CHAPTER II

LITERATURE REVIEW

Cognition and human information processing

Cognition can be defined as "the act or process of knowing in the broadest sense; specifically, an intellectual process by which knowledge is gained from perception or ideas" (18). Cognition is central to the development of psychology as a scientific discipline. Cognitive psychology is one of the major approaches within psychology and can be contrasted with the behavioral view (a focus on observable behavior), a psychoanalytic view (a focus on the unconscious), a humanistic view (a focus on personal growth and interpersonal relationships) and a social cognitive view (a focus on the social environment as it impacts personal qualities such as thinking and feeling) (18). Cognitive psychology approach studies about how to improve the teaching/learning process. Information processing approach focuses on the study of the structure and function of mental processing within specific contexts, environments, or ecologies.

Information-processing approach (19)

Information is presented to the human as input. Various information-processing stages within the system generate a series of operations on this information, eventually resulting in skilled movement as output. This simple information-processing approach is shown in Figure 1.

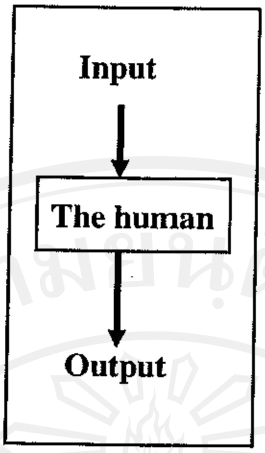

Figure 1 The simple information-processing approach (19)

Information-Processing Stages

This stage analysis of performance generally assumes that peripheral information enters the system and is processed by the first stage. When this stage has completed its operation, the result is passed to the third stage, and so on, the process finally resulting in an action, an output. Figure 2 describes information processing stage.

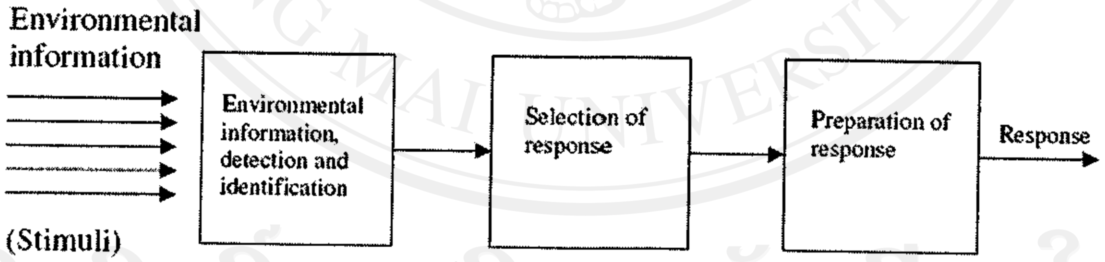

Figure 2 Information processing stages of human performance (20)

1) Stimulus-Identification Stage (19)

During this first stage the system's problem is to decide whether a stimulus has been presented and, if so, what it is. Thus, stimulus identification is primarily a sensory stage, analyzing environmental information from a variety of sources, such as vision, audition, touch, kinesthesia, and smell. The components, or separate dimensions, of these stimuli are thought to be "assembled" in this stage, such as the combination of edges and colors that form a representation of a moving at all, what direction and how quickly it is moving. The result of this stage is thought to be some representation of the stimulus, with this information being passed on to the next stage-response selection.

2) Response-Selection Stage (19)

The activities of the response-selection stage being when the stimulus-identification stage provides information about the nature environmental stimulus. The response-selection stage has the task of deciding what movement to make, given the nature of the environment. Here the choice from available movement is made. Thus, this stage is a kind of translation mechanism between sensory input and movement output.

3) Response-Programming Stage (19)

This final stage is a processing upon receiving the decision about what movement to make as determined by the response-selection stage. The response-programming stage has the task of organizing the motor system for the desired movement. Before producing a movement, the system must ready the lower-level mechanisms in the brainstem and organize a motor program that will eventually control the movement, and it must direct the muscles to contract in the proper order and with the proper levels of force and timing to produce the movement effectively.

Attention as a human performance limitation (20)

Attention refers to engagement in the perceptual, cognitive, and motor activities associated with performing skills (21). These activities may be performed consciously or none consciously. For example, detecting information in the environment is an attention-demanding activity.

Researchers investigating human performance have shown that attention-related activities are tied to an important human performance limitation. This limitation is well illustrated when we are required to divide our attention among the tasks to be performed such as doing more than only thing at a time.

Attention Theories (22)

The most prominent among the early theories addressing attention limitations was the filter theory of attention, sometimes referred to as the bottleneck theory. This theory, which evolved into many variations, proposed that person has difficulty doing several things at one time. The reason for this limitation is because the human information-processing system performs each of its functions in serial order, and some of these functions can process only one piece of information at a time. This means that somewhere along the stages of information processing, the system has a bottleneck, where it filters out information not selected for further processing.

Another attention theory is the central-resource theory. This theory compares human attention capacity to a single source from which all activities must be funded. For example, Figure 3 reveals the available attention resources as existing within one large circle. The smaller circles are the specific tasks that require these resources, such as driving a car and talking with a friend. Each circle by itself fits inside the lager circle. However, for person to successfully perform both tasks simultaneously, both small circles must fit into the large circle.

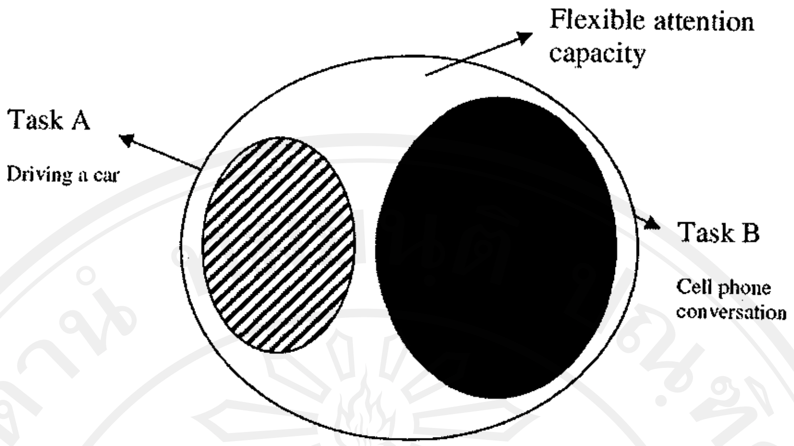

Figure 3 Diagram described of two task performing ability (20)

Reaction time and decision making (19)

An important performance measure indicating the speed and effectiveness of decision making is reaction time (RT). RT is the interval of time from a suddenly presented, unanticipated stimulus until the beginning of the response.
RT is thought to be a component of many other activities, where it represents the speed of making decisions and initiating actions. In many rapid skills, success depends on the speed with which the performer can detect some feature of the environment or of an opponent's movement, decide what to do, and then initiate an effective countermove. Such activities are numerous, as in boxing, playing soccer, and driving a car.

RT is the interval of time between the onset of a signal (stimulus) that indicates the required action and the initiation of the action. The characteristic of RT is presented in Figure 4. RT does not include any movement related to the action, but only the time before movement begins. The stimulus (or "go") signal is the indication to act. In laboratory or clinical settings, the signal can take one of a variety of forms, such as a light, a buzzer, a shock, a word on a screen, or a spoken word or sound. As such, the signal can relate to any sensory system, i.e., vision, hearing, to touch. The person can be required to perform any type of movement. For example, the person might be required to lift a finger off a telegraph key, depress a keyboard key, speak a word, kick a board or walk a step. Finally, to assess optimal RT, some type of warning signal should be given prior to the stimulus signal.

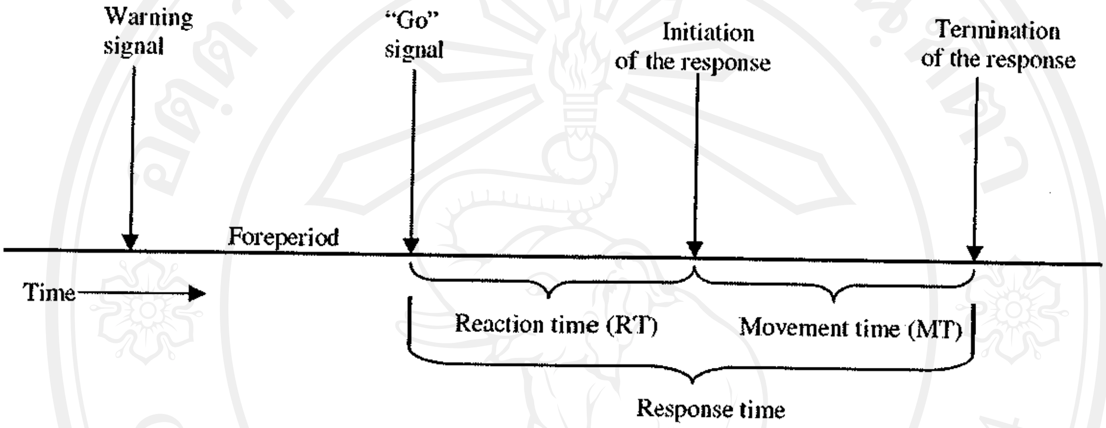

Figure 4 Characteristic of reaction time (20)

RT interval components

Through the use of electromyography (EMG) to measure the beginning of muscle activity in an RT situation, a researcher can fractionate RT into two component parts. The EMG recording will indicate the time at which the muscle shows increased activity after the stimulus signal has occurred. However, there is a period of time between the onset of the stimulus signal and the beginning of the muscle activity. This "quiet" interval of time is the first component part of RT and is called the premotor time. The second component is the period of time from the increase in muscle activity until the actual beginning of observable limb movement. This RT component is called the motor time. By fractioning the RT interval into two parts, researchers interested in understanding the movement preparation process are able to obtain more specific insights into what occurs as a person prepares to move.

Most researchers agree that the premotor time is a measure of the receipt and transmission of information from the environment, through the nervous system, to the muscle itself. This time interval seems to be an indicator of perceptual and cognitive decision-making activity in which the person is engaging while preparing a movement. The motor time interval indicates that there is muscle activity before observable limb movement occurs. Researchers commonly agree that this activity indicates a time lag in the muscle that it needs in order to overcome the inertia of the limb after the muscle receives the command to contract.

Relating RT to movement time and response time

In any situation in which a person must perform an action in response to a signal, two additional performance measures can be assessed. These are movement time (MT) and response time. Movement time (MT) begins when RT ends, It is the interval of time between the initiation and the completion of an action. Response time is the total time interval, involving both RT and MT. An important characteristic of RT and MT is that they are relatively independent measures. This means that the correlation between them is typically low, indicating that RT does not predict MT.

Type of RT situation (20)

RT in the experiment can be divided into 3 types. Figure 5 presents the classification of RT. The types of RT are:

- Simple RT is the term of a situation involves only one signal and requires only one action in response.

- Choice RT is the term of a situation of more than one signal to which the person must response, and each signal has a specified response.
- Discrimination RT is the terms of a situation where there is also more than one signal, but only one response to a specific signal is required

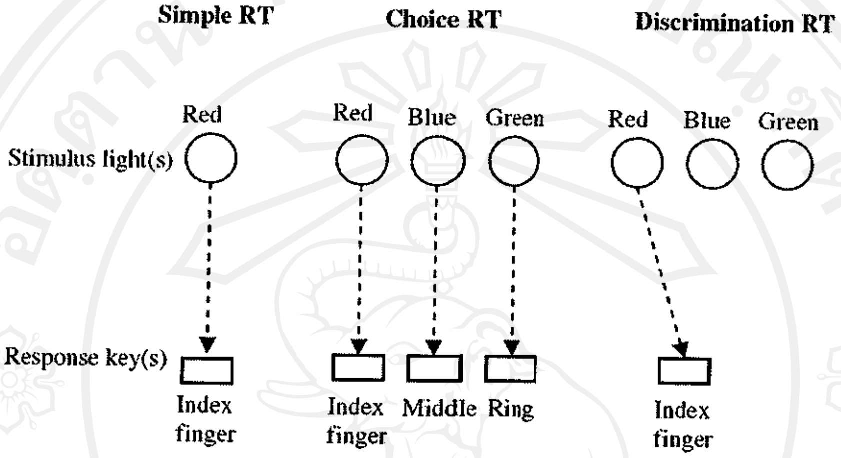

Figure 5 Classification of reaction time (20)

The use of RT in research

Reaction time has a long history as a popular measure of human motor skill performance. Although RT can be used as a performance measure to assess how quickly a person can initiate a required action, researchers also use it as a basis for inferring other characteristics. The most common is to identify the information a person may use while preparing to produce a required action.

Cognitive workload assessment

Cognitive workload refers to the processing that is required to perform a task given the resources available to the individual. It was mostly defined as the ratio between task demands and the capacity of the operator. Under excessive mental workload, human operators may exhibit delayed information processing, or even not respond at all to incoming information, because the amount of information surpasses their capacity to process it. In contrast, when their cognitive workload is much lower than the proper level, they become bored and then also tend to make mistakes.

There is no direct method for measuring cognitive workload. Technique for measuring cognitive workload can be divided into performance subjective rating and physiological measures.

Physiological measurements have made a significant contribution to the assessment of cognitive workload. They are believed to represent cognitive workload levels because information processing involves the central nervous system. Physiological measures of cognitive workload also offer some advantages over alternative methods. Continuous data can be collected during task performance that may not interfere with primary task performance. Physiological measures can be classified into three major categories as a function of the physiological organs involved: (1) brain-related measures, (2) eye-related measures and (3) heart related measures.

Heart rate and skin temperature

Heart rate is commonly used as a primary indicator of physiological stress. Veltman et al. (23) found an association of subjective report of the participant's cognitive workload and increase of heart rate during simulated flight task. Several of previous studies revealed that greater heart rate level indicated the increase of participant's effort to perform the task (14, 15, and 17).

Skin temperature can be used as an indicator for the autonomic nervous system activity. It is mainly regulated locally by two sympathetic effectors organs, the coetaneous blood vessels and the sweat glands under the control of the central nervous system. Sympathetic activation increase level of skin temperature. Skin temperature is generally stated to be around 32° C. Previous work by Alpers et al. (24) found that skin temperature was sensitive to changes of emotion. It was largely increased in the emotion of anger. In contrast, it was lower in the emotion of fear and sadness.

Heart rate variability (25)

Heart rate variability is a noninvasive electrocardiographic marker reflecting the modulation of the sympathetic and vagal components of the ANS on the sinus node of the heart. It expresses the total amount of variations of both instantaneous HR and RR intervals (intervals between QRS complexes of normal sinus depolarisations). Thus, HRV analyses the tonic baseline autonomic function. In a normal heart with an integer ANS, there will be continuous physiological variations of the sinus cycles reflecting a balanced symptho-vagal state and normal HRV. In a damaged heart which suffered from myocardial necrosis, the changes in activity in the afferent and efferent fibers of the ANS and in the local neural regulation will contribute to the resulting sympathovagal imbalance reflected by a dimished HRV.

Measurements of heart rate variability

Task Force of the European Society of Cardiology (ESC) and the North American Society of Pacing and Electrophysiology (NASPE) (25) defined and established standards of measurement, physiological interpretation and clinical use of HRV. HRV can be divided to time domain analysis and frequency domain analysis.

1) Time domain analysis

Time domain analysis measures the changes in heart rate over time or the intervals between successive normal cardiac cycles. From a continuous ECG recording (Holter), usually of 24 hours, each QRS complex is detected and the normal RR intervals (NN intervals), due to sinus depolarization, or the instantaneous heart rate are then determined. The calculated time domain variables may be simple, such as the mean RR interval, the mean heart rate, the difference between the longest and shortest RR interval and the difference between night and day heart rate, and more complex based on statistical measurements.

These statistical time domain indices are divided into two categories, including beat-to-beat intervals or variables derived directly from the intervals themselves or the instantaneous HR and intervals derived from the differences between adjacent NN intervals. Table 1 summarizes the most frequently used parameters of the time domain.

SDNN is a global index of HRV and reflects all the long-term components and circadian rhythms responsible for variability in the recording period. SDANN is an index of the variability of the average of 5-minute intervals over 24 hours. Thus, it provides long-term information. It is a sensitive index of low frequencies like physical activity, changes in position, circadian rhythm. SD is generally considered to reflect the day/night changes of HRV. RMSSD and pNN50 are the most common parameters based on interval differences. These measurements correspond to short-term HRV changes and are not dependent on day/night variations. They reflect alterations in autonomic tone that are predominantly vagally mediated. Compared to pNN50, RMSSD seems to be more stable and should be preferred for clinical use.

Table 1 Time domain analysis of HRV (26)

Variable	Units	Description
SDNN	ms	standard deviation of all NN intervals
SDANN	ms	standard deviation of the averages of NN intervals in all 5-minute segments of the entire recording
SD (or SDSD)	ms	standard deviation of differences between adjacent NN intervals
RMSSD	ms	square root of the mean of the sum of the squares of differences between adjacent NN interval
pnn50	%	percent of difference between adjacent NN intervals that are greater than 50 ms

2) Frequency domain analysis

Frequency domain (power spectral density) analysis describes the periodic oscillations of the heart rate signal decomposed at different frequencies and amplitudes, and provides information on the amount of their relative intensity (termed variance or power) in the heart's sinus rhythm. Schematically, spectral analysis may be compared to the results obtained when white light passes through a prism, resulting in different lights of different color and wave length. Power spectral analysis can be performed in two ways: 1) by a nonparametric method, the fast Fourier transformation (FFT), which is characterized by discrete peaks for the several frequency components, and 2) by a parametric method, the autoregressive model estimation, resulting in a continuous smooth spectrum of activity. While the FFT is a simple and rapid method, the parametric method is more complex and needs verification of the suitability of the chosen model. When using the FFT the individual RR intervals stored in the computer are transformed into bands with different spectral frequencies. This process is similar to decomposing the sound of a symphony orchestra into the underlying notes. The results obtained can be transformed in Hertz (Hz) by dividing by the mean RR interval length. The power spectrum consists of frequency bands ranging from 0 to

0.5 Hz and can be classified into four bands: the ultra low frequency band (ULF), the very low frequency band (VLF), the low frequency band (LF) and the high frequency band (HF). Table 2 shows all parameters of frequency domain analysis of HRV.

Table 2 Frequency domain analysis of HRV (26)

Variable	Units	Description	Frequency range
Total power	ms^2	variance of all NN intervals	<0.4 Hz
ULF	ms^2	ultra low frequency	<0.003 Hz
VLF	ms^2	very low frequency	<0.003–0.04 Hz
LF	ms^2	low frequency power	0.04–0.15 Hz
HF	ms^2	high frequency power	0.15–0.4 Hz
LF/HF ratio		ratio of low-high frequency power	

To minimize the effects of the changes in total power on the LF and HF components, it is useful when evaluating the effects of different interventions in the same subject (graded tilting) or when comparing subjects with major differences in total power. Normalized units are obtained from this equation.

$$\text{LF or HF norm (nu)} = \frac{\text{LF or HF } (ms^2)}{\text{total power } (ms^2) - \text{VLF } (ms^2)} \times 100 \qquad (25)$$

The normal values of standard measures of heart rate variability are presented in Table 3.

Table 3 Normal values of standard measures of heart rate variability (25)

Variable	Units	Normal value (mean ± SD)
Time domain analysis of nominal 24 h[18]		
SDNN	ms	141 ± 39
SDANN	ms	127 ± 35
RMSSD	ms	27 ± 12
HRV triangular index		37 ± 15
Spectral analysis of stationary supine 5-min recording		
total power	ms^2	3466 ± 1018
LF	ms^2	1170 ± 416
HF	ms^2	975 ± 203
LF	n.u.	54 ± 4
HF	n.u.	29 ± 3
LF/HF ratio		1·5–2·0

Effect of cell phone distraction on driving performance

Consiglio and colleagues (27) studied the effect of cellular phone conversation on reaction time (RT) of breaking response in 11 males and 11 female participants. The result showed that RT of breaking response was significantly longer in the condition when the subject talked on the phone while driving (RT = 465 ms) than the condition when the subject only concern on driving (no phone conversation) (RT = 392 ms), p<0.001. Hancock and colleagues (28) studied the effect of cellular phone conversation on a crucial stopping decision making response in 42 participants. The result showed that participants exhibited a significant slower breaking response time when driving and engaging a phone conversation at the same time (RT = 0.71 s) compared to when driving without engaging a phone conversation (RT = 0.52 s), p<0.01. The result suggests that a phone conversation distracts the driver from vehicle control, resulting in driving degradations. On the other hand, Liu (9) examined the effect of different driving environments and conversation contents on driving performance of 12 subjects. The subjects were required to use the vehicle audio phone system under different driving load environments and different conversation contents. Reaction time and accuracy for traffic light detection improves when subjects engage with short cell phone conversation in a low load driving condition. The result suggests that in the low driving load situations, cell phone conversations can improve driving performance. The author suggested that the improved performance may be due to the increase in attentional demand, which in turn increases arousal level. However, in a condition when a driver's attention resources are limited, car phone conversation showed negative effect on driving safety.

Effect of cell phone conversation types on driving performance

Rakauskas and colleagues (29) investigated the effect of two types of conversation (easy and difficult) on driving performance in 12 male and 12 female participants. They found that the difficult level of conversation resulted in slower and more variations in speed and required a higher level of workload compared to the easy level of conversation and no phone conversations ($p<0.05$). This result suggests that in the difficult level conversation condition, subjects have to lower the driving goal (by decreasing driving speed) so that they can engage in phone conversation at the same time. Chotirot (30) studied effects of 3 types of distraction (no distraction, answer simple questions and answer complex questions) on foot response time in 30 male and 30 female participants. The result showed that response time was significantly shorter in simple question condition compared to the no distraction condition. The result suggests that short conversation on cell phone during driving may increase task difficulty and activate subject's arousal and resulted in shorter reaction time. Response time in the complex question condition was significantly longer than that in the simple question and no distraction conditions. The result indicated that distraction from complex conversation interferes and erodes spare cognitive capacity. An insufficient cognitive capacity increases driver's reaction time due to a slow decision making process.

Effect of cell phone types on driving performance studies

Matthews and colleagues (31) investigated the effect of three types of cell phone (hand held, hand free with external speaker, and personal hand free) on subject's workload and physical demand while driving on a highway. The result revealed that in the same conversation condition, cognitive workload was lowest in a condition when subject used the hand free cell phone (with an external speaker or personal hand free) compared with the condition that used hand-held phone ($p<0.001$). In contrast, results for driving performance was not significant different to the hand-held and hand free phone. Mazzae and colleagues (32) studied effects of phone types on driver's ability compared between hands held, hand free and hand-free speaker in 27 male and 27 female participants. The researcher found that when the participants used hand free phone, they answered the phone more quickly than that the used of hand held or hand free speaker phone.

Cell phone conversation and cognitive workload

Several studies indicated that cell phone conversation while driving lead to increase of cognitive workload. Patten et al. (15) examined effects of different cell phone conversation types on the participant's cognitive workload. They used reaction time as an indicator for cognitive workload. Result revealed that cognitive workload was significantly difference between simple and complex conversation. Reaction time increased significantly in the complex conversation condition compared to that in the simple conversation condition.

Another study used the peripheral detection task performance to test the cognitive workload. Tornros and Bolling (33) studied the effects of mobile phone conversation on simulated driving in different traffic environments. Differences of driving situations (urban and rural) were used. The results showed that driving ability degraded when subjects talked on the phone while driving. Reaction time was longest when subjects concurrently talking and driving in urban situation.

The most widely used of physiological index reflecting cognitive workload were heart rate variability and heart rate (14). Moreover, increase of skin temperature in different emotional states was also investigated. Several studies suggested that using a mobile phone while driving may have implications for safety margins that may not be immediately apparent. Driving simultaneously with talking on the phone is not safe, although drivers tend to compensate by reducing the car's speed.