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HEART RATE READING PATTERNS AT MOMENT OF INFORMATION OVERLOAD DURING ONLINE INFORMATION SEARCHING

Natrah Abdullah & Nur Amirah Mustapar
Faculty of Computer and Mathematical Sciences
Universiti Teknologi Mara, Malaysia

natrah@tmsk.uitm.edu.my;mira.mustapar@gmail.com

ABSTRACT

Users are confronted with information overload when searching for information in virtual libraries. Studies claim that information overload leads to changes in the physiological signals of an individual which later results in decreased efficiency in information processing. There is a strong perception that when something changes, there is a moment in which the change occurs. The primary purpose of this research is to detect an indication at the moment of change occurring when searching in virtual libraries by focusing on the pattern reflected in physiological data that can potentially be used as a signal to convey information overload. This study adopted user test methods and methods from psychophysiology. The results from quantitative analysis were presented through graphs and tables. The results indicated that heart rate measurement was the best measure compared to other physiological measurements and the underlying pattern signalling information overload was presented in the form of a matrix. Recommendations for future work include using the pattern to design an application to monitor information load in individuals.

Keywords: Moment of information overload, psychophysiology measure, user experience.

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INTRODUCTION

There has been continuing growth in information technology around the world. The Internet especially has modified the way people work. It is by now apparent that the Internet has ushered in a new era, giving unimaginable wealth of information. Moreover, electronic networks together with numerous mobile devices allow people to access information quickly and at little cost anywhere and anytime. This development is beneficial for the individual as well as for society. Since much information has already been digitized, the individual has at his fingertips most of human knowledge, daily information and unlimited human contacts (Morris, Alvarez, Barney, & Molloy, 2017).

This enormous amount of information available will benefit researchers as information is a valuable and crucial element in research activities. In doing research, there are many tasks involved such as searching for journals and doing extensive reading of books and articles. With the various activities that researchers are involved in, they can be overwhelmed by the amount of information available to choose from. When a person is oversupplied with information or when the volume of information exceeds the human processing capacity of an individual, a person is confronted with information overload (Ji & Sypher, 2014; Rodriguez, Gummadi, & Schoelkopf, 2014; Pentina & Tarafdar, 2014; Whelan & Teigland, 2013; Chen, Pederson & Murphy, 2012; Memmi, 2012; Song, Jung & Kim, 2017).

According to Jackson and Farzaneh's (2012) conceptual information overload model, information overload consists of two groups of factors: intrinsic factor and extraneous factor. Intrinsic factor refers to the fundamental element of information overload, including the human information processing capacity, volume of information, and available time. Extraneous factor has an indirect impact on information overload but a direct impact on intrinsic factor which includes quality of information, characteristics of information, task and process as well as personal factors.

Studies on the fundamentals of information overload has shown that individuals have limited capacity for information processing (Ji & Sypher, 2014; Pentina & Tarafdar, 2014; Whelan & Teigland, 2013; Chen, Pederson & Murphy, 2012; Memmi, 2012; Song, Jung & Kim, 2017) and when they have exceeded the limit of information processing capacity, individuals are subjected to cognitive limitations that lead to information overload. Under these situations, physical symptoms include headaches (Pentina & Tarafdar, 2014; Persson,

2018; White & Dorman, 2000), cardiovascular stress, weakened vision, stomach pains, and digestive disorders (White & Dorman, 2000). Numerous mental difficulties may increase the level of stress (Benselin & Ragsdell, 2015; Persson, 2018) irritability, anger (Persson, 2018; White & Dorman, 2000), lack of focus, lethargy, shortened attention span (Pentina & Tarafdar, 2014; White & Dorman, 2000), depression (Benselin & Ragsdell, 2015; Oldroyd & Morris, 2012) and insomnia (White & Dorman, 2000). Long exposure to information overload produces symptoms related to discouragement and fatigue (Bezroukov, 2015). Consequently, key consequences of information overload include lost productivity, diminished quality of thoughts (Persson, 2018; Benselin & Ragsdell, 2015), distraction, procrastination, (Benselin & Ragsdell, 2015), terminated or unfinished information processing (Benselin & Ragsdell, 2015; Pentina & Tarafdar, 2014; Persson, 2018; Oldroyd & Morris, 2012).

Xu (2012) and Reed (2018) remarked that the moment is an element of an outcome of what happened before. An outcome is also known as a cause. That moment is fixed as a point in time in which the event's antecedent had the outcome (Rodopi, 2004). Thus, the "moment" of an event can then be marked as a point along the chronological continuum in which a certain outcome occurs. This is supported by Littmann (2012) who found that there is a strong intuition that when something in the world changes, there is a moment in which the change occurs.

Figure 1 as discussed by Mustapar, Abdullah and Md Noor (2016) in a previous paper shows the inverted U-curve of information overload from Schroder and Suedfeld (1971). The paper discusses the limitations of the individual in information processing and at a certain state when the information received exceeds the limited human information processing capacity, it leads to information overload. Thus, Figure 1 with dotted line shows the point where information processing has reached its highest point and starts declining. Any information received beyond that dotted line will not be processed (Sasaki, Kawai & Kitamura, 2015; Whelan & Teiglanf, 2013; Eppler & Mengis, 2003). According to Mustapar et al. (2016), the moment which has been marked as an event can then be represented as a point along a chronological continuum in which a certain outcome occurs. It has been suggested by Mustapar et al. (2016) that the moment occurs along the dotted line in Figure 1. Further study on a representation of the dotted line is highly needed to cater for limitations of the individual's information processing.

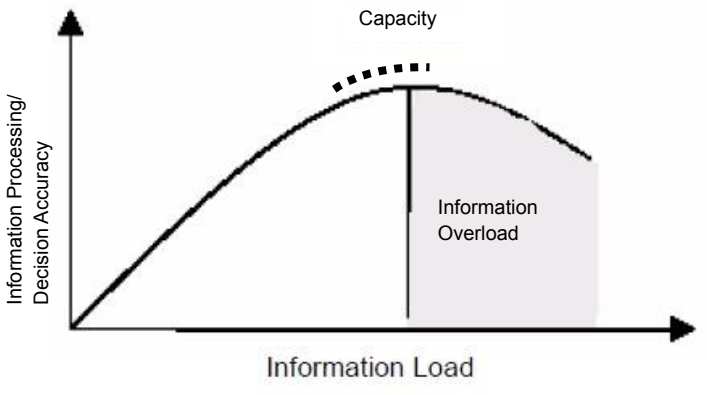


Figure 1. The inverted U-curve of information overload and moment.

This paper aims to inform designers, a psychophysiology measure as a representation of the dotted line towards limitations of the individual's information processing. By examining individual psychophysiology states, personal searching environment can be monitored and user experience during searching activities can be enriched.

BACKGROUND OF PROBLEM

Previous research investigated symptoms, effects, causes, and countermeasures of information overload but lacked representation in the form of empirical data on moment of information overload. This claim was supported by Eppler and Mengis (2004), who discussed important topics of information overload. In addition, Ji and Sypher (2014); Pentina and Tarafdar (2014); Whelan and Teigland (2013); Chen, Pederson and Murphy (2012); Memmi (2012); Song, Jung and Kim (2017), and Jackson and Farzaneh (2012) studied the causes of information overload. While Benselin and Ragsdell (2015); Oldroyd and Morris (2012); and White and Dorman (2000) investigated the phenomenon of information overload by recognising the effects and symptoms of information overload. Meanwhile, Mungly and Singh (2012) examined the phenomenon of information overload. These showed that previous studies did not really focus on the moment of information overload.

Hence, the purpose of having empirical data on moment of information overload is so that it can eliminate the effects of information overload. Studies have shown that information overload will cause changes in the information seeking

capability of an individual which later results in decreased productivity in information processing. Earlier studies on design support systems showed that as information load increases, the individual tends to shift from compensatory to non-compensatory search patterns based on the level of difficulty of the searching environment. In addition, the individual also tends to selectively extract only a few information cues from a piece of information to comprehend its original meaning or ignore particular information to control the amount of information received (Zou & Webster, 2014). While information processing strategies help individuals cope with inadequate cognitive capacities, they may potentially introduce biases in information selection and lead to information overload (Edmunds & Morris, 2000).

A survey has been conducted with a group of postgraduate students in Universiti Teknologi MARA to identify crucial tasks during their studies which lead to stress (Mustaphar et al., 2016). Based on the result of the survey, searching for journals, books, articles, proceeding papers and other digital publications was a crucial task in order to get the information needed to conduct a research. The students had to deal with various content database provided on the Net in order to search for related information that could be useful in conducting their research. However, in the event of searching for unfamiliar content, they needed more time and effort searching using multiple data base. The deployment of advanced information technologies posed a serious problem in information overload. With the information repository system provided together with too many searching tasks, the students felt overloaded with information during the searching task. This situation compelled us to extend a study on the moment of information overload by collecting empirical data which was suggested as a measure to eliminate the effects of information overload. This study measured information overload during the process of literature searching phase because based on a preliminary study, most postgraduate researchers suffered from information overload during this phase.

RESEARCH BACKGROUND

Information Searching and Individual Load

Information search process is a process in finding meaning from information. It consists of six different stages. The six stages are initiation, followed by selection, then continue with exploration, followed by formulation, proceed with collection and lastly presentation (Kuhlthau, 1991; Wiley, Wiley & Williams, 2015). Each stage incorporates individual feelings, thoughts, and actions. Proponents of Cognitive Load Theory (CLT) suggest that information

processing is related to the amount of mental load associated with thinking, reasoning and information processing environment demands higher mental effort than others, and thus it requires an individual's working memory to use a higher data input or loads of information processing resources (Kaylor, 2014).

CLT comprises three types of cognitive load which are intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (Kaylor, 2014; Mostyn, 2012). Intrinsic cognitive load is imposed by the inherent properties of the information processing resources itself, together with the level of expertise of the individuals. Perceived intrinsic load varies significantly between a novice individual and a more experienced individual (Kaylor, 2014; Mostyn, 2012) and the intrinsic cognitive load generally cannot be controlled or manipulated (Kaylor, 2014). However, extraneous load associates to how information is being presented to the individual and it can be manipulated or controlled. This load increases when irrelevant information is presented, thus requiring an unnecessary demand on the individual's working memory (Zaki, Wook, & Ahmad, 2017). Because of the limitation capacity on the working memory, using resources to process extraneous cognitive load will result in a reduced amount of available resources to process intrinsic and germane loads.

In defining search task difficulty, there is no single meaning of task difficulty. With the various definitions of search task difficulty available in previous studies, this current research agreed with Kim (2002) in which she argued that task difficulty relies on individual perception, understanding and judgment of the objective task complexity. Kim (2002) examined the searcher's characteristics such as search experience, and topic knowledge, intrinsic task characteristics such as specificity of target information and information sources, and intrinsic search process characteristics which is assessing or navigating a website and locating information on a webpage as contributing factors to the perceived task difficulty. Issues experienced during the search process were recognized by the study subjects as the main reason for a posteriori perception of tasks as difficult (Gwizdka & Spence, 2016). Therefore, the difficulty of the search task would vary among people as people have different psychological abilities and searching skills. This research examined the difficulty of the search task by comparing difficult and easy tasks by way of ascertaining how many databases (single database vs. multiple databases) were used in finding desired information using psychophysiology measures.

Psychophysiology Measures

Psychophysiological measures are used in studying user's attention responses to given tasks. There are several possible methods to represent the psychological

state of the user. This current study used a combination of cardiovascular measurements which consisted of: Heart Rate (HR) and Blood Pressure (BP) and Body Temperature (BT) measurements with the purpose of measuring the physiological states of an individual. This combination of measurements known as vital signs is a measurement of the body's basic functions. The advantage of using psychophysiological indices is that their measures are covert and implicit, and that their changes are continuous (Knaepen et al., 2015). It only deals with available information when the user interacts with the computer system without any explicit communication or input device. This psychophysiological measure is a precise one-to-one representation of a significant or relevant psychological dimension such as task engagement, mental effort, and frustration.

Heart rate (HR) is the speed of the heartbeat measured by the number of contractions of the heart per minute (bpm). The heart rate can vary according to the body's physical needs. It is usually equal or close to the pulse measured at any peripheral point. Activities that can provoke change include physical exercise, sleep, anxiety, stress, illness, and ingestion of drugs. The normal resting HR of a human adult ranges from 60 and 100 bpm (Laskowski, 2016). According to the American Heart Association, (2016), tachycardia is a fast HR, defined as above 100 bpm at rest. Bradycardia is a slow HR, defined as below 60 bpm at rest. Several studies and expert consensus have indicated that the normal resting adult's HR is probably closer to a range of between 50 and 90 bpm (American Heart Association, 2016). In order to secure empirical data, we employed a user testing method that measured the current user's physiological states.

RESEARCH METHODOLOGY

In an attempt to gather signs of information overload during information searching in virtual libraries; the researchers used Sweller's (1994) CLT as a conceptual framework to drive the investigations. Sweller (1994) posited that components of the mental effort and mental load of an individual have an impact on the performance of an individual. In the context of this study, the researchers regarded the mental effort of the individual as a personal factor and mental load set by the searching environment and performance as physiological states. The cognitive style represents the personal factor, while task difficulty represents the searching environment.

The researchers' approach to tackle research issues related to information overload is to merge knowledge and method from psychophysiology and to adopt user testing methods. The user testing methods seek to record the

performance of a user while dealing with the system (Hasan, 2014). The framework as visualized in Figure 2 shows three important aspects required to conduct this research: personal factor, searching environment (task difficulty) and the physiological states of an individual. The task difficulty is related to its level of complexity. The level of complexity is different in terms of the scope of the search (the breadth and depth), the amount of input/information provided, and the extent of the output required. Difficulty of the search task could be varied among people as people have different psychological abilities and searching skills. This research examined the difficulty of the task by comparing easy and difficult tasks by way of how much information is supplied when finding the desired information. When the information received by an individual did not fit his/her brain capacity that is, when the individual receives more information than he/she can digest, it will lead to information overload and will cause changes in the physiological states of the individual which will finally reveal the moment of information overload.

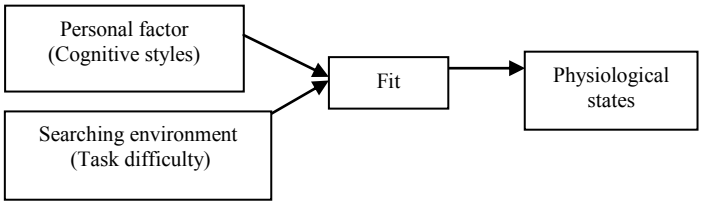


Figure 2. Research framework.

Data Collection

The experiment started with the researchers briefing the participants about the task they were going to perform. After that the participants filled out a consent form. Next, the researchers recorded the initial blood pressure, body temperature and HR of the participants. After that, the participants were given a research topic to search. While the participants were doing their searching process, the researchers measured their blood pressure, body temperature and their HR. After the participants had completed their searching task, the researchers put forward post experiment questions to the participants on the symptoms of experiencing information overload. Figure 3 shows the experimental procedure of the data collection phase.

To get the empirical data on moment of information overload, the researchers used a combination of cardiovascular measurements, which were HR, BP, and

BT measurement. The researchers used ProComp Infiniti encoder to measure the changes in the physiological signals of the participants. To assess individual differences in dealing with information overload, the researchers measured physiological signals of the participants on a task in a controlled situation. The researchers constructed a task based situation in which information overload could be reached and the output could be measured and quantified. After analyzing a few task environments to choose from, a journal-searching task environment was chosen whereby journals (from 2012 to 2015) with a certain topic had to be searched within a limited time of 60 minutes (30 minutes for each level) in a certain repository (e.g. EZAccess UiTM). Time acted as a constraint in this research. The information searching consisted of two levels, easy and difficult. For the easy level, the participants were only allowed to do the searching task in a single browser. For the difficult level, the participants were required to do the searching task in a multiple browser at the same time.

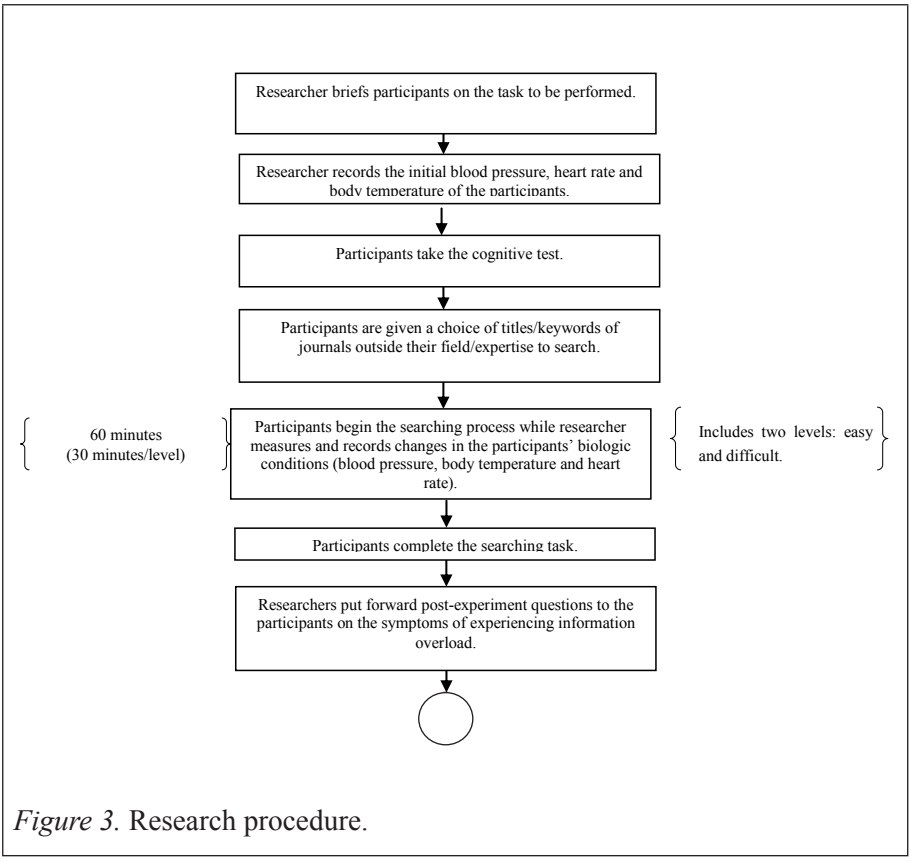


Figure 3. Research procedure.

In defining search task difficulty, there is no single meaning of task difficulty. Previous studies claim that task difficulty is subjective (Liu et al., 2015)

as people have different psychological abilities and searching skills. This research determined the difficulty of the task by comparing easy and difficult tasks by way of how much information was supplied when finding the desired information. The amount of data accessed using a single browser was less than data accessed using multiple browsers. This condition was expected to give a different impact to the participants. Figure 4 shows the summary of data collection as follows.

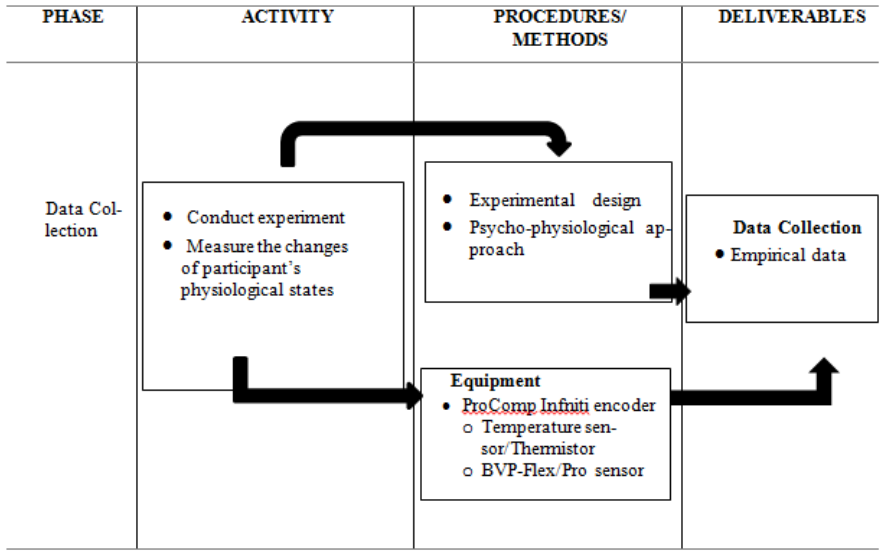


Figure 4. Summary of data collection.

Data Analysis

In the process of analyzing the signals retrieved using quantitative analysis, each recorded signal of BP, BT and HR underwent a preprocessing phase in which all the signals from the "Physiological Suite" software was converted into data set and then transferred into Microsoft Excel. All the data set from 12 participants were combined into one sheet in order to see the differences among them. The data set was then converted into specified data set by finding their mean and then transforming them into a graph. Later the data underwent an extraction phase where the graph was divided into 10 minute intervals to show where the changing pattern lay in the graphs for 15 participants. The patterns in the graphs were compared between easy and difficult tasks. This was to obtain the changes which occurred in the patterns during easy and difficult searching tasks according to Gerin and Zawadzki (2012). People

who were stressed would have an increased reading of BP and HR and BT (Mientka, 2015) and these were some of the effects of information overload. Thus, with the changes in the reading of these three empirical data, the moment of information overload would be revealed. The different patterns of the empirical data were classified in this extraction phase. Figure 5 shows the summary of data analysis as follows.

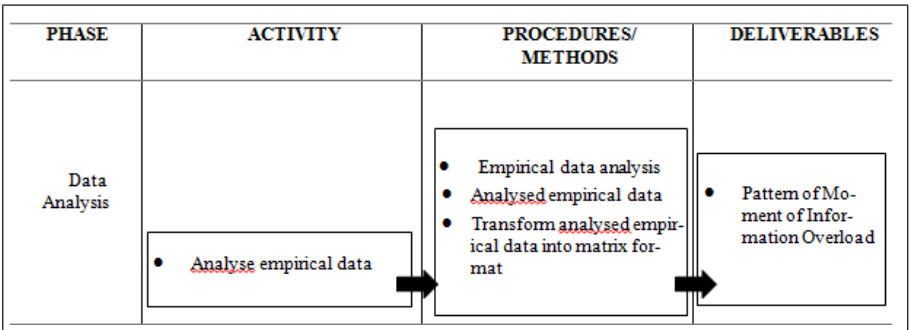


Figure 5. Summary of data analysis.

RESULTS AND DISCUSSION

Demographic Characteristics

Participants in this study comprised 15 postgraduate students from four different areas in Universiti Teknologi Mara (UiTM Shah Alam), Selangor. Their backgrounds ranged from computer and mathematical sciences, policy management, electrical engineering to chemical engineering. Most of the participants (80%) were pursuing their master's program, 73.3% were female and 86.7% were in the 25-34 age group. An equal percentage of participants were from the field of electrical engineering and chemical engineering (6.7%), while about 90% of all participants were either from computer and mathematical sciences (66.6%) or administrative science and policy studies (20%).

Results on Physiological Measures

Blood pressure

In this research, the autonomic nervous system was assessed through BP. Mean BP readings showed no major differences within 30 minutes of task

completion for both levels. Most of the participants had a slight decrease in their BP readings in the first 10 minutes compared to their initial readings and there was no change in the last 20 minutes of the searching task. Most of the participants showed a constant slight increase and decrease in their BP readings when their BP was compared during easy level and difficult level tasks. Based on the analysis of the results, the moment of information overload could not be demonstrated using this study measure. Even though the readings showed some variations in values, the values still fell within the range of their initial BP readings. This was supported by the American Heart Association, (2014), which claimed that there were no clear links between stress which was the symptom of information overload and BP even though stress definitely affected the body. There was a statistically non-significant difference from Easy Level (M=35.35, SD=0.48) to Difficult Level (M=35.62, SD=0.480, $t(14)=-1.776$, $p>0.0005$). The eta squared statistic (.475) indicated a moderate effect size.

Body temperature

BT was monitored in this study in order to demonstrate the moment of information overload. Most of the participants showed a constant reduction in their BT readings when their BT was compared for changes during the easy and difficult levels of the searching task. Even though the readings showed some variations in values, the moment of information overload could not be demonstrated by using this study measure. Before their exposure to stress, the BT of the participants was expected to rise but the experiment showed a different result as the experiment was held in a cold room. This was because the BT of the participants was affected by the external factor which was the temperature of the room. Hence the readings of the participants' body temperature were below the normal human BT as their bodies lost more heat than could be generated. Even though BT may increase temporarily when people are stressed, the participants' BT was already affected by the external environment. Hence this study needs more physiological measures in order to demonstrate the moment of information overload. The next physiological measure used HR.

Heart rate

The HR showed a major difference within 60 minutes of task completion for both levels. Most of the participants had a rapid change in their HR readings during task completion in the difficult level when their HR readings were compared during the easy and difficult levels of the searching tasks. The HR of the participants increased gradually over the minutes during the difficult

level of the searching task as compared to the HR readings in the easy level of the searching task. Figure 6 shows the pattern of moment of information overload through the HR measure.

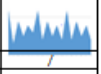
	No.	Easy Level				Difficult Level			
Range		100≤150 (bps)		150≤200 (bps)		100≤150 (bps)		150≤200 (bps)	
Pattern									
First 10 minutes	R1		/		/		/		/
	R2			/			/	/	
	R3		/	/			/	/	
	R4		/			/			
	R5		/			/		/	
	R6		/				/	/	
	R7						/		/
	R8	/					/		
	R9	/		/			/		/
	R10		/		/		/		/
	R11		/		/		/		/
	R12		/		/		/		/
	R13		/	/			/	/	
	R14	/					/		
	R15		/				/	/	
TOTAL (Participant)		3	10	4	4	2	13	6	6
TOTAL ALL (Occurrence)		21				27			
Next 20 minutes	R1	/			/		/		/
	R2	/		/			/		/
	R3		/	/			/	/	
	R4		/	/		/		/	
	R5		/	/			/	/	
	R6		/			/		/	
	R7						/		/
	R8	/					/	/	
	R9		/	/	/		/		/
	R10		/		/		/		/
	R11		/		/		/		/
	R12	/			/		/		/
	R13		/	/			/	/	
	R14	/					/	/	
	R15		/			/		/	
TOTAL (Participant)		5	9	6	5	3	12	8	7
TOTAL ALL (Occurrence)		25				30			
Last 30 minutes	R1		/		/		/	/	
	R2	/		/		/		/	
	R3		/	/			/	/	
	R4						/		/
	R5	/					/	/	
	R6	/		/			/	/	
	R7		/		/		/		/
	R8			/			/	/	
	R9		/		/		/		/
	R10		/		/		/		/
	R11		/		/		/		/
	R12		/		/		/	/	
	R13		/	/			/	/	
	R14			/			/	/	
	R15	/		/			/	/	
TOTAL (Participant)		4	8	7	6	1	14	10	5
TOTAL ALL (Occurrence)		25				30			

Figure 6. Pattern of moment of information overload through heart rate measure

Most of the participants had a rapid occurrence of HR readings which range from 100≤150 beats per minute (bpm) for both levels, easy and difficult in the first 10 minutes of the task. However, the total number of participants who reached a maximum range of HR readings which was 150≤200 (bpm) increased from eight participants to 12 participants in the difficult level. The total number of occurrences of abnormal readings from easy and difficult levels increased from 21 occurrences to 27 occurrences in the first 10 minutes. Then after 20 minutes of the easy level task, most of the participants started to reach a maximum range of HR readings which was 150≤200 bpm. Meanwhile most of the participants had a rapid occurrence of HR readings ranging from 100≤150 bpm in the difficult level task. However, during this period, the total number of participants who did reach a maximum range of HR readings increased from 11 participants to 15 participants in the difficult level. Hence, the total number of occurrences of abnormal readings from easy to difficult levels increased from 25 occurrences to 30 occurrences.

In the last 30 minutes, compared to the easy level, most of the participants had a rapid occurrence for both abnormal readings in HR, 100≤150 and 150≤200 (bpm) in the difficult level and the total number of participants who did reach a maximum range of HR readings increased from 13 participants to 15 participants in the difficult level. Hence, it can be concluded that, in between the easy and difficult levels, most of the participants had the most number of occurrences of abnormal readings during the difficult level of the task. Based on the above results, a paired sample t-test was conducted to evaluate the differences in occurrence of abnormal readings between the easy and difficult levels of the searching task. There was a statistically significant increase from Easy Level (M=4.73, SD=1.53) to Difficult Level (M=5.80, SD=0.41, t(14)=-3.096 p<0.0005). The eta squared statistic (.475) indicated a moderate effect size.

Table 1

Pattern of occurrence of abnormal readings

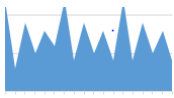
Information Searching Environment	Easy Task	Difficult Task
Pattern of occurrence of abnormal reading (100 ≤ 200 bpm)		

Table 1 shows the matrix of patterns of occurrence of abnormal readings of information searching and Figure 7 illustrates the HR representing the moment of information overload. All the participants reached the maximum value of HR in the 20th minute and continued to the 30th minute of the session. This can be seen as an indicator of information overload which occurred and here lies the moment of information overload.

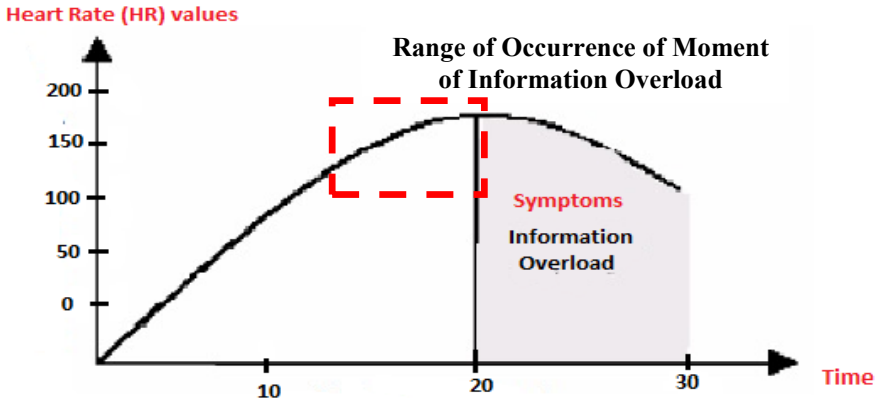


Figure 7. Indication of the moment of information overload through heart rate readings.

CONCLUSION

This paper presented a user testing method and based on Cognitive Load Theory, a framework for this study was proposed to drive an investigation on HR, BP and BT. The association between difficulty of task and participants' overall performance was described from the perspective of the occurrence of abnormal HR readings.

There are two patterns of occurrence of the searching task. The occurrence of abnormal HR readings was relatively less during the easy level searching task as compared to the occurrence of abnormal HR readings during the difficult level searching task. Most participants had a rapid occurrence of abnormal HR readings during the difficult level searching task. This was due to the amount of information supplied being higher than the participants could digest. With the limited searching duration and too much information being supplied, they were overwhelmed by the amount of information and this led them to experience information overload. Based on the analysis of the empirical data

retrieved and the post-experiment questionnaire, most of the participants experienced stress during the difficult level of the task and the results of the empirical data showed that the HR of the participants was the best measure compared to BP and BT. This finding is parallel with the claims by Gerin and Zawadzki (2012) who posited that people who are stressed will have an increased reading in heart rate besides Newell (2015) who viewed that stress can cause a rapid and large increase in HR. This can be an indication signalling the point of information overload occurring and it is here that the moment of information overload can be related with the IPC model by Schneider (1991) who illustrated that when information processing requirement (IPR) exceeded the information processing capacity (IPC), it led to information overload. The heart rate values that dropped after reaching its maximum value over time revealed that participants were already experiencing symptoms of information overload. Therefore, these patterns provide a prognosis of the occurrence of information overload and can be used by system developers, system designers and practitioners to provide a better experience during searching activities.

In addition, this research has also provided a conceptual framework on the study of user cognitive capabilities and task complexity when experiencing information overload. This study has established a relationship between the components of the framework. Hence, it justifies the usefulness of the developed framework as it has been verified with real users via one-to-one user testing. The findings in this research are relevant in related areas as it indicates the applicability of the framework besides its significant implications for future research.

FUTURE WORK

The results of the experiment can be used to design an application which controls information load among individuals. Apart from this, this research can be used to examine further symptoms of information overload. Empirical data consisting of moments of information overload can provide a credible basis for justifying the symptoms of information overload. An in depth understanding of the information overload problem will provide numerous benefits to society as it can lead to enhancement in performance among individuals.

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