0.833$). In addition, the three researchers pointed out that a decrease in CFF value is connected with a feeling of fatigue.

Marek and Noworol (1986) reported that changes in threshold values based on the theory of fuzzy sets (FCFF) can be used to measure mental workload and mental fatigue. Twenty-four video display terminal operators were investigated three times, before and after three and

six hours of mental workload. They found that threshold level set length, obtained from FCFF, was highly related to the self-scaling questionnaire on fatigue. There are ten scales between each designation. The designations are as follows: refreshed-tired ($r = 0.878$), awake-sleepy ($r = 0.820$), strong-weak ($r = 0.823$), vigorous-exhausted ($r = 0.851$). The two researchers concluded that the changes in FCFF are due to mental workload and fatigue.