THE EFFECT OF STRESS ON TASK CAPACITY AND SITUATIONAL AWARENESS

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ABSTRACT

In today's industry, many occupations require manpower resources to include both labor and cognitive resources. As the technology is rapidly changing and businesses are becoming more dependent on cognitive performance, it is essential to find any effect physical stress might have on task performance. Situational awareness is also becoming an integral part of human task performance. It is critical for many operations to design systems such that the effects of physical stress, however minute, on task performance and situational awareness are considered.

The test methodology developed here measures the effect of stress on cognitive task performance as a result of situational awareness related to the task. The test measured and compared task capacity among different age groups and different working groups. A comparison was made on task performance based on the effects of low level physical stress and lack of it. Response time and accuracy were measured for statistical analysis. The subject's stress levels were measured before starting the test to create a baseline for the candidates stress level. The developed tool was able to detect the effect of stress on task performance successfully and efficiently. Subjects with previous work experience performed better both in Phase I and Phase II of the experiment as compared to subjects with no previous work experience. The analysis indicates low level stress does have significant effects on task performance. In reality, stress is an unavoidable factor in daily activities. When designing any system that requires cognitive tasks, stress needs to be considered as a contributing factor to the variability of operation.

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I am very much grateful to my Ph.D. supervisor, Dr. Kambiz Farahmand. With his guidance, support, inspiration, and positive thinking, he helped me to stay on course and complete my dissertation. He was always there beside me whenever I needed any help, whether it is related to my education or my career path. I will always remember that.

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1. INTRODUCTION

Task Capacity is the maximum potential to understand and follow the general logic of real world tasks. Human perception, cognition and action take place in a sequential manner: input is sensed then processed and output follows (Kroemer, 2003). All current information on how the human mind works is based on this principle. Task Capacity has been studied in many areas. Task Capacity studies in Psychology or Clinical Psychology investigate relationships to mental disease. Neuroscience research evaluates the physical capability of the human brain. In comparison to Task Capacity, Situational Awareness is the foundation of decision making. Task capacity is a complex process; there are many questions to answer on how to standardize and measure task capacity and situational awareness.

The effect of stress on task performance is enormous as the technology is changing rapidly and the user or the operator must cope with the change. Human capacity can be classified into physical ability and task capacity. There are many ways to measure physical ability such as strength, oxygen consumption and heart rate. The Measurement of task capacity is challenging and is accomplished by indirect approaches of objective and subjective measurement.

In today's dynamic environment situational awareness is becoming an integrated part of the task performance. Previously, situational awareness measurement was only considered for space, defense, air-traffic and any other similar critical operations. But due to the rapid technological advancement in recent times, industries and manufacturing facilities are looking for people with improved performance and the ability to adapt as the situation demands.

The need of a standard process describing and measuring task performance has well been recognized. Task efficiency and quality of performance require standardized work procedures. The standard task method developed requires the ability to 1) measure the effect of stress on cognitive task performance with greater degree of accuracy, and 2) to determine whether the person is aware of the surrounding situation and is able to adjust with the situation demand.

Task performance capacity and physical performance capability varies from person to person (Weimer, 1995). Task capacity and physical capacity conditions are independent of each other. For example a basketball player may be very good in physical activities but may not be as good when it comes to performing cognitive tasks. There are different mechanisms developed to measure physical abilities (Weimer, 1995, Sanders, 1993). There are not, however, many standard methods developed to measure cognitive task performance and situational awareness simultaneously to find the effect of physical stress.

Workload is defined as the physical labor combined with the mental requirements associated with a task. The proportion of physical load and mental load varies with the task performed. Workload as a function of task requirement places demand on human subject. The capacity of the subject is challenged to perform the assigned task. If the workload is higher than the operator capacity, the subject feels overloaded. Most often, due to stresses on the operators of Plane and car and operator's situational awareness, accidents occur. A subject can be stressed from physical conditions, physiological conditions or mental challenges at that particular time period while performing a task and accidents occur when the tolerable limit is exceeded. Environmental conditions and task loads develop stress in

normal work environmental conditions and as well in any type of confined work environment.

Rapid advancement of technology and increased complexity of work force operators to adapt their decision making process in a dynamic environment. Dynamic decision making process is considered as a real-time decision maker which is constrained by the decision making environment (Edward, 1962). Putting the right person on the right job is a tremendous challenge for companies and there are no specific levels of knowledge or problem-solving capacity that are required for any job category. The current trends in task design are routine, repetitive and multifaceted throughout the industries and manufacturing facilities. Dynamic and versatile work environment challenges the development of a standardized task battery, and is ignored in the development of a standard task tool. When there is a lack of consensus on how to standardize a method, Delphi technique is applied. Delphi technique considers multistage approach to come to a decision. Until recently Delphi technique has widely been implemented in social science and nursing institutes to develop standardized task strategies. Currently there is a trend in applying Delphi study in healthcare industries (Farahmand, et al., 2011, Farahmand, et al., 2011). There is not much research conducted in applying Delphi method to evaluate a tool designed for data collection for human task capacity analysis.

1.1. Human Brain And Task Capacity

Task capacity combines two characteristics of the brain, one is the capacity to store and recall information (Memory capacity) and the other is the capacity to perform logic-processing operations (Problem-solving capacity). Figure 1 shows human sensing systems

in brain and which component is responsible for what job function. For example, vision sense is considered for human perception for this research.

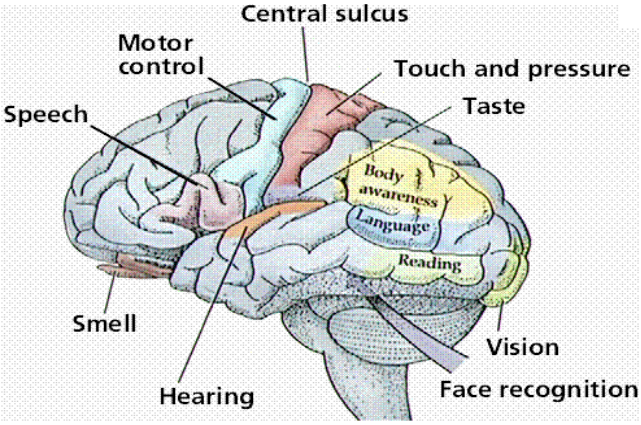


Figure 1. Human Sensing System

(http://www.uic.edu/classes/bios/bios100/lecturesf04am/lect22.htm)

The human brain model is like a computer: the physical brain is similar to computer hardware, and the information from the surroundings is similar to computer software (Trent, 1985). Figure 2 displays transformation of information in a computer. The computer information processing can be converted to human brain functioning process as shown in Figure 3.

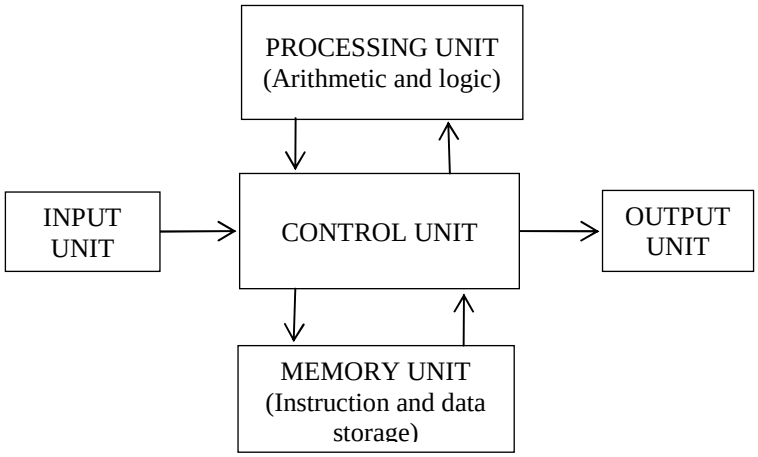


Figure 2. Block Diagram of Computer Information Processing

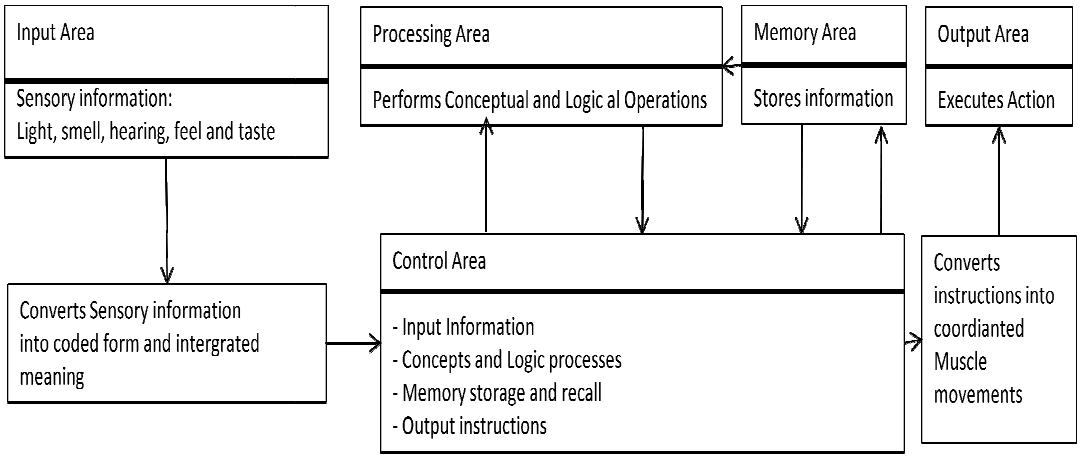


Figure 3. Conceptual Model of Brain Functioning (Adopted from Trent, 1985)

The brain elements analogous to hardware parts are responsible for memory, logic processing, and control of body action or situational awareness. Memory, logic-processing and control of actions are the essential elements of brain to human understanding. These three elements are independent of each other and there is no relationship between the capacities of these elements. The capacities of these three critical elements are genetically fixed and there is little change over the period of adult life and the capacities varies from person to person (Trent, 1985). Similar to the hardware of a computer, brain elements are functional when information likewise software is supplied to from the environment to the brain. The performance of these brain functions depends on their inherited capacities and the quality and quantity of the information received.

1.2. Real World And Situational Awareness

Situational Awareness is defined as the ability to identify the desired elements from the environment, process information and combine the critical elements of the information on the current situation and predict the future state of the gathered information. Situational Awareness (SA) measurement is a critical element of a real-world task performance, yet

the measurement of SA remains ambiguous (Rousseau, 2010). SA of human operators' of a system is important in designing the system and it is critical to quantify the SA level of human operator to reduce any error during operating the system. The situational awareness measurement has become a core theme within human factor research community (Salmon, 2006). There are various approaches available to measure SA. There are subjective self-rating techniques such as Situational Awareness rating Technique (SART), Crew Awareness Rating Scale and Quantitative Analysis of Situational Awareness (QUASA). And also there are Objective SA measures such as Situational Awareness Global Assessment Technique (SAGAT) which is a real-time probe technique.

1.3. Physical Workload And Stress

Lazarus (1990) defines stress as a feeling experienced when a person thinks that the social demand or work demand exceeds the personal and social resources the person is able to mobilize. In medical science stress is defined as a physical or psychological stimulus which results mental tension or physiological reactions causing illness. Under stress condition adrenal gland releases corticosteroids that eventually cause an immune suppressive effect in the human body.

Stress and anxiety are core concepts of psychopathology (Kroemer, 2003). A diathesis-stress model assumes that most of the stress related complication arises from complex interaction between environmental stressors and biological dispositions that can make an individual collapse. Physical load can cause stress and influence operator performance. There is also evidence that stress and physical illness are related. In the case of a short duration of high intensity physical activities, decrease of accuracy in performing

cognitive tasks was observed, such as in the case of map interpretation while running in treadmill (Hancock, 1986).

There are different methods for direct stress detection and measurement such as measurement of adrenaline and cortisol levels in blood, measurement of skin conductivity, electro-encephalography and measurement of pupils' diameter. Besides these methods there are indirect approaches to measure stress such as questionnaires, measurement of heart rate and magnetic resonance imaging (MRI) of brain. Human factors researchers recognized the difficulties in defining the construct of physical stress or fatigue and measuring the effect of fatigue under experimental conditions (Gawron et al. 2001, Holding, 1983, Soames Job and Dalziel, 2001). There is a lack of research to measure indirectly the physical stress effect on task performance accounting the situational awareness level of the operator.

1.4. Standardized Task Measurement

In Delphi methodology opinion is collected on the problems that lack consensus to solve it. Opinion is obtained from diversified domain of experts (Delbecq, 1975) and collected information is evaluated and narrowed it down to a justified form of decision to be applied to the particular problem. In the current research Delphi technique is used to evaluate the questionnaire and validate the content of each question. The Delphi technique has a great success in problem solving, decision making, task evaluation and task development. The Delphi method is generally used to develop the test procedure by consulting the experts in the specific field of application of the test battery. The test tasks and sequence of tasks are developed from expert opinion to fit the test objectives. The method standardizes the procedure to conduct the task capacity test. Task capacity is a

complex process and situational awareness is the foundation of predicting decision making process. Situational awareness is considered critical in aviation and defense industry, but as the system is becoming more automated in industries one person has to keep eye on different operations simultaneously and there is little room for any errors, resulting SA and as well task capacity to play a vital role in today's industry. There are many questions to answer on how to standardize and measure task capacity and situational awareness at the same time using a single tool. There is a demand for high skilled persons in industry but the demand is shifting to have multi-skilled persons and capable to cope with any change.

1.5. Research Scope

The present research examined the effect of physical workload on a standardized task developed using Delphi technique to measure task capacity and situational awareness. The research was conducted on the laboratory setup as well as online with subjects from diversified working fields. The subjects participated online only completed the test without considering any stress factors. The subjects participated in the laboratory completed the test in two steps: first, took the test at a stress free condition and second, took the same test after performing a physical exercise to induce low level physical stress.

1.6. Research Approach

The present study is described as per following sections. In the Literature Review section it is discussed on different task capacity and situational awareness techniques, physical stress related experiments and application of Delphi techniques application in various fields where there is a lack of consensus. In the Problem Formulation section background of the current study is described along with the research objectives and hypotheses. In the Experimental Methods section experimental parameters, variables,

procedures, experimental characteristics, number of subjects required, subjects' qualification, time commitments of subjects, equipment requirement, and physical exertion protocol, procedures followed by the subjects to complete the test and research efforts considered by the researcher for test design, data collection and test completion. In the Task Capacity Test Design section test construction procedure, technology used and test construction procedure is described. In the Test Report section data collection tools where described and analyzed. In the Results and Discussion section test results were analyzed, plotted and interpreted. In the conclusion section research finding are described along with the application of the developed tool. Also limitations faced during the current research and future scopes of the research are described.

2. LITERATURE REVIEW

Following subsections discusses findings in cognitive task, situational awareness, physical stress concerns and Delphi technique application.

2.1. Cognitive Task Capacity Measurement Techniques

The evaluation of mental workload is very important in the research and improvement of human-machine interfaces for comfort, satisfaction, efficiency and safety in the workplace.

Studies show a decrement in performance as workload decreases (Cox-Fuenzalida, 2007). In the experiment same subjects were introduced in two different types of tasks: one was from low to high workload and the other was from high to low workload scenarios and time gap between two tests were 15 minutes. A sudden decrease or increase of work load leads a loss of accuracy and slows response time in a longer work period. Experimental studies on cognitive performance usually keep workload constant. Cognitive abilities play a key role in the adequate management of workload by individuals performing complex tasks (Gonzalez, 2005). Workload is dependent on task demand and it varies on the capacity of the subject to meet those demands (Gopher, 1986).

Performance parameters such as intelligent level, knowledge performance level, aptitude test and behavioral conditions are measured using different tests (Srikaew, 1999). Alfred Binet in 1911 first developed the Intelligence scale to measure overall score. He is the pioneer in creating the scale to sort people in category in terms of intelligence. It measures overall IQ. For proper assessment of anyone's intelligence a subset analysis of the overall test is important and based on the need of subset analysis different IQ measurement tools were developed. In most of the tests subsets are classified in verbal

reasoning, quantitative reasoning, visual reasoning and memory. A list of the Intelligence tests includes:

- Wechsler Scales of Intelligence (1932)
- Wechsler Scales of Intelligence Revised (WAIS-R)
- Stanford-Binet: Fourth Edition (SB:FE)
- Detroit Test of Learning Aptitude-3 (DTLA-3)
- Kaufman Brief Intelligence Test (K-BIT)

For admission purpose in different colleges and universities national admission tests are developed. These tests are developed from the educational knowledge. A list of the Knowledge Performance test includes:

- Scholastic Assessment Test (SAT, 1926)
- American College Test (CT, 1959)
- Graduate Record Examination (GRE, 1949)

Employment services developed aptitude battery for screening workers for general job hiring. This type of test covers intelligence, verbal aptitude, arithmetical aptitude, spatial aptitude, clerical perception and manual dexterity. A list of the Aptitude test measurement includes:

- The Differential Aptitude Test (DAT)
- The General Aptitude Test Battery (GATB)
- The Armed Services Vocational Aptitude Battery (ASVAB)
- Minnesota Clerical Test (MCT)

Task capacity can be measured from objective and subjective queries. Several researches related to human factors show that self-report (subjective) measures can be useful (Muckler, 1992).

An assessment of workload called overall workload level (OWL) using subjective ratings was developed to show a linear relationship among physiological measurements, illness rates and OWL (Jung, 2001).

A comparison of Subjective Workload Assessment (SWAT), NASA-TLX and Workload Profile (WP) methods were evaluated in a laboratory environment for single task and dual task (Rubio et al., 2004) and the result shows there are no differences in the evaluation. WP was sensitive to the different task manipulations. NASA-TLX uses six dimensions to assess mental workload and these are: mental demand, physical demand, temporal demand, performance, effort and frustration. It is classified from 0-100 scale. In SWAT three levels: low, medium and high are used for subjective ratings. In this method the subject classifies the tasks in difficulty level set by his or her perception of load and then the subject rates the task in 0-100 scale. In WP method tasks are set in random order and provided to the subject to rate the tasks perceptual processing, response selection & execution, spatial processing, verbal processing, visual processing, auditory processing, manual output and speech out. A rating scale of 0 and 1 used to rate each task. “0” means the task places no demand on the task and “1” means maximum workload demand required for the task.

The available studies in gender differences provide conflicting results because of complexity of variables influencing cognitive sex differences. The verbal and visual-spatial functions were compared with self-ratings in healthy men and women and observed that

women tend to perform better on verbal tasks and men tend to perform better on visual-spatial tasks (Weiss, Elisabeth M., 2003).

Unlike many physical types of task, cognitive tasks have fewer consensuses in taxonomies. As the industrial jobs are becoming more cognitive in nature there is more demand to find a well acceptable methods to measure cognitive task capacity (Buck, 1998). Lower order cognitive tasks are the tasks that are elementary. Higher order cognitive tasks are problem-solving and decision making tasks. Buck identified information seeking (IS) tasks with real-world Lower order cognitive tasks such as compare, locate, verify, identify, classify and compute.

2.2. Situational Awareness Measurement Techniques

SA has been a critical element of mental construct on which complex systems such as a flexible manufacturing system is dependent (Endsley, 1995a). Operator of complex systems must rely on up-to-date knowledge of machine tool parameters, as well as recognize existence of any patterns among the parameters that provides the necessary information to the functioning of machines (Usher and Kaber, 2000). Rousseau (2010) measured SA using SART and QUASA, and no correlation was found between QUASA confidence and accuracy scores. SART score showed a negative correlation with QUASA accuracy score. SAGAT, which is an objective measurement method, is the most established method to measure SA (Endsley, 1995a). In SAGAT technique individuals answers queries about the current situation by freezing an ongoing event. SART technique, developed by Taylor (1990) method is usually used at the end of a test trial or an exercise. Individual participants rate the level of demand on attention resources (D), supply of

attention resources (S) and understanding of the situation (U). Three subscales are used to rate D, S and U and later combined to generate global SA index.

SART provides indication of subjective confidence level on individual's SA and it does not measure objective level of individual's SA (Endsley 1995b, Jones and Endsley 2004). Endsley et al. (1998) conducted a study on cockpit display evaluation using SART ratings and SAGAT probes on a section by section basis. The participants rated their overall SA, the sufficiency of their SA and confidence level on their SA. There were no correlations between subjective and objective ratings. But there were correlation between SART SA, understanding of SA and confidence level. It gives a clear view that subjective SA provides individual's confidence on SA. It is important to know if the individual confidence level is affected by stress as in many situations operator a machine or system need to make critical decisions.

Lee (1999) tested support systems for car driver to validate the claim that subjective SA techniques measures confidence level of individual's SA. Lee used SAGAT technique for objective SA combined with the confidence ratings on a scale of 0 to 100 to measure subjective SA for each answer. There was low correlation between accuracy and confidence level of each answer. The finding indicates that the participants are poor in evaluating their own SA. The finding resembles with the report of Endsley et al. (2000) on low correlation between SAGAT and SART.

QUASA technique, developed by Edgar et al. (2000) is most frequently used to collect data on SA (McGuinness 2004, 2007). Objective SA is measured from accuracy of responses to queries using true or false probe about a situation. Subjective SA is measured from self-rating of confidence for each probe response. A diagonal plot is generated to

show the relationship between selecting correct probe and confidence level. Point falling below the ideal diagonal line represents over-confidence and points falling above the ideal diagonal line represent under-confidence.

The individual beliefs and knowledge has an influence on confidence level shown by individuals on making decisions, and confidence level is an integral part of SA research (Lichacz, 2008). There is a lack of research on determining if the same subject is put in same situation with different stress condition. QUASA technique is considered more useful as this allows finding the relationship of subjective rating on confidence and objective measure on any type of problem.

2.3. Physical Stress Measurement

Physical stress effect on task performance is very critical in today's industrial operation. There are three types of physical stress scenarios: Low stress, medium stress and high stress. A review by Tomporowski (2003) shows that physical load enhances performance of some cognitive tasks under certain circumstances and as well reduces performance on certain cognitive tasks. Occupations such as emergency medical staff require physical exertion in performing their duty that places demands on human mental or cognitive resources (Mozrall and Drury, 1996). Poor performance can occur using less friendly devices and could cause catastrophic error. Buckle (2006) outlined the design challenges in the healthcare sector. The author provided some approaches and methods that ergonomist can use in the design of the healthcare systems. Silver (2004) studied the process carried out by providers to improve the quality of the service provided based on the human factors approach. The key design considerations include task information characteristics, task allocation, redundancies and the competing goals of the operator.

Spear (2002) has discussed about the ergonomics issues arising in the emergency department. The quality of healthcare service was improved by reducing the physical stress induced in the staff and patients due to the physical layout of the machines and equipments in a facility. The problems caused by the faulty design induces physical complication like back injuries among the staff. This causes increase in operating costs as claims filed by the staff.

Physical exercise affects human information processing. Analysis of different reports indicates a wide and inconsistent relationship between physical exertion and cognitive task performance (Tomporowski and Ellis, 1986; Mozrall and Drury, 1996). In some studies it is shown that increment in physical workload improved performance on the decision task and reduced performance on perception task, and decrement in physical workload reduced performance on decision task and improved performance on the perception task (Paas and Adam, 1991). Yerkes-Dodson (1908) first formulated an inverted U-shaped function between arousal and performance.

Basahel et al. (2010) conducted experiment on measuring human performance accuracy on assigned verbal task and spatial task. The subjects were asked to pedaling on a bicycle-ergometer at three different physical and mental load conditions: low, medium and high. The authors observed poor work performance at low and high level of physical workload and increase of work performance at medium physical workload and mental workload. Some findings indicate increase of accuracy in arithmetic task performance at an intermediate level of physical task (Reilly, 1986). The inconsistency between the task demand and human physical limitations causes psychological distress in human operator causing in mental over-load or under-load (Young and Stanton, 2002).

Perry et al. (2008) conducted experiment on sixteen participants performing a military operations using simulation tool to load weight in a helicopter within an allocated timeframe. The participants stood, walked or jogged on treadmill while performing the simulated cognitive task. Task performance was measured by tracking loading rate and number of correct decisions. SA was measured using queries during performing the simulation and freezing the event. Subjective workload was measured using the NASA-TLX scale. The results indicated decrease of SA as a result of increased physical workload. There is an increase of workload as the physical load increased, but there was no significant effect on cognitive task performance due to physical load increase. According to Perry (2008) walking is defined as self chosen normal speed ranged from 3.2-5.4 kph, and jogging is defined as 50% faster than their self-chosen walking speed. And the reason the author chose the speeds is to quantify differences between levels.

McMorris, Terry et al. (2011) used meta-analytic techniques to study the effect of acute and intermediate intensity exercise to determine the speed and accuracy of performance of working memory tasks. Intermediate intensity was identified as 50%-75% maximum volume of oxygen uptake (VO_{2MAX}) (Borer, 2003). Low intensity exercise is identified as <50% VO_{2MAX} and high intensity exercise is identified as >75% VO_{2MAX}. The speed of response was high but the accuracy was less under acute intensity exercise condition.

Joyce et al. (2009) studied the time course effect of moderate intensity exercise where the authors set the warm-up period of 5 minutes at 75 watt and workload progressive increased until exhaustion (25 W/min for males and 15W/min for females).

Though VO_{2max} is influenced by age, sex, exercise habit, heredity and cardiovascular clinical status, the highest value of VO_{2max} and heart rate are obtained with pedaling speed of 50 rpm to 80 rpm (Fletcher et al., 2001). According to Fletcher and Wikipedia the moderate physical stress is express by METs (metabolic equivalent of task) number as shown in Table 1.

Table 1. Physical Stress Measurement in METs

Light Intensity Activities	**METs <3**
Sleeping	0.9
watching television	1
writing, desk work, typing	1.8
walking, 1.7 mph (2.7 km/h), level ground, strolling, very slow	2.3
walking, 2.5 mph	2.9
Activities (Moderate)	**METs: 3 to 6**
bicycling, stationary, 50 watts, very light effort	3
walking 3.0 mph	3.3
calisthenics, home exercise, light or moderate effort, general	3.5
walking 3.4 mph	3.6
bicycling, <10 mph (16 km/h), leisure, to work or for pleasure	4
bicycling, stationary, 100 watts, light effort	5.5
Vigorous Intensity Activities	**METs: >6**
jogging, general	7
calisthenics (e.g. pushups, jumping jacks), vigorous effort	8
running jogging, in place	8
rope jumping	10

A cycle ergometer is a non-weight bearing, watts can be converted to oxygen uptake in milliliter per minute. MET are obtained by dividing VO_{2max} in milliliter per minute by the product of body weight in Kg multiplied by 3.5. 3.5 ml of O_2 per kg of weight is an accepted value of oxygen consumption at rest. Table 2 shows the METs value at different age groups with VO_{2max} (Fletcher et al., 2001).

Table 2. Normal Values of Maximum Oxygen Uptake at Different Ages

Age	VO_{2max} / METs	Men	Women
20-29	mL/Kg/min	43	36
	METs	12	10
30-39	mL/Kg/min	42	34
	METs	12	10
40-49	mL/Kg/min	40	32
	METs	11	9
50-59	mL/Kg/min	36	29
	METs	10	8
60-69	mL/Kg/min	33	27
	METs	9	8
70-79	mL/Kg/min	29	27
	METs	8	8

Aks (1998) evaluated visual and conjunction search task performance after 10 minutes of cycling at a low level of physical work and then again after high level of physical work. The results indicated an increase of visual search speed and a decrease in frequency of error following both the physical work. And compare to the low level and the high level physical work, high level exertion showed better result. Arcelin et al. (1997) conducted a test on subject's choice-reaction time on a cycle ergometer at 60% of participant's VO_{2max}. The tasks were performed and measured after 3 minute of biking and after 8 minute of biking. The results indicated shorter reaction time after 8 minute biking.

2.4. Delphi Technique

The Delphi technique is used where there is lack of agreement or incomplete state of knowledge on a particular problem exists. Individual judgments recorded and combined in addressing the issues. The first round questionnaire is unstructured and obtains open response, allows participants to elaborate the topic, and a qualitative analysis of the results allows constructing the second and subsequent questionnaires. The diversity of viewpoints that develops controversy helps generate interest and involvement. A heterogeneous group produces high quality acceptable solutions than homogeneous group. Goodman (1987) described Delphi method where information is collected from a group of expertise on a specific problem based on anonymity. Interpersonal interaction is eliminated in Delphi method to avoid the controlling variables in decision making. The key characteristics, anonymity, use of experts and controlled feedback are examined in Delphi study.

There are four features of Delphi technique distinguishing from other group decision making processes. These are anonymity, iteration with controlled feedback, statistical group response and expert input. Anonymity has advantages of making true opinion, and not influenced by any peer pressure. Disadvantage of Delphi method is there might be a case of lack of accountability. On the other hand since the panel is selected on the basis of their knowledge and willingness to participate, accountability problem may not be an issue. The validity of the study depends on the selection of experts instead of random sample. Hasson (2000) conducted methodological issues in nursing research, such as preparation, action steps and difficulties that are inherent within the Delphi technique. Findings from Delphi study helps streamline work.

Three issues guide data collection: the discovery of opinion, the process of determining the most important issues and managing opinions-data analysis. In Delphi study the experts need to know what they will be asked to do, how much time they need to contribute and use will be on the information they provide. Combination of verbal and written approach found to be more effective in decision making from the study. McKenna (1994) described what is Delphi technique, and criteria for selecting it as a research tool. Delphi is a method for systematic collection and aggregation of information provided by the group of experts on specific questions and issues. There is no precise analytical technique but subjective judgments on collective basis can be useful. The research population covers diverse background in experience or expertise. If there is lack of empirical data Delphi is appropriate. The unique aspect of this method is convergence towards agreement. It helps developing future knowledge and policy of a particular problem. Because of grassroots' involvement the results from Delphi is widely accepted. Powell (2003) emphasized on the development of scientific merit questions and the way findings of Delphi studied need to be evaluated. Villiers (1987) described two types of Delphi technique: Conventional and real-time. In the conventional method first questionnaire sent to group of experts and in the second round questionnaire sent back to the experts based on the result from first one. Third round is used depending on the consensus level from previous rounds. In the real-time technique the process takes place using meeting where summary of the responses of the respondent is made immediately. The decision maker obtains information on options with supporting evidence from the forum and makes the decision.

3. PROBLEM FORMULATION

The focus of this research is to develop a task capacity and situational awareness (SA) evaluation model and to investigate the effect of low level physical stress on capacity to perform tasks and SA tasks. Task complexity can be altered by changing the number of elements of a task. Task complexity effects attention, accuracy and repeatability of a task. The task capacity model developed considers a standard task performance procedure created using the Delphi technique.

Not much attention is paid on the relationship between task demand, cognitive abilities and situational awareness of the operators who perform manual tasks. Task capacity combines two characteristics of the brain: one is the capacity to store and recall information (Memory capacity) and the other is the capacity to perform logic-processing operations (Problem-solving capacity). Problem-solving capacity and knowledge are independent measures of task capacity. But high level of knowledge can enhance problem-solving efficiency. General Aptitude Test Battery (GATB) and the Employment National Job Service Committee (ENJSC) have been used in the United States for hiring purposes. Many authors have described on the short comings of the GATB method by (Hartigan, 1989). Time given for the test is also a concern. IQ, SAT, ACT, academic records, GPA or work experience are considered for hiring as well. But Problem-Solving capacity and behavioral characteristics are not considered in many test methods developed.

Situational Awareness measures one's ability to recognize the present scenario and predict future state of the gathered information. Performance parameter in a complex task model is dependent on situation awareness (SA). For example, in a flexible manufacturing system, operators must have up-to-date knowledge on machine tool parameter as well as

the functioning for future process state changes (Usher, 2000). Military personnel frequently rely on SA to make decisions on the battle field (Kaber, 2005). Inaccurate or incomplete SA could cause loss of life or unnecessary expenditure of resources. In recent years there are increased sophisticated military equipment used on the battle field which requires portable computing operations. The solders are required to be able to perform simultaneously cognitive demanding information processing tasks and physical tasks. Many studies show high SA score supports a better task performance. Stress may affect SA through decrement in working memory capacity and retrieval (Endsley, 1995). Literature suggests that sensory tasks are enhanced by all level of physical activities (Tomporowski, 1986). There is a lack of research on developing a single tool to measure SA and task capacity to find the effect of stress.

Studies indicate physical stress increases performance on some tasks under the job specific conditions and decreases or remains unchanged for the same task performance or other task performance with different conditions. There is a research gap in finding the effect of physical stress on tasks in terms of perception (PER), knowledge (IQ), problem solving capacity (PSQ), memory (MEM), creativity (CRE), and situational awareness (SA). It is observed from different studies IQ level do not change after certain age but the Problem Solving Ability increases with age. Studies show that IQ level measured in one test does not change even if a different test is taken after a three month period.

Previously SA application was considered for space, defense and air-traffic control. In recent times there were issues discovered in air-traffic control system such as operator was sleeping or operator provided wrong information to the pilot. As there is zero percentage of tolerance allowed in air-traffic control system, there were several

investigation conducted by FAA and found that the reason behind the operator error was due to long working hour. The low level stress can cause catastrophic failure even in lower order cognitive tasks.

The Delphi technique is implemented to develop the computer test model in general area by evaluating feedback from people working in different engineering, science and teaching fields. Also graduate students provided their view on the test model. Since the test was built with the view that the participants are expected to be students and professionals from wide range of fields, the test questionnaire formed is from general area. The participants in the Delphi study were from science background and test was designed considering the test subjects will have a science background. Initially eight people were sent the test material to participate in the test and five people responded. Later more requests were sent to other people through contacts and total number of participants increased to twenty-one subjects who completed the survey. About the finding of Delphi study is described in the Laboratory Test Report section. The subjects did not know each other and were located in different locations in USA and other parts of the world. In the first step the subjects were asked to comment on the test setup, time allocated for each question, total time taken for the test, and user friendliness. Based on their feedback on the model, time allocation on some of the questions was increased and the tutorial was improved. In the second step, since the subjects were from science background and test was in general type of tasks, the subjects were asked to evaluate each of the questions of the test to check the task validity. In the third step based on their feedback, all the designed tasks evaluated if any modifications were required. The method standardizes the procedure to conduct the task capacity test. As discussed in earlier section about the application of WP

method for subjective ratings on mental tasks are considered as an appropriate approach to implement Delphi in the research tool development.

Human factor issues are considered when designing the test setup. The test is computer generated. Computer table and adjustable swivel chair are provided to allow the participant to adjust seat to his or her comfort level and taking care of postural variations. Current set value of central air conditioning temperature and illumination of the room is considered standard for this test as all the subjects will be exposed to the same environment and also the study will be evaluated by comparison of two phase I and phase II.

In early 20th century in industry and manufacturing plants percentage of physical workload required was much higher than cognitive capacity required, but in today's industry due to automation percentage of physical workload is decreasing and lower order cognitive task load is increasing. Due to automation in industries a single error can be catastrophic. The percentage of error allowed is decreasing. Lean and Six sigma principles, which are used to reduce wastages and standardize tasks in manufacturing industry, process industry, offices and healthcare industry, are becoming an integrated part of industrial operation. More industries are following Toyota Production System (TPS) to standardize work flow and as well mental task. Study on the effect of low level stress is mental task and situational awareness level of operator is becoming more demanding and necessary.

3.1. Scientific Background

The assessment of task load, situational awareness and stress, and the impact in performing a task, is very important when a person for a specific type of work is required. To find an appropriate person in an appropriate designed task is a challenge in the continuous demanding field of aviation, mining, military, transportation and other

industries involved in engineering processes. Critical decisions are made under stressful conditions resulting in poor performance which could often be catastrophic. Most accidents occur due to operator error.

The way today's manufacturing industry is growing tasks require cognitive skills and as well awareness of the events surrounding the operation. Experimental design to find the effect of stress using combined task capacity and situation awareness measurement techniques has a potential to implement in many industrial engineering processes. The present study developed a computer based tool to measure task capacity and situational awareness, and to evaluate the relationship between the measured values to determine if low level physical stress contributes significantly to any change in performance.

3.2. Research Objectives

The tool developed in the research measures task performance capacity and performance due to tasks requiring situational awareness. The results are compared among different age group and professional groups under two stress conditions. The tool collected performance results before and after doing a low level physical exercise. Subjective ratings on confidence level were recorded after the subject answered each question. Signal Detection theory was applied using the measured confidence level to find the noise factor associated with finding of cognitive task capacity and situational awareness of individuals in stressed condition. True or false response was recorded with confidence level of attempting the response.

The task model developed for this research is in macro-level task serving the general job environment. And this model can be adapted to serve a micro-level need.

The study designed to find the effect of stress on task performance. The test was conducted among an age group of 21 to 40. A group of students and professionals working in different fields were considered as subjects for the test. Task capacities of different subjects were measured in the current research and statistical analysis was conducted to evaluate if the low level physical stress is a concerning factor on subject's performance of a task. The test was conducted in a noise free and comfortable temperature environment.

The research focused on developing the tool to use effectively and efficiently. The following procedures were set to develop the data collection instrument:

1. Task Capacity measurement tool developed using task functions described by Miller (1974)
2. Microsoft Visual C # (Pronounced C Sharp) 4.0 programs in Microsoft.Net Framework 4.0 (ASP.net) were used to construct the instrument. SQL server 2005 was used as a database
3. The data collection process, which includes the computer model and test questionnaire, was standardized using Delphi Techniques
4. Signal Detection Theory implemented to determine subjective confidence level as a noise factor on stress
5. Objective queries and subjective self-ratings of confidence for each response determined
6. Effect of a low level physical stress on task performance measured

The task performance measured, before and after introducing a low level physical work determines if stress has any effect on task performance. Task capacity and situational awareness measured expected to differ among the groups based on stress level of the

subject. The developed instrument determines any relationship between task performance and individual situational awareness. Response time and accuracy of performing a given task was recorded for statistical analysis to justify the findings. Delphi technique was used to standardize the computer model along with the questionnaire, through opinions from a panel. A questionnaire developed was used to measure the level of stress level experienced by the subject participating in the test before hand. This pre-test creates a baseline of the candidate's stress level.

3.3. Original Contribution And Hypotheses

The motivation of the current research is five-folded. First, the literature review indicates a gap in measuring indirectly the low level physical stress effect on cognitive task performance, specifically in perception, knowledge, problem solving, memory and creativity. This is an interesting area to explore as there are a number of professions that combine physical workload with cognitive task. Secondly, there is a lack of research on measuring a low level physical stress effect on SA. The literature review suggests most of the present occupation requires some level of situational awareness as the world is becoming more high-tech. Thirdly, there is a research gap to develop a single tool to measure performance on task capacity and situational awareness simultaneously and determine the effect of physical stress on perception, knowledge, problem solving, memory and creativity. Current job setting demand operator to have both task capacity and situational awareness to perform tasks. Fourthly, there is a research gap to implement consensus developing tool such as Delphi technique to standardize the task measurement tool. Fifthly, overall task capacity was calculated from the results of task performance.

Original contribution can be stated as:

1. A single tool developed to measure Task Capacity and Situational Awareness considering IQ, Memory, Problem Solving and Situational Awareness parameters in the tasks of Computation, Three-dimensional review, Vocabulary, Pattern recognition, Comparison and Arithmetic reasoning area.
2. C# program is used to develop the computer tool for data collection which has never been implemented.
3. It will be attempted to find if different age group and professional group has any physical stress effect on Knowledge and Problem-solving using this tool simultaneously.
4. Thirteen lower order task functions are selected from Miller (1974) described task functions to classify in the four parameters and tasks in the area of Computation, Three-dimensional review, Vocabulary, Pattern recognition, Comparison and Arithmetic reasoning area.
5. The data collection tools is attempted to standardize using Delphi Techniques which has never been implemented in designing tasks to measure cognitive performance.
6. To measure the effect of a low level stress on task performance and situational awareness simultaneously has never been attempted.
7. Signal Detection Theory has never been implemented to determine subjective confidence rating as a noise factor on physical stress.

The hypotheses tested were:

1) Low level stress has combined effect on the task capacity and situational awareness performances measured, before and after introducing a physical workload.
2) Task capacity and situational awareness has linear relationship.

4. EXPERIMENTAL METHODS

The following section describes on experimental variables, experimental parameters, experimental procedures, and requirement for human volunteers, along with duties and procedures to be performed by human volunteers.

4.1. Experimental Parameters

People are different on how they express themselves in different cultures. Goal is the same, process is the same, but the path is different. Brain is trained differently in different cultures- in Asian sub-continent *Science and Math* are emphasized in children's education and in Western countries like USA *Creativity* is give priority. Five performance parameters including Perception, Knowledge, Problem Solving, Memory and Creativity are used to develop the Test Battery. Figure 4 depicts the human brain displaying the structural location of the five parameters considered.

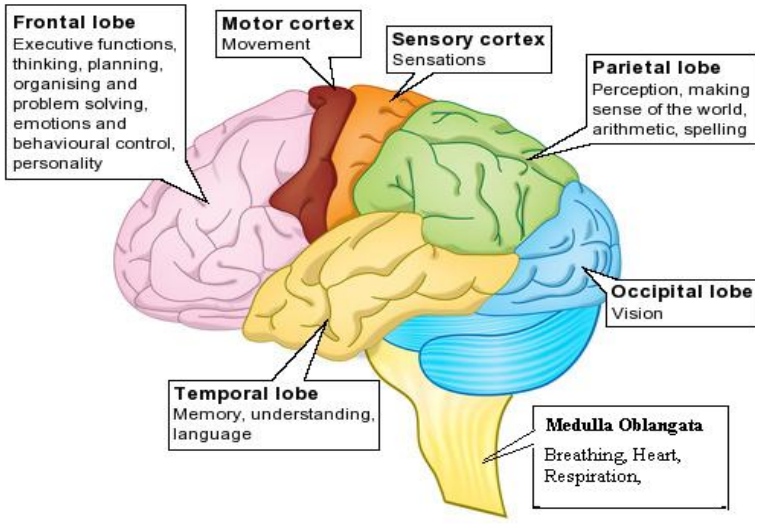


Figure 4. Human Brain Structure

(http://www.uic.edu/classes/bios/bios100/lecturesf04am/lect22.htm)

These five performance parameters representing the real world tasks are described by Miller (1974) with twenty five task functions. Cognitive tasks which serve activities

such as identify, compute, search etc. are stated as lower-order cognitive tasks. Problem solving and decision making tasks are stated as higher-order cognitive tasks. Table 3 is developed to show the twenty task functions described by Miller which are used to establish the relationship between task functions and task performance parameters. Sensory process initiates cognitive tasks as an input to memory and information processing and motor cortex complete the task as an output. From the relationships between task functions and test parameters, the scoring technique is developed. It is assumed that all the task functions utilize the equal brain capacity to complete a task and a task may consist of two or more sub-tasks.

Table 3. Relationship Between Task Functions and Task Parameter (Miller, 1974)

	Task Parameters				
Task Functions	Perception	Knowledge	Problem Solving	Memory	Creativity
	(PER)	(IQ)	(PSQ)	(MEM)	(CRE)
Message	X				
Input Select	X	X			
Detect	X		X		
Search/Locate	X			X	
Identify	X	X			
Filter		X	X	X	
Code			X	X	
Interpret		X			
Count			X	X	
Compute		X	X	X	
Decide/Select		X	X	X	
Compare			X	X	
Categorize		X	X	X	
Transmit		X		X	
Store			X	X	
Short-Memory				X	
Plan		X	X		
Analyze		X	X	X	
Adapt/Learn		X	X	X	X
Goal Image					X

4.2. Experimental Variables

Experimental variables in the study are:

1. Independent: Task functions described in Table 3 lists the independent variables. Stress, age and profession are considered as independent variable for the designed test.
2. Dependent: Task capacity and situational awareness is dependent variable.

4.3. Experimental Procedures

Test specifications used are: Measure of Response Time (RT) and Accuracy (AC). Cognitive capacity is measured in terms of IQ, MEM and PSQ. Effect of SA is measured by describing a situation and after a set time period, questions appears and subject need to select the correct answer. The SA question covers tasks under IQ, MEM and PSQ.

This study is broken into two phases: Phase I and Phase II. Phase I tasks and Phase II tasks are identical. Order of appearance of the questions in both the test is random in nature. Phase I is considered as performance without any stress. Phase II is considered as performance after stress. There is one experimental trial for each subject in Phase I. Each experimental trial consists of thirty tests in a random order. Similarly Phase II consists of one experimental trial with thirty tests in a random order. Phase II test follows right after ten minutes of light to moderate physical work at the set room air temperature and relative humidity. Later pre-test and post-test results are compared in terms of accuracy and completion time.

4.4. Experimental Characteristics

The characteristics of test battery include:

- A 30 questions test which is taken on a computer.

- Time of test is approximately 35 minutes for phase I test and 45 minutes for phase II test.
- Thirteen test components were considered featuring five test characteristics.
- Time taken to answer each question is recorded.
- The numbers of correct answers is recorded.
- A time lapse of four weeks is scheduled between Phase I test and Phase II test.

4.5. Number Of Subjects Required

A literature search was conducted on determining the sample size. The minimum size requirement for the research in human task capacity is a commonly asked question. Power analysis helps to determine required sample size as well to interpret research results (Lan and Lian, 2010). The statistical power of study depends on the effect size the research hypothesis considers and how many subjects are participating in the study. The larger the effect size, the more statistical power in the research. Similarly the more people are participating in the study, the more statistical power. Sample size has a significant role in controlling the statistical power because the larger the sample size, the smaller the standard deviation of the sample means. Significance level chosen has also an effect on statistical power. Statistical power is an important parameter to explain the result of a research in terms of if the results are statistically significant or not but practically insignificant. A statistically insignificant result with a high statistical power is explained as either the research hypothesis is not properly selected or there is less of an effect than predicted. The other approach of sample size determination is to run a pilot test (F, Faul et al., 2007). The results from the study should provide a reasonable estimate of the effect size. A pilot study is not always feasible and in that case previous experience and theories are used to estimate

the effect size. Based on statistical power, sample size is estimated using t-test and paired t-test.

Paas and Adam (1991) studied two information processing tasks with sixteen subjects. Eight of the sixteen subjects participated in the test of endurance versus interval protocol physical exertion information processing. Rest of the eight subjects participated in the rest versus minimal load protocol exertion information processing. The authors did not discuss the process of selecting the number of the samples and statistical power considered in the test. But the authors were able to find statistically significant result using F-test.

Aks (1998) studied on influence of exercise on visual search with eighteen participants and were able to find statistically significant result using ANOVA.

Mastroianni et al. (2003) studied mental arithmetic tasks while walking using subjective ratings. Ten subjects participated in the test. The small number of subjects and smaller differences in performance are the reason for not being able to detect any effect of physical exertion on task.

Joyce et al. (2009) conducted time course effect of moderate intensity exercise on response execution with ten subjects. The authors found statistically significance result using F-test. But the authors did not discuss the statistical power and how the number of participants was determined for the test.

Basahel et al. (2010) conducted physical and mental workload interaction in two experiments with fifteen participants in each experiment. The results of the findings are not yet available.

The goal of the current research is to have a balanced experimental design for subsequent statistical analysis. It is desired that the same subjects participate in both

experimental phases. However, if subject drops out after completing phase I they are not be replaced by other volunteers during phase II.

Three approaches were considered to determine the sample size.

Approach One:

The minimum number of participants required for the test is calculated from the sensitivity, the power, and statistical analysis of IQ level. The sample size is determined from Operating Characteristics "OC" curve (Montgomery, 2001) as shown in Figure 5. OC curve is the plot for type II error. The β error is a function of sample size. For a given value of δ (difference of two means), β error decreases as the sample size increases. The task capacity measured in the current research uses lower order cognitive tasks. The tasks selected for the test are considered under general science category and the subjects who participated have science background. From the report of Army General Classification Test Scores for Civilian Occupation (Trent, 1985) the Binet Intelligence Scale mean IQ values for accountants, engineers and lawyers are 122 with standard deviation of 16. The minimum value is 96 and maximum value is 144. The level of difficulty for this test is considered 90% and it can be assumed equivalent to the maximum score of 144. The mean score of 122 can be converted to 76.25% with a converted standard deviation of 4.58. Initially in the experiment it was assumed that task capacity differences between phase I and phase II is not more than 15% with standard deviation of less than 5%. The effect size (d) is calculated by

$$d = \frac{|\mu 1 - \mu 2|}{2\delta} \qquad (1)$$

$$= 15/2*4.58 = 1.64$$

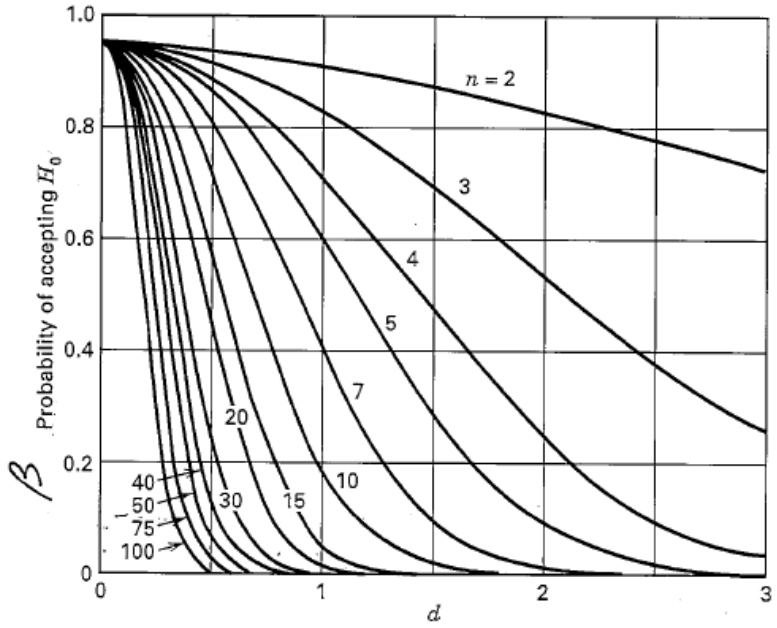


Figure 5. Operating Characteristics Curve (Montgomery, 2001)

From the OC curve (Figure 5) for β = 0.1 and d value from equation (1),

$$n^* = 6.5 \quad (2)$$

And sample size (n) calculated by

$$n = (n^* + 1)/2 \quad (3)$$

$$= 3.75 \approx 4$$

Based on this approach sample size determined was only four. But later as the research progressed it was observed that mean difference was lower than 15%.

Approach Two:

Initially five participants responded to the request for participating in the test that completed the Phase I test. Sample size n is calculated based on the collected data from Phase I as shown in Table 4. Since this result is only from phase I, the correlation factor is not included for calculation of sample size.

Table 4. Preliminary Data

Overall Correct Answer (%)	Standard Deviation (σ)	Average (μ)	Difference (τ)
85	6.5	84	1
90		84	6
80		84	-4
90		84	6
75		84	-9

A sample size is calculated from the equation give by

$$\Phi^2 = n*\sum \tau_i^2 /a* \sigma^2 \quad (4)$$

where Φ parameter is related to type II error β as shown in appendix Chart V (operating characteristics curve from Montgomery Book on Design & Analysis of Experiment for finding β from the Graph), τ is the difference of mean**,** σ is the overall Standard deviation, n is the number of replication and a is the number of subjects.

Based on the preliminary data and equation (4),

$$\Phi^2 = n*\sum \tau_i^2 /a* \sigma^2 = n*170 / 5*6.5^2 = 0.80*n \quad (5)$$

Operating Characteristics curve for

$$(a-1) =5-1 = 4 \quad (6)$$

Where (a-1) = degrees of freedom.

And error degree of freedom

$$N-a = a*(n-1) = 5*(n-1) \quad (7)$$

Where (N-a) = degrees of freedom.

At $\alpha = 0.05$ and considering a sample size of n =8, from equation (5)

$$\Phi = 2.53 \quad (8)$$

Error of degree of freedom from equation (7)

$$5*(8-1) = 35 \quad (9)$$

From Figure 6, using the results of equation (6), (8) and (9), β is determined which is much less than the set value of β = 0.1 at sample size of eight. The graph indicates, the sample size of eight was sufficient to the power of 0.9 (β = 0.1).

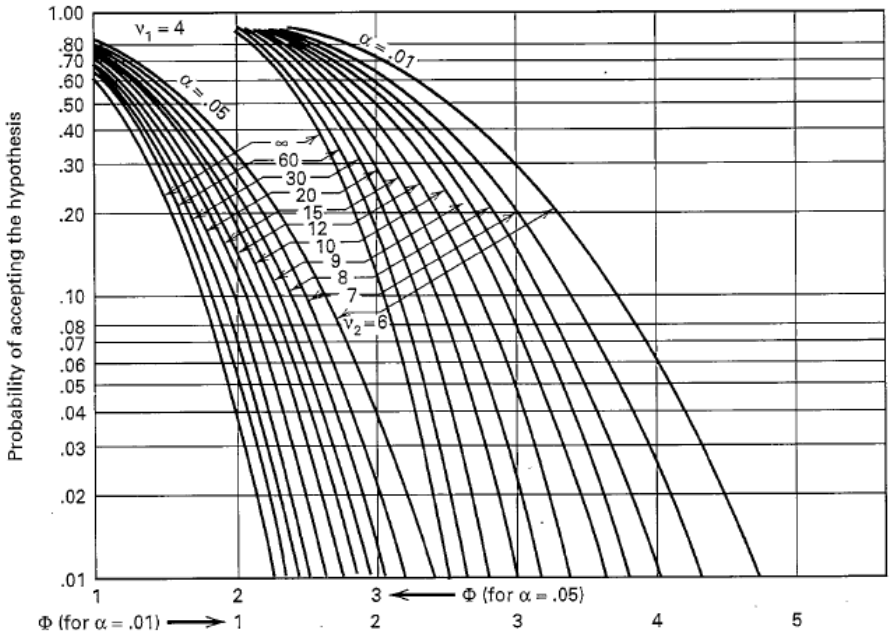


Figure 6. Sample Size using Φ at α = 0.05 (Montgomery, 2001)

From the analysis of preliminary data collected in Phase I, it was determined that sample size of eight was expected to be sufficient. Thirty two subjects were considered for this research as the variability between subject to subject is high and some subjects are expected to not complete both tests.

Approach Three:

A paired t-test is considered to determine sample size using SAS program. The program code is shown in Appendix A.1. Table 5 shows results from paired-t test run for mean difference (2, 3, 4 and 5), Standard deviation (5, 6, 7 and 8), Correlation (0.5, 0.6, 0.7 and 0.8) and Power considered for the test is 0.8.

Table 5. SAS Paired-t Test

		Computed N Total			
Index	Mean Diff.	Std Dev.	Corr.	Actual Power	N Total
1	2	5	0.5	0.818	52
2	2	5	0.6	0.809	42
3	2	5	0.7	0.804	32
4	2	5	0.8	0.803	22
5	2	6	0.5	0.806	73
6	2	6	0.6	0.818	59
7	2	6	0.7	0.807	45
8	2	6	0.8	0.808	31
9	2	7	0.5	0.818	99
10	2	7	0.6	0.828	79
11	2	7	0.7	0.818	60
12	2	7	0.8	0.823	41
13	2	8	0.5	0.852	128
14	2	8	0.6	0.837	103
15	2	8	0.7	0.813	78
16	2	8	0.8	0.818	53
17	3	5	0.5	0.818	24
18	3	5	0.6	0.809	20
19	3	5	0.7	0.804	16
20	3	5	0.8	0.803	11
21	3	6	0.5	0.806	34
22	3	6	0.6	0.818	28
23	3	6	0.7	0.807	21
24	3	6	0.8	0.808	15
25	3	7	0.5	0.818	45
26	3	7	0.6	0.828	37
27	3	7	0.7	0.818	28
28	3	7	0.8	0.823	20
29	3	8	0.5	0.852	58
30	3	8	0.6	0.837	47
31	3	8	0.7	0.813	36
32	3	8	0.8	0.818	25
33	4	5	0.5	0.818	15
34	4	5	0.6	0.809	12
35	4	5	0.7	0.804	10
36	4	5	0.8	0.803	8
37	4	6	0.5	0.806	20
38	4	6	0.6	0.818	17
39	4	6	0.7	0.807	13
40	4	6	0.8	0.808	10
41	4	7	0.5	0.818	27

Table 5 (Continued)

	Computed N Total				
Index	Mean Diff.	Std Dev.	Corr.	Actual Power	N Total
42	4	7	0.6	0.828	22
43	4	7	0.7	0.818	17
44	4	7	0.8	0.823	12
45	4	8	0.5	0.852	34
46	4	8	0.6	0.837	28
47	4	8	0.7	0.813	21
48	4	8	0.8	0.818	15
49	5	5	0.5	0.818	10
50	5	5	0.6	0.809	9
51	5	5	0.7	0.804	7
52	5	5	0.8	0.803	6
53	5	6	0.5	0.806	14
54	5	6	0.6	0.818	12
55	5	6	0.7	0.807	9
56	5	6	0.8	0.808	7
57	5	7	0.5	0.818	18
58	5	7	0.6	0.828	15
59	5	7	0.7	0.818	12
60	5	7	0.8	0.823	9
61	5	8	0.5	0.852	23
62	5	8	0.6	0.837	19
63	5	8	0.7	0.813	15
64	5	8	0.8	0.818	11

Another SAS program was run for two sample t-test for mean differences. The program was run for 1:1 ratio and 2:1 ratio between phase I and Phase II. The Mean differences considered 5, 6, 7 and 8, and Standard deviation 5, 6, 7, and 8. The program code is listed in Appendix A.2. Table 6 and Table 7 shows the results from the two run.

4.6. Subject Qualifications

Subjects are volunteers from the student population currently completing their Bachelors' or higher degree and/or individuals currently working at educational institution or companies. In addition, qualified subjects were expected to be physically fit to perform light to moderate physical work. Each subject was fully briefed regarding the procedures

and was asked to sign an informed consent statement before being allowed to participate. Pregnant women are not permitted to participate as subjects in the current study, because these studies are not intended to examine any aspects of pregnancy. Males and non-pregnant females provide an adequate volunteer population. Individuals who have any problem performing a light physical workout are not permitted to participate.

Table 6. 2:1 Ratio t-Test for Mean Differences

Computed N Total				
Index	Mean Diff.	Std Dev.	Actual Power	N Total
1	5	5	0.818	39
2	5	6	0.809	54
3	5	7	0.804	72
4	5	8	0.803	93
5	6	5	0.806	27
6	6	6	0.818	39
7	6	7	0.807	51
8	6	8	0.808	66
9	7	5	0.818	21
10	7	6	0.828	30
11	7	7	0.818	39
12	7	8	0.823	51
13	8	5	0.852	18
14	8	6	0.837	24
15	8	7	0.813	30
16	8	8	0.818	39

4.7. Time Commitments Of Subjects

Each subject participating in Phase I and Phase II were exposed to each of the test conditions one time. Time elapse between the two tests is approximately four weeks. If a test is terminated due to a computer failure, malfunction, or work day limitations, the subject may be asked to repeat that test condition on another day. During the Phase II physical workout condition, if a subject requests to stop due to discomfort, the test is terminated for that day.

Table 7. 1:1 Ratio of t-Test for Mean Differences

Computed N Total				
Index	Mean Diff.	Std Dev.	Actual Power	N Total
1	5	5	0.807	34
2	5	6	0.807	48
3	5	7	0.803	64
4	5	8	0.808	84
5	6	5	0.801	104
6	6	6	0.802	24
7	6	7	0.807	34
8	6	8	0.808	46
9	7	5	0.818	58
10	7	6	0.841	74
11	7	7	0.814	20
12	7	8	0.807	26
13	8	5	0.809	34
14	8	6	0.809	44
15	8	7	0.801	54
16	8	8	0.808	16

4.8. Required Equipment And Supplies

A desktop computer with internet connection is required for both the Phase I and Phase II part of the experiment. Also a Monark Ergometer (Cardio Care 827E, see Figure 7) at the workload of 100 watts or 2 kp braking power (600 kpm/min) will be utilized during the Phase II experiment.

Figure 7. Monark Ergometer (Cardio Care 827E)

The cycle ergometer is less expensive compare to treadmill. It occupies less space and also less noisy than a treadmill. A major limitation to cycle ergometer testing is the discomfort and fatigue of the leg muscles. Since the current research focuses on low intensity ten minutes of biking, fatigue will not be an issue. For a cycle ergometer, the power output is usually 10W (60 kpm/min) to 25W (150 kpm/min) for the initial few seconds, followed by an increase of 25W for every 2 to 3 minutes until a workload equivalent to 100W is reached. The average pedaling rate of below 50 cycles per minute is required by the participant to perform cycling and to achieve 600 kpm/min of workload.

Before performing the biking task the subject need to adjust the saddle and handlebar to suit them for the most comfortable position. Initially at the start of biking the pendulum weight is set at lower scale to reduce friction between wheel and the chain and increased to a specified level at the workload of 100 watts when the participant reaches a steady RPM. The subject is set to bike for ten minutes based on the assumption that participant will have the same level of physical stress condition as prior to the phase II session. If the subject bikes at a higher RPM, the distance of 3 miles is used as the maximum distance for stress consideration in the current experiment. This distance limit is imposed to equalize the level of fatigue or stress condition for all participants.

Borg (1982) scale shown in Table 8 is used to measure the stress level before and after the biking. The subject is set to bike for ten minutes based on the assumption that participant will have the same level of physical stress condition as prior to the phase II session. Low level stress considered for the test subject when the Borg scale rating of the participant is below 11. An adjustable swivel chair is used as a sitting arrangement for the

subjects. Room lighting is adjusted to accommodate illumination requirement of each subject.

Table 8. Borg Scale for Rating Perceived Exertion

Borg Scale	Rating
6-7	Very, very light
8-9	very light
10-11	Fairly light
12-13	Somewhat hard
14-15	Hard
16-17	Very hard
18-20	Very, very hard

4.9. Physical Exertion Protocol

Borg Scale rating is used as a subjective rating for the participant's stress level and verbal expression is used to rate the scale for the sensory rating rather than cognitive frame expression (Borg GA, 1982). The verbal rating reduces the Borg Scale review differences from person to person. It also reduces the variability of physical exertion performance of participant, 'Physically fit' factor and PAR-Q checklist (Appendix A1) will be used to verify the participant's physical condition. The stress rating of 11 or less from the Borg scale will give a better deterministic factor of the low level stress.

Guideline for Workload:

Step 1: Warm-up time for 2-3 minutes with a resistance of 0 Kg and RPM of 50.

Step 2: 1st stage workload of for 3-4 minutes at 150 kg.m / minute (=25 Watt).

[Workload=Resistance (K_p) X Revolution /min (RPM) X Flywheel Travel Distance ($m.rev^{-1}$)] (In this stage 0.5 Kg weight is considered)

Step 3: 2-3 minutes at 600 Kg.m/minute (=100 Watt)

Step 4: Verbally Borg stress rating will be asked to the subject

Limiting Traveling Distance of biking = (50 rpm X 6 m.rev^{-1}) X 10 min =3000 m = 1.86 miles ~ 2 miles (approximately).

4.10. Procedures Performed By Human Subjects

The test is designed to be user friendly. The interactions between the subject and the computer are set to perform with minimal physical requirements using computer keystrokes. A real time clock was used to record each question response time and used for statistical analysis. The accuracy of each task was recorded along with the response time. The Human Factor laboratory of Industrial Engineering Department of North Dakota State University was used for the test. The room size is approximately 15 feet by 20 feet with central air conditioning system set at 75°F. During the test only the subject was present in the room set in a quite environment. Illumination was controlled in this experiment. A set of thirty tasks was presented to each subject after completely reading the task description. Instructions were described to each subject clearly in the tutorial. The task was presented to each subject in a sequential order after each task is completed.

There is no specific attire required for the test. Any type of clothing is fine as long as it does not generate any sort of restriction or thermal stress. Drinking water was provided to subjects during the test. All personal information data input was stored in the database with a unique user ID. The answers to the question trigger different formulas to calculate points. A button on the desktop is used to enter into the program and once entered; there are other buttons for personal DATA, Pre-Stress, DESCRIPTION of the test, TUTORIAL, TEST 1, Post-Stress and TEST 2. TEST 2 is conducted after the participants perform a physical task for a specified amount of time to simulate stress. The tutorial demo which takes approximately 5 minutes was shown. Test 2 was conducted within four

weeks from Test 1. Initially ten participants were considered for the test. Later, the sample size required was calculated and the total number of participants was increased to thirty two. Same participants appear on TEST 1 and TEST 2. In TEST 1 module, there are thirty tasks and each task is developed from the relationship between task functions and task parameters shown in Table 7.Time taken to execute each task is recorded in milliseconds. The participants only take TEST 1or TEST 2 in round one and TEST 2 or TEST 1 in round two respectively in four weeks. Table 9 outlines and explains the duties performed by volunteer test subjects.

Table 9. Duties Performed by Volunteer Test Subjects

Phase	Laboratory Testing: pre-test	Laboratory Testing: perform-test
Phase I	• Arrive well rested • Sit in the chair allocated for the test and adjust to individual comfort height • Adjust monitor and keyboard to individual comfort level	• Click the button located on the desktop designated for the test • Follow the self-described steps explained in the test
Phase I	• Subject's physical condition in terms of illness and if had enough sleep before coming to the test • Report subjective state (comfort, sweating, fatigue, temperature) • Short Survey on the Computer test • Overall performance rating on tasks after test	• If the self-reported stress exceeds a threshold value set, the subject will be asked to repeat the test at a later date • After completion close the window and set a date for the phase II test

Table 9 (Continued)

Phase	Laboratory Testing: pre-test	Laboratory Testing: perform-test
Phase II	• Arrive well rested • Sit in the chair allocated for the test and adjust to individual comfort height • Adjust monitor and keyboard to individual comfort level • Subject's physical condition in terms of illness and if had enough sleep before coming to the test	• Click the button located on the desktop designated for the test • Follow the self-described steps explained in the test • If the self-reported stress exceeds a threshold value set, the subject will be asked to repeat the test at a later date
Phase II	• Report subjective state (comfort, sweating, fatigue, temperature) • PAR-Q form completion before appearing for the biking (Appendix A.3) • Physical workout for approximately10 minutes • Short Survey on the Computer test • Overall performance rating on tasks after test	

Phase I Test: Tests was presented visually without any audio devices on the desktop computer. The keyboard as the primary response device was set where the subject is comfortable and the computer monitor angle will be adjustable. An adjustable swivel chair

will be used so the subjects can make arrangements for self comfort and postural variations.

Phase II Test: The test was conducted under stressed conditions. The physical workout was treated as a stressor and will be performed by each subject prior to appearing for the Phase II test. A bicycle Ergometer at the workload of 100 watts braking power was used by the subject for the physical workout. The duration of workload was calculated to be maximum of 1000 watts in 10 minutes. The participants were given Physical Activity Readiness Questionnaire (Appendix A.3) right after their exercise is complete.

4.11. Organization Of Research Effort

The researcher was responsible for designing and developing the instrument for data collection, experimental design of the study, obtaining research subjects, scheduling research trials, coordinating data collection and analysis to include ensuring compliance with safety requirements. Advisor office (PI) was used to store the paper document which is locked when the advisor is not at the office. Name and date of birth (excluding year) was stored in the paper records. The user name and password was saved in the paper record. This user ID and password was given to the participant, so he or she can log-in and input all required information described earlier in test. Electronic data safeguard is provided by:

1. Go daddy server database security provided by the server itself.
2. Asp.net is used to develop the input forms, security is provided by the Asp.net, and where user ID and password is used to protect the data form.
3. While downloading from the server to local computer at NDSU: Antivirus (McAfee) + Firewall is active.
4. Local server security where the data is downloaded is provided by the local NDSU.

5. TASK CAPACITY TEST DESIGN

To evaluate task capacity and situational awareness of a subject under normal and low-stress level conditions, test questions are developed from major tests used in cognitive capacity analysis. Since the test is designed such that it forces the subjects to answer all the questions and the questions are designed for lower-order cognitive performance, each question is categorized into the three task parameters and situational awareness parameter. Perception and Creativity parameter is not considered for the test.

5.1. Test Construction

Combination of lower-order and situational awareness parameters are considered for the test design. Table 10 shows the thirteen parameters considered for the test. The test questionnaires are presented in a random order. The 30 questions will also appear in different order for different participants.

Table 10. Modified Task Function and Task Parameter

	Task Parameters			
Task Functions	Knowledge	Situational Awareness	Problem Solving	Memory
	(IQ)	(SA)	(PSQ)	(MEM)
Search/Locate		X		X
Identify	X	X		X
Filter	X	X	X	X
Interpret	X	X		
Count		X	X	X
Compute	X	X		X
Decide/Select	X	X	X	X
Compare		X		X
Categorize	X	X	X	X
Store		X		X
Short-Memory	X	X		X
Plan	X	X	X	
Analyze		X	X	

For analysis purpose IQ` is considered as tasks that require only IQ; only Knowledge; combination of IQ and Knowledge; and PSQ is considered tasks that require PSQ or any combination of PSQ and IQ`.

The six task functions which are categorized under IQ` are Search, Identify, Interpret, Short memory, Store and Count. The six task functions which are categorized under PSQ are Filter, Compute, Compare, Categorize, Plan and Analyze. Since answers are selected as True or False, Decision task function is considered as a common task function for IQ` and PSQ. Since any task can be a combination of multiple tasks, if such multi-tasks require PSQ this multi-task will be classified under PSQ for measuring the Task Capacity. The explanation for each question provided below was presented to the test subjects in order to evaluate the test questions.

1. **Compare & Decide Problem:** The question used to compare a pair of names to measure and compare the task function and decision task function in terms of IQ and MEM.

Strategy: Pair of names is compared.

Test Characteristics: Subjects visually see the question, read the message, identify all the components for comparison purpose and then select a true/false statement from the answers.

2. **Compute & Decide Problem:** The question used for solving a mathematical problem is to measure the computational task function and decision task function in terms of IQ and MEM.

Strategy: Addition of two numeric values.

Test Characteristics: Subjects visually see the question, read the message, compute the summation and then select a true/false answer.

3. Analyze & Decide Problem: The question used a picture to measure the analyze task function and goal-image task function in terms of PSQ.

Strategy: A three dimensional picture is displayed to analyze the flat state.

Test Characteristics: Subjects visually see the picture, analyze the flat state and then select a statement to be true/false.

4. Compare, Categorize, SA & Decide Problem: To measure the Compare, Categorize & Decide task function in terms of IQ, PSQ and MEM. The question is also intended to measure SA of the participant.

Strategy: Comparison of two words having the same meaning. Question is displayed for certain period of time with a Sand-clock.

Test Characteristics: Subjects compare the words to select words with the same meaning and then select a true/false statement from the answers.

5. Compare, Categorize, SA & Decide Problem: To measure the Compare, Categorize & Decide task function in terms of IQ, PSQ and MEM. The question is also designed to measure SA of the participant.

Strategy: Comparison of two words having opposite meaning. Question is displayed for certain period of time with a Sand-clock.

Test Characteristics: Subjects compares the words to select opposite meaning and then select a true/false statement from the answers.

6. Identify, Compare & Decide Problem: To measure the Identify, Compare & Decide task function in terms of IQ, PSQ and MEM.

Strategy: A tool is displayed to find the identical shape and color from the given tools.

Test Characteristics: Subjects compare all the displayed tools to select the identical tool displayed and then select a true/false statement from the answers.

7. Compute, Short-Memory, SA and Decide Problem: The question uses the solving of a mathematical problem to measure Compute, Decide, Filter and Short-term memory task function in terms of IQ and MEM. In addition, the question measures SA of the participant.

Strategy: Multiplication of two numerical units and filter unnecessary information. Question is displayed for certain period of time with a Sand-clock.

Test Characteristics: Subjects visually see the question, read the message, compute the summation and then select a true/false statement from the answers.

8. Identify, Analyze, Compare and Decide Problem: The question uses a set of pictures to analyze, Identify and Compare task function in terms of IQ, PSQ and MEM.

Strategy: A number of shapes are displayed to identify which shape is not matching.

Test Characteristics: Subjects visually see the picture, analyze the shapes, identify & compare similar shapes and then select a true/false statement from the answers.

9. Store, Short- Memory and Decide Problem: The question is used to recall part of the information displayed in the screen for a certain time period and a secondary object is displayed to remind the time factor. Store, Short-term Memory and Decide task function are measured in terms of IQ and MEM. Also, the question measures SA of the participant.

Strategy: The question uses a 7-digit random number displayed for 8 seconds both with a sand-clock displayed on the screen simultaneously.

Test Characteristics: Subjects visually see the 7-digit number, memorize the number, recall last 3-digits and then select a true/false statement from the answers.

10. Category, Store, Short-term Memory and Decide Problem: The question is used to recall part of the information displayed on the screen for a certain time period and a secondary object is displayed to remind the time factor. Category, Store, Short-term Memory and Decide task function are measured in terms of IQ, PSQ and MEM. Also the question measures SA of the participant.

Strategy: A description is displayed for 15 seconds with a sand-clock displayed on the screen simultaneously. The description contains different category of information.

Test Characteristics: Subjects read the description, memorize the information, recall area information and then select a true/false statement from the answers.

11. Compute & Decide Problem: The question is used to solve a mathematical problem and to measure the computational task function and decision task function in terms of IQ and MEM.

Strategy: Multiplication of two numeric values. Question is displayed for certain period of time with a Sand-clock.

Test Characteristics: Subjects visually see the question, read the message, compute the multiplication and then select a true/false statement from the answers.

12. Category, Store, Short-term Memory and Decide Problem: The question is used to recall a part of the information that is displayed in the screen for a certain time. A secondary object is displayed to remind the time factor. Category, Store, Short-term Memory and Decide task function are measured in terms of IQ, PSQ and MEM. The question is also designed to measure SA of the participant.

Strategy: A description is displayed for 10 seconds with a sand-clock in the screen simultaneously. The description contains different category of information.

Test Characteristics: Subjects read the description, memorize the information, recall area information and then select a true/false statement from the answers.

13. Compute & Decide Problem: The question is used to solve a mathematical problem and to measure the computational task function and decision task functions are measured in terms of IQ and MEM.

Strategy: Division of two numeric values.

Test Characteristics: Subjects visually see the question, read the message, compute the division and then select a true/false statement from the answers.

14. Identify & Decide Problem: The question uses a picture to identify what it represents. The computational task function and decision task function are measured in terms of IQ and MEM.

Strategy: An image is displayed to identify a product.

Test Characteristics: Subjects see the image, identify the product displayed and then select a true/false statement from the answers.

15. Store, Short-term Memory and Decide Problem: The question is used to recall part of the information displayed in the screen for a certain time period and a secondary object is displayed to remind the time factor. Store, Short-term Memory and Decide task function are measured in terms of IQ and MEM. The question is also designed to measure SA of the participant.

Strategy: The question uses a 7-digit random number displayed for 15 seconds both with a sand-clock displayed on the screen simultaneously.

Test Characteristics: Subjects visually see the 7-digit number, memorize the number, recall last 3-digits and then select a true/false statement from the answers.

16. Compare, Analyze, Plan and Decide Problem: Compare, Analyze, Plan and Decide task function are measured in terms of IQ, PSQ and MEM.

Strategy: The question displays a pattern in different directions and subject is asked if the pattern is same row wise.

Test Characteristics: An array of pattern is displayed. Subjects first plan on how to approach the pattern recognition, then compare and analyze the pattern, and then select a true/false statement from the answers.

17. Compare, Analyze and Decide Problem: Compare, Analyze, and Decide task function are measured in terms of IQ, PSQ and MEM.

Strategy: The question displays two patterns and subject is asked if the patterns are identical or not.

Test Characteristics: Two patterns are displayed. Subject compare and analyze the pattern, and then select a true/false statement from the answers.

18. Identify, Count, Short-term memory & Decide Problem: The question is used to identify displayed items, count total quantity and short-term memory task function and decision task function are measured in terms of IQ, PSQ and MEM.

Strategy: Two pictures are displayed representing two different items. Subject has to identify the items, count items from each picture.

Test Characteristics: Subjects see the displayed pictures, count the quantity, memorize the number and then select a true/false statement from the answers.

19. Search, Identify & Decide Problem: The question is used to search and identify displayed items task function and decision task functions are measured in terms of IQ, PSQ and MEM.

Strategy: Several figures are displayed representing different geometric shapes. Subjects search and identify the desired items.

Test Characteristics: Subjects see the displayed figures, search for missing figures, identifies the missing figure and then select a true/false statement from the answers.

20. Search, Identify, Count, Short-term memory & Decide Problem: The question is used to search and identify displayed shapes, count total quantity and short-term memory task function and decision task function in terms of IQ, PSQ and MEM. The sand-clock is displayed in the monitor. The question is also designed to measure SA of the participant.

Strategy: Different geometric shapes are displayed. Subject search for a specific shape and identify the item, count items from the display. The picture is displayed for 15 seconds and then the question is appeared.

Test Characteristics: Subjects see the displayed pictures, count the quantity, memorize the number and then select a true/false statement from the answers.

21. Identify, interpret, Filter & Decide Problem: The question is used to identify what the pair of words mean. Identify, interpret and decision task function are measured in terms of IQ, PSQ and MEM.

Strategy: Two words are displayed to define two different things.

Test Characteristics: Subjects see the words, identify the words, interpret the meaning of the words and then select a true/false statement from the answers.

22. Compute & Decide Problem: The question uses the solving of a mathematical problem to measure the computational task function and decision task functions are measured in terms of IQ and MEM.

Strategy: Multiplication of three numeric values.

Test Characteristics: Subjects visually see the question, read the message, compute the multiplication and then select a true/false statement from the answers.

23. Identify, Short-term Memory, Plan, Analyze and Decide Problem: Identify, Short-term Memory, Plan, Analyze and Decide task function are measured in terms of IQ, PSQ, and MEM.

Strategy: A pattern is displayed and subject is asked what the next pattern type in the series is.

Test Characteristics: Subjects analyzes the displayed pattern and then select a true/false statement from the answers.

24. Identify & Decide Problem: The question uses words to identify the correct spelling. The identify task function and decision task function are measured in terms of IQ, PSQ and MEM.

Strategy: Four words are displayed to identify the correct spelling.

Test Characteristics: Subjects see the word, identify the correct spelling of word and then select a true/false statement from the answers.

25. Compute, Analyze & Decide Problem: The question uses a graph to compute an object location. The Compute task function and decision task function are measured in terms of IQ, PSQ and MEM.

Strategy: A graph is displayed to calculate the location of an object.

Test Characteristics: Subjects see the graph, compute the location and then select a true/false statement from the answers.

26. Analyze, Plan and Decide Problem: Analyze, Plan and Decide task function are measured in terms of IQ, PSQ and MEM.

Strategy: Sequences of photos are displayed, which is shown as a function of time. The subject is asked which pattern is not in a sequence.

Test Characteristics: Subjects first analyzes the photos, and then plans for the sequence, and then select a true/false statement from the answers.

27. Compare, Analyze and Decide Problem: Compare, Analyze and Decide task function are measured in terms of IQ, PSQ and MEM.

Strategy: Photos of a person is taken at different time frame. One of the photos is taken under surveillance. The subjects are asked to identify which picture is taken under surveillance.

Test Characteristics: Subjects first compares the photos, then analyzes the photos, and then select a true/false statement from the answers.

28. Identify, Short-term Memory, Compute, Plan and Decide Problem: Identify, Short-term Memory, Plan, Analyze and Decide task function are measured in terms of IQ, PSQ and MEM.

Strategy: A sequence of number is displayed in series and subject is asked what will be the next series numbers.

Test Characteristics: A number series is displayed. Identify, short memory, plan, analyze task functions are measured, and then subjects select a true/false statement from the answers.

29. Category, Store, Short-term Memory and Decide Problem: The question is used to recall a part of the information that is displayed in the screen for a certain time period and a secondary object is displayed to remind the time factor. Category, Store, Short-term

Memory and Decide task function are measured in terms of IQ, PSQ and MEM. The question is also designed to measure SA of the participant.

Strategy: A description is displayed for 10 seconds with a sand-clock displayed in the screen. The description contains different categories of information.

Test Characteristics: Subjects read the description, memorize the information, recall area information and then select a true/false statement from the answers.

30. Identify, Compute, Interpret, Short-term Memory and Decide Problem: Identify, Interpret, Short-term Memory, Analyze and Decide task functions are measured in terms of IQ, PSQ and MEM.

Strategy: Price of two products is given as a sum. Difference of prices between the two products is given and subjects are asked of an individual product.

Test Characteristics: Subjects uses identify, compute, interpret and short memory task functions, and then select a true/false statement from the answers.

Based on the Tasks selects for the test, task functions are categorized by IQ, PSQ and MEM as shown in Table 11. In this Table, IQ` is represented as tasks involved using IQ and MEM capacity.

The Content validity plot is also improved from the initially proposed plot. It is determined that subjects have difficulty in evaluating the X-axis and Y-axis. The X-axis (3-low and 9 high scale) of the Content Validity Plot is how important the task is in daily life and Y-axis (0-100%) presents how much it is used (frequency) in daily life. Figure 8 shows the modified content validity chart.

Table 11. Task Functions and Modified Task Parameter

Task List	Task Functions	IQ`	PSQ	SA
Question # 1	Compare	X		
Question # 2	Compute	X		
Question # 3	Analyze		X	
Question # 4	Compare and Categorize	X	X	X
Question # 5	Compare and Categorize	X	X	X
Question # 6	Identify and Categorize	X	X	
Question # 7	Compute and Short-memory	X		X
Question # 8	Identify, Analyze and Compare	X	X	
Question # 9	Store and Short-memory	X		X
Question # 10	Category, Store and Short-memory	X	X	X
Question # 11	Compute	X		X
Question # 12	Category, Store and Short-memory	X	X	X
Question # 13	Compute	X		
Question # 14	Identify	X		
Question # 15	Store and Short-memory	X		X
Question # 16	Compare, Analyze and Plan	X	X	
Question # 17	Compare and Analyze	X	X	
Question # 18	Identify, Count and Short-memory	X	X	
Question # 19	Search and identify	X	X	
Question # 20	Search, Identify, Count and Short-memory	X	X	X

Table 11 (Continued)

Task List	Task Functions	IQ`	PSQ	SA
Question # 21	Identify, Interpret and Filter	X	X	
Question # 22	Compute	X		
Question # 23	Identify, Short-memory, Plan and Analyze	X	X	
Question # 24	Identify	X		
Question # 25	Compute and Analyze	X	X	
Question # 26	Analyze and Plan	X	X	
Question # 27	Compare and Analyze	X	X	
Question # 28	Identify, Short-memory, Plan and Compute	X	X	
Question # 29	Category, Store and Short-memory	X	X	X
Question # 30	Identify, Compute, Interpret and Short-memory	X	X	

The designed protocol of the test is approved by the Institutional Review Board (IRB) of North Dakota State University. The protocol approval notice, protocol form, adult consent form, expedited review form and other necessary supporting documents are presented in Appendix B.

5.2. Technology Analysis

Visual Studio (http://msdn.microsoft.com) is a complete set of development tools for building ASP.NET Web applications, XML Web Services, desktop applications, and mobile applications. Visual Basic, Visual C#, and Visual C++ all use the same integrated development environment (IDE), which enables tool sharing and eases the creation of

mixed-language solutions. In addition, these languages use the functionality of the .NET Framework. ASP.NET builds on the programming classes in the .NET Framework, and provides a Web application model along with a set of controls and infrastructure that make it easy to build Web applications. Visual C# is designed for building a variety of applications that run on the .NET Framework. Visual C# is simple, powerful, type-safe, and object-oriented. With its many innovations, Visual C# enables rapid application development and also retains the expressiveness and elegance of C-style languages. Visual C# is an implementation of the C# language by Microsoft. Visual Studio supports Visual C# with a full-featured code editor, compiler, project templates, designers, code wizards, a powerful and easy-to-use debugger, and other tools. The .NET Framework class library provides access to many operating system services and other useful, well-designed classes that speed up the development cycle significantly.

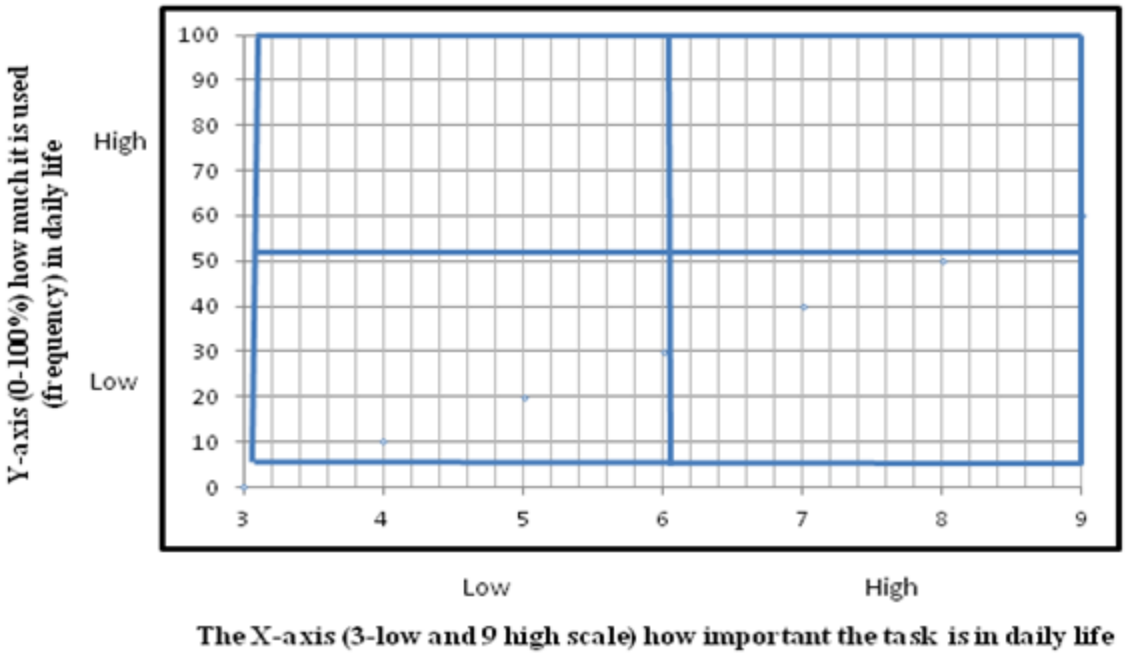


Figure 8. Content Validity Plot

5.3. Test Construction

The test questionnaire is developed in two formats, one is time independent and the other is time dependent. Figure 9 shows the designed template for generating the test questionnaire. The question is written in the Question text box. Second box is utilized for presenting the answer to the participant. Third box is used to record the correct answer for the question. There are three buttons to choose from in order to make a selection such as Show Image, Show Text and Show Timer. If the question is only in text, then <Show Text> button is selected and if the question contains image, <Show Image> button is selected. If the question is SA related then <Show Timer> button is selected. In the next step, the questions are placed in a preferred order with an option to active the desired questions for a test. The type of question is selected by checking the appropriate boxes such as PER, IQ, PSQ, MEM, CRE and SA.

A snapshot of the test questionnaire with all the questions set in desired order is shown in Figure 10. Figure 11 shows the design template of the stress questions and determination of the order of the questions. This set of stress questions is used before the participant starts the thirty question test.

The six stress level measurement questionnaire is developed using the stress template as shown in Figure 12. Each stress level is assigned a numerical value to calculate the stress score. The stress level is measured in six levels: No stress at all (0), Very low stress (1), Stress is not a concern (0), Moderate stress (2), Very stress (3) and stress is not applicable (0). Since the test is designed to find the effect of low level stress, it is observed that subjects sometimes ignore this low level of stress and describes it as not being a concern to them or as not applicable to their performance. The maximum stress score can

be 18 from response to the six questions and cut-off score is considered as 10 and under, or a score of 10 which is considered as not a significant stress level for the test.

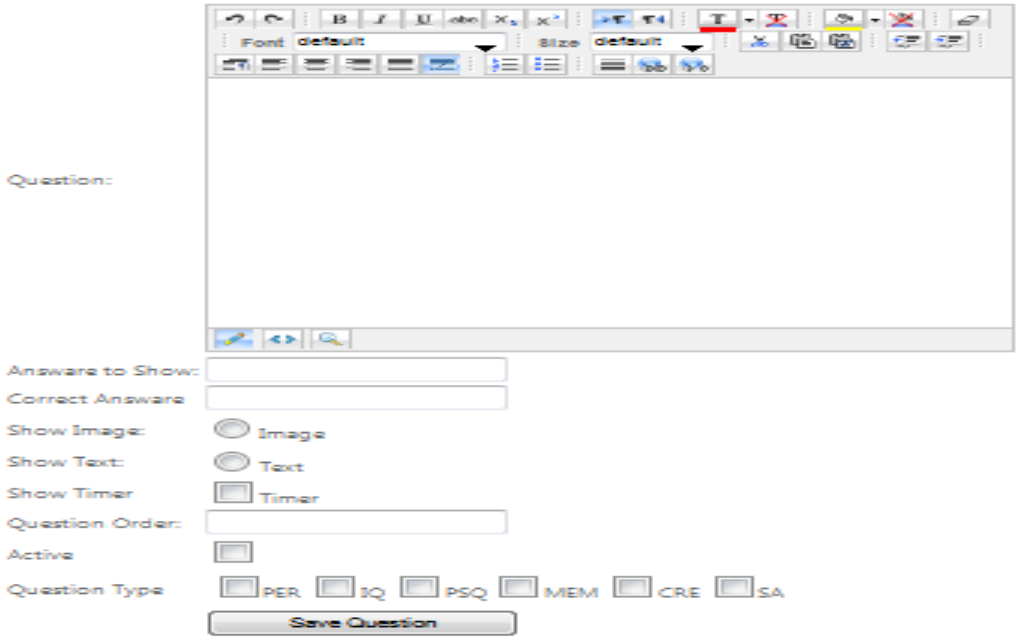


Figure 9. Template of the Test Question Formulation

	Question	Answer	Correct Answer	Active	Has Timer	Timer Max Value	Display Order	Question Added	Edit Question
Delete	Add (+): 76543 and 11111 	C	C	☑	☐		2	1/11/2011 12:00:00 AM	Edit
Delete	Which pair of name is the same? 	B	A	☑	☐		1	1/17/2011 12:00:00 AM	Edit
Delete	Which of the picture displays the flat piece of Cylinder, Drum, Cubical or Rectangular? 	B	B	☑	☐		3	1/25/2011 12:00:00 AM	Edit
Delete	Which two words have the same meaning? 	b AND c	b AND c	☑	☑	10	4	1/29/2011 7:40:53 PM	Edit
Delete	Which two words have the opposite meaning? 	a AND c	a AND d	☑	☑	5	5	1/29/2011 8:41:40 PM	Edit
Delete	Which tools are not identical in color and shape to the displayed tool? 	A, B, D	A, B, C	☑	☐		6	1/29/2011 8:43:23 PM	Edit

Figure 10. A Snapshot of Questionnaire in Desired Order

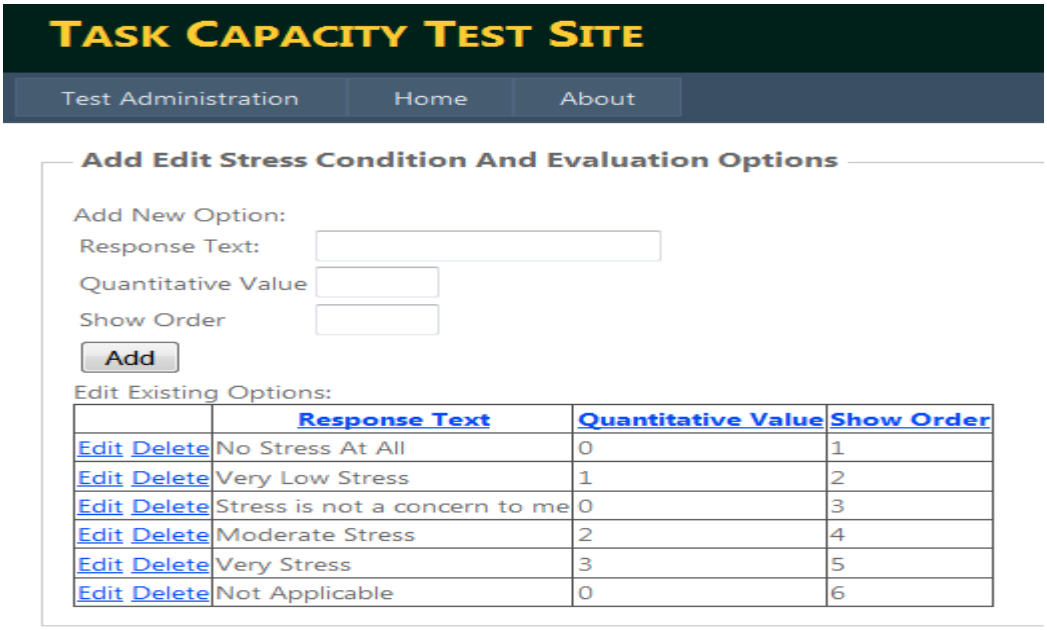


Figure 11. Stress Evaluation Questionnaire With Add/Edit/Delete Options

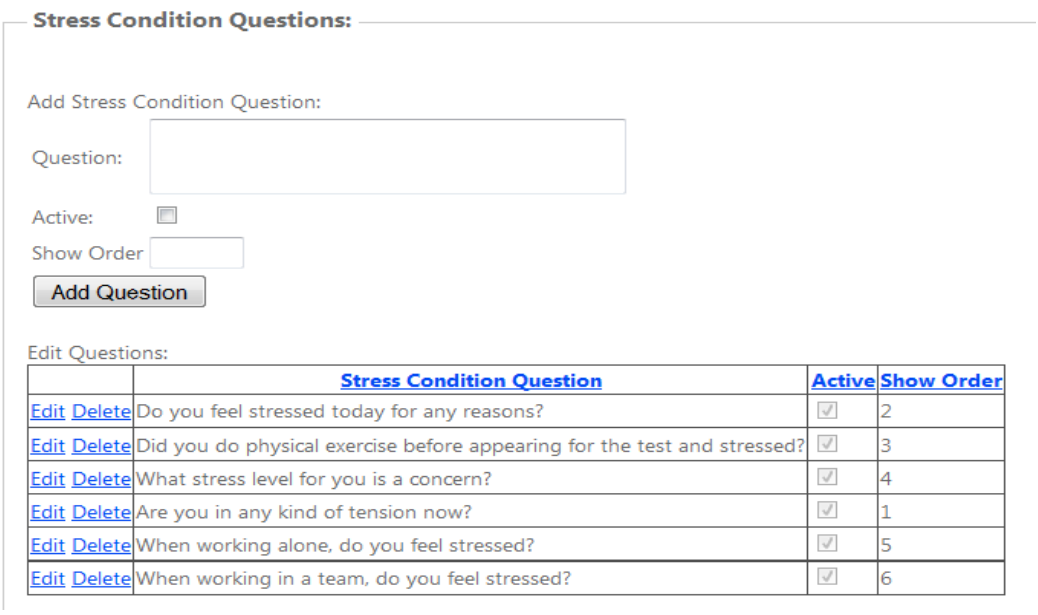


Figure 12. Stress Level Questions

The informed consent was obtained from participants after the participants verbally agree to participate and shows up for the test in the Human Factor Lab of IME, NDSU. The participant was shown the arrangement of the test site, and explained the procedure of the test at the time of participation and if participant wants to continue to do the computer test,

the consent form was signed. The participant enter the given user name and password as shown in Figure 13. User ID and Password Information

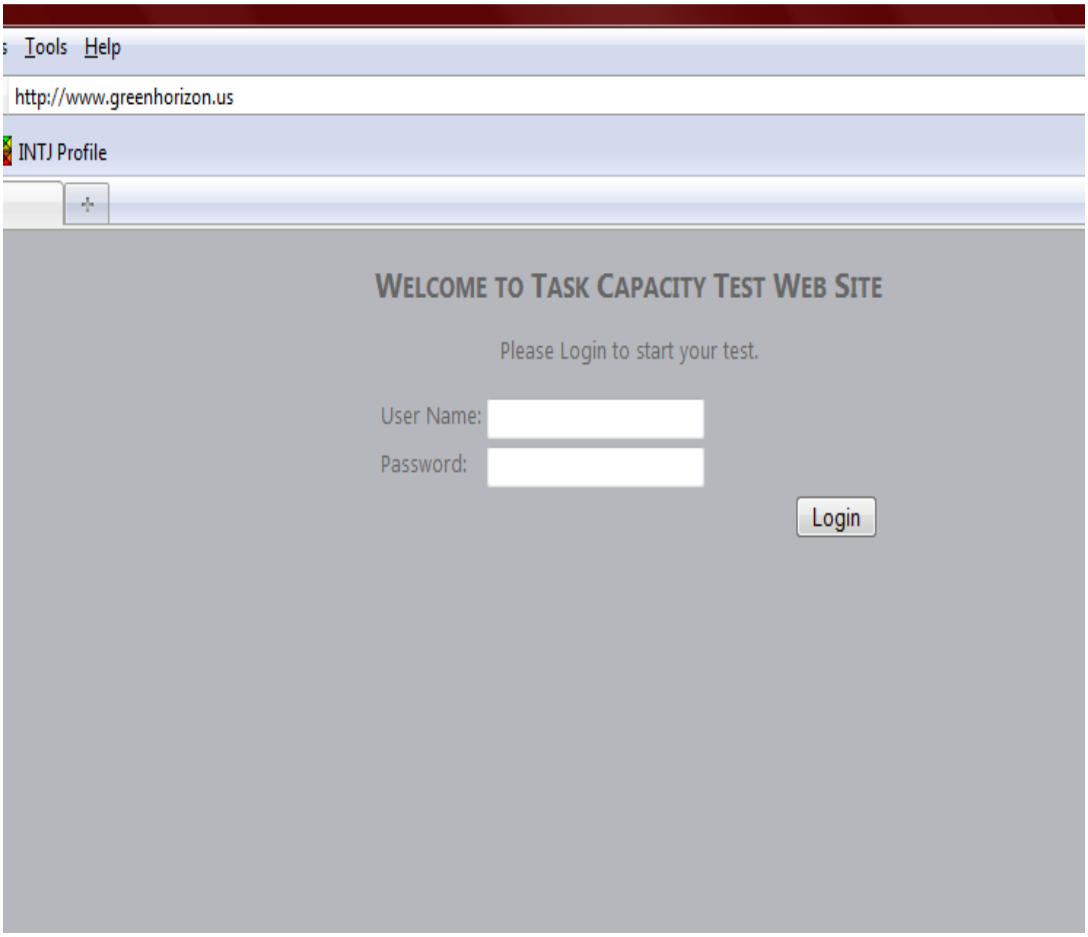


Figure 13. User ID and Password Information

Personal information was proposed to be recorded as shown in Figure 14. Personal Information Data Based on the feedback from IRB committee, personal information data collection tool is modified as shown in Figure 15.

Name and date-of-birth information is collected in paper (Appendix C.1) and stored separately with user name and password. After the personal information section is complete the participant will press *Save and Next* button to read the Instructions as shown in Figure 16 on how to answer the test.

Figure 14. Personal Information Data Sheet

The instruction section of the test takes about five minutes to read and after reading is completed a check box is marked by user indicating the procedure is read and understood (Appendix C.2). The subject then click and start Phase I as shown as step 3. This takes the subject to the Stress level Questionnaire.

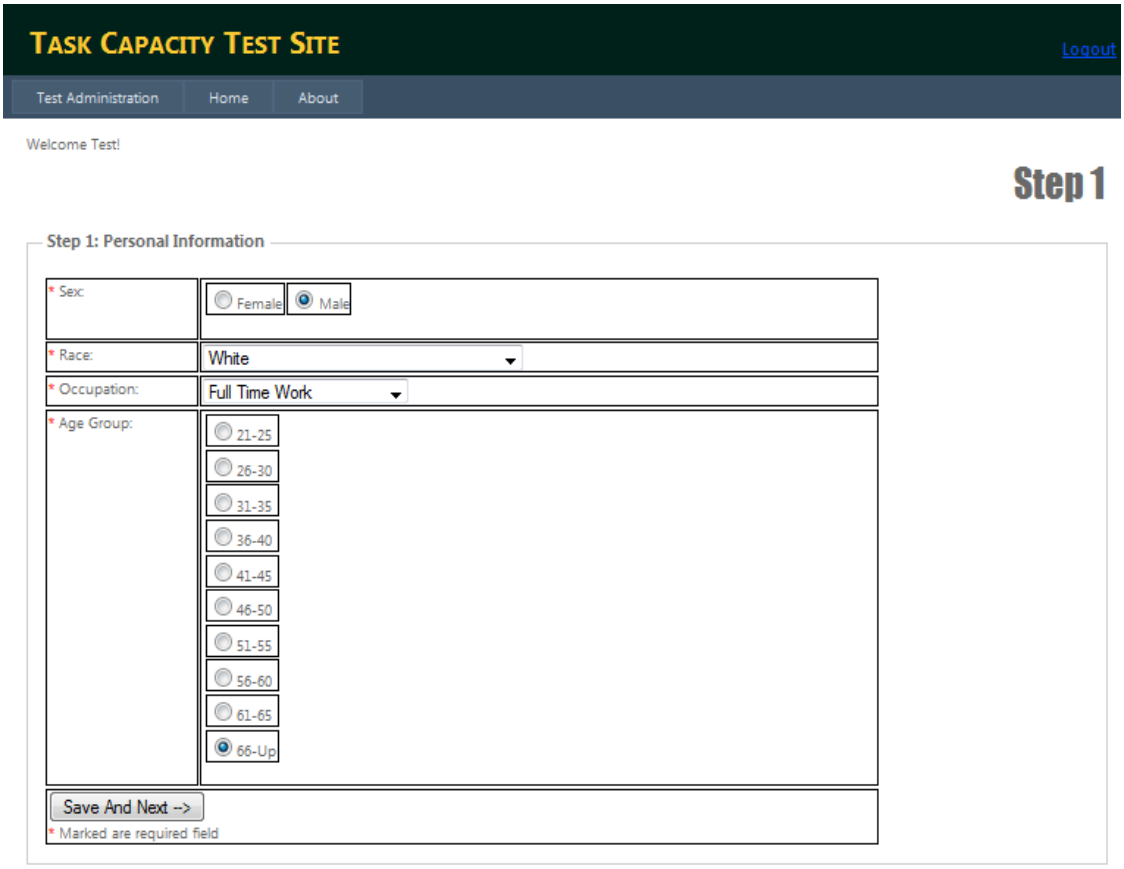


Figure 15. Modified Personal Information Data Sheet

Participant's stress level is measured using self-rating response as shown in Figure 17 and details of the questions are presented in Appendix C.3. The stress levels are measured using six categories:

1. No stress at all (0)
2. Very low stress (1)
3. Stress is not a concern (0)
4. Moderate stress (2)
5. Very high stress (3) and
6. Stress is not applicable (0)

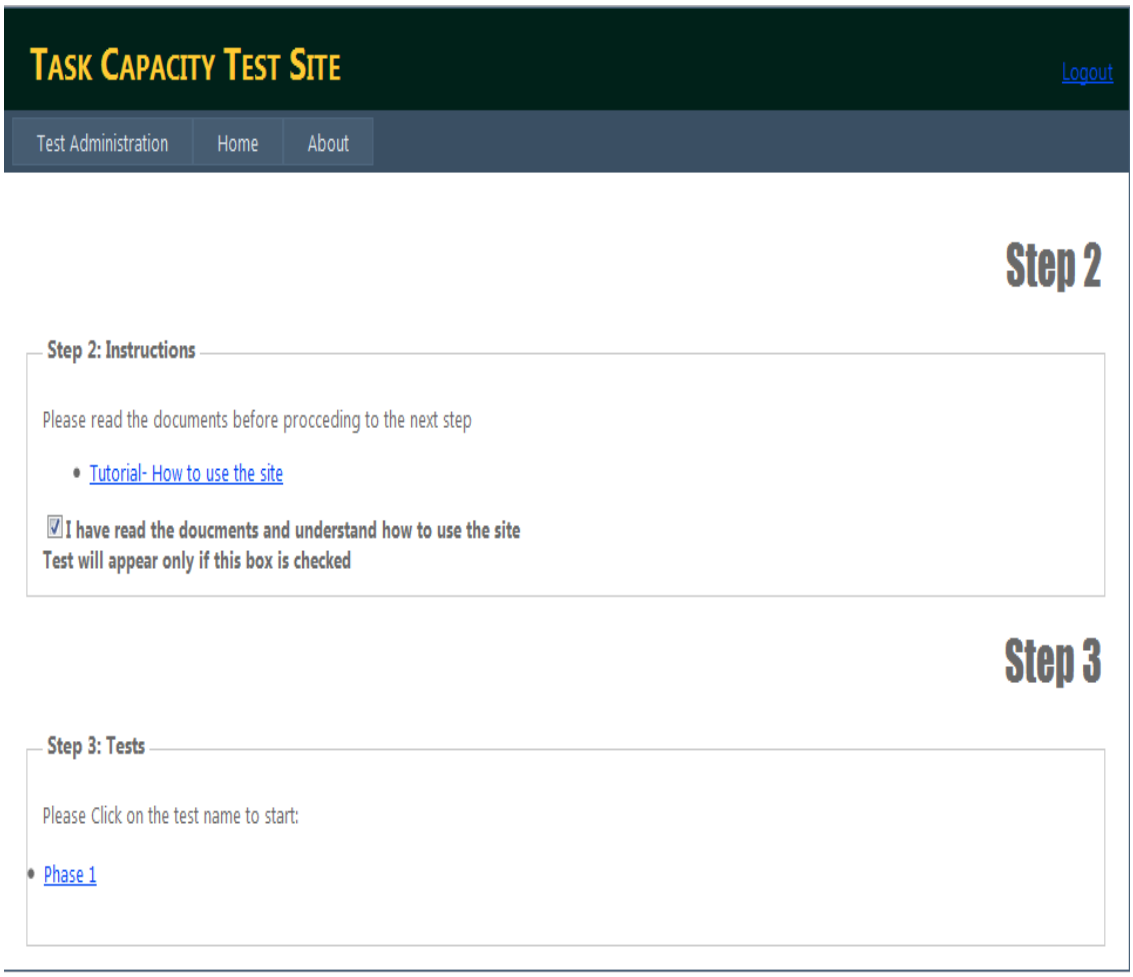


Figure 16. Test Completion Instruction

The maximum stress score can be calculated to be 18 from the six questions and a 10 is considered the cutoff score and anything under 10 is considered as not a significant stress level for the test.

Subjects have to select a response using a desktop-mouse and after a selection is made based on an appropriate response the subjects press *Save and Next* button to go to the thirty question test.

Following section provides some examples of the test questionnaire. The entire questionnaire is shown in Appendix C.4.

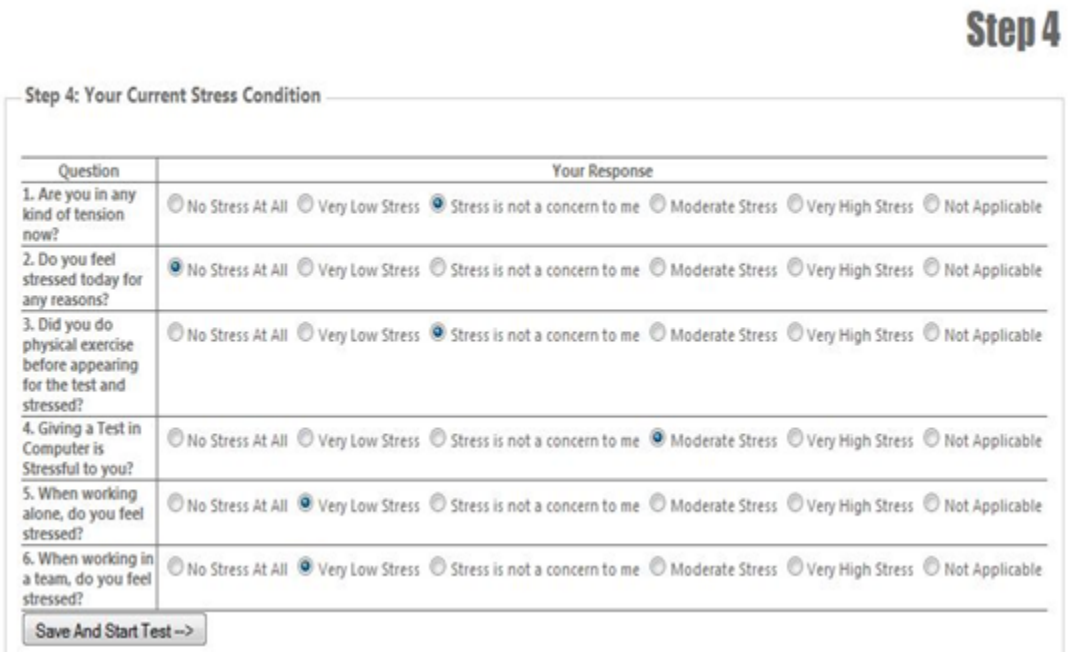


Figure 17. Stress Measurement Self-Rating

Figure 18 shows a sample question the participants are presented with. Subjects read the question, then check the answers and then respond. The participant uses a mouse to select if the displayed answer is *correct* by selecting *YES* or *NO* respectively. Right after selecting YES/NO, participants select a *CONFIDENCE LEVEL* that indicates how confident they are about their answer. Participant press *Submit and go to Next Question* once done with the answer and confidence level selection.

Another example of arithmetic problem is shown in Figure 19. The answer selection processes is the same as described earlier. Participants read the question, check the answers, and make a selection in the *Given Answer* section. The participants then confirm that the answer is *correct* by selecting *YES* or *NO* button respectively. A *CONFIDENCE LEVEL* is also chosen describing how confident the participants are about the selected answer. They press *Submit and go to Next Question* once done with this question.

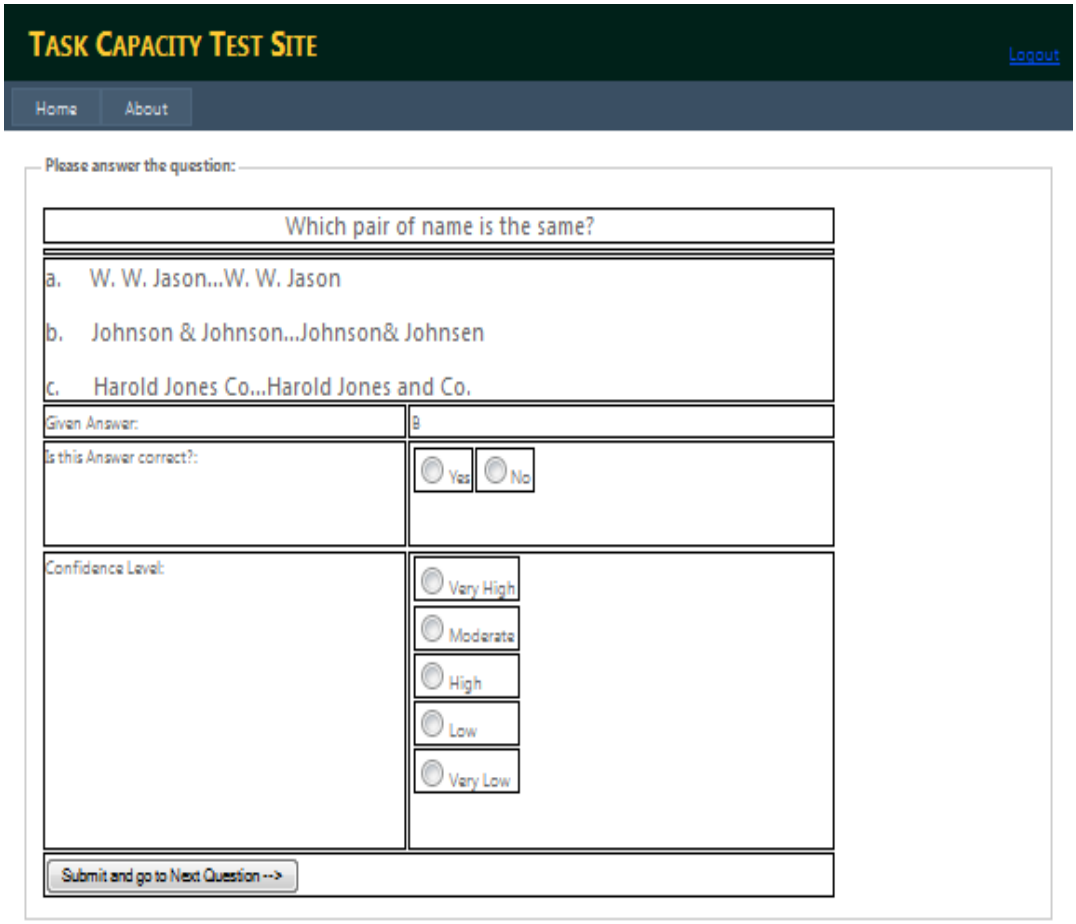


Figure 18. Sample 'Comparison' Test Question

Figure 20 shows a sample question on situational awareness. Participants read the paragraph while tracking the time button. After a predetermined time, the paragraph disappears and a question will appear. Participants read the question, then check the answers and compare them with the *Given Answer*. The participants use a mouse to select if the displayed answer is *correct* by selecting *YES* or *NO* respectively. After selecting YES/NO, participants choose a *CONFIDENCE LEVEL* that describes how confident they are about the answers they selected. Participant press *Submit and go to Next Question* once done.

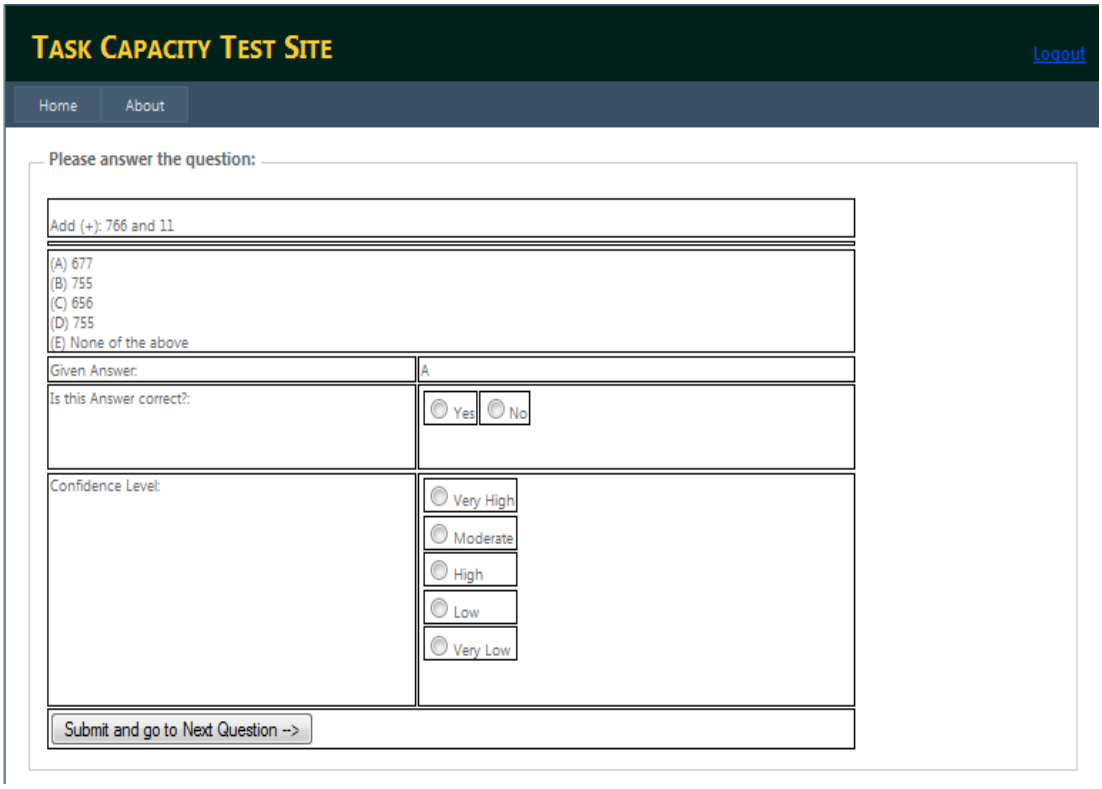


Figure 19. Sample 'Arithmetic' Test Question

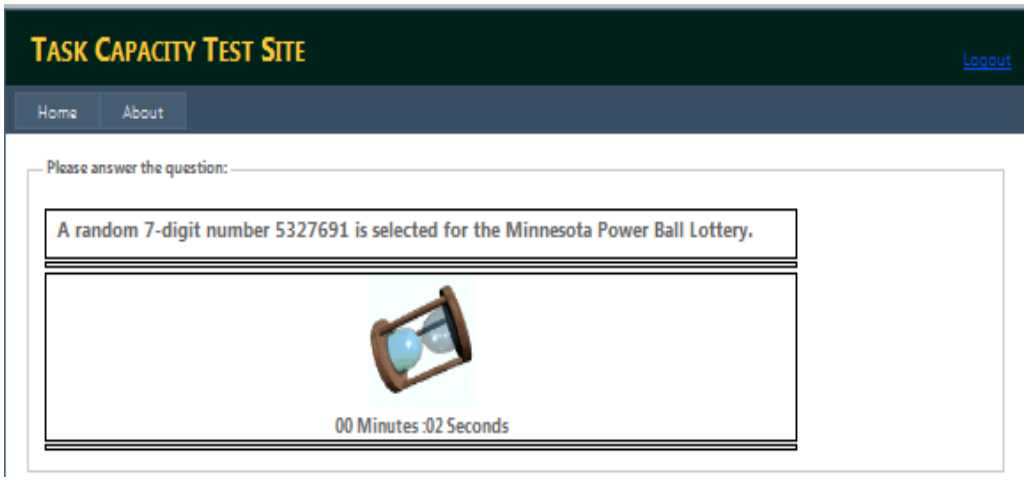


Figure 20. Situational Awareness Determination Test Question

After successful completion of the entire questionnaires, again the *STRESS level* measurement questions appear as shown in Figure 21. The details of the questions are

presented in Appendix C.5. The participants select the level that appropriately describes the stress level after the test.

Participants press *Save andFinish Test* once done with the answer and finish the test in Phase I. Subjects press *logout* button on the right top corner. All information and responses are recorded in the database after the completion of the test. The snapshot of the data base is shown in Figure 22.

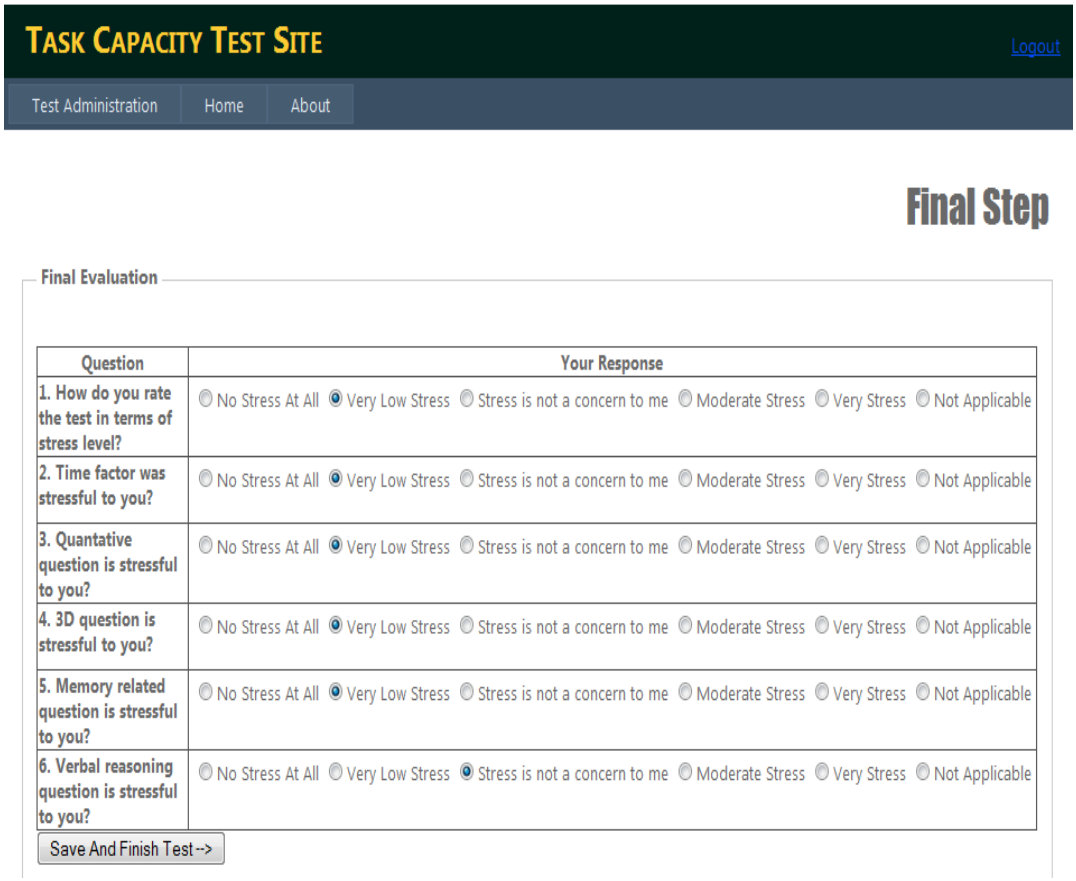
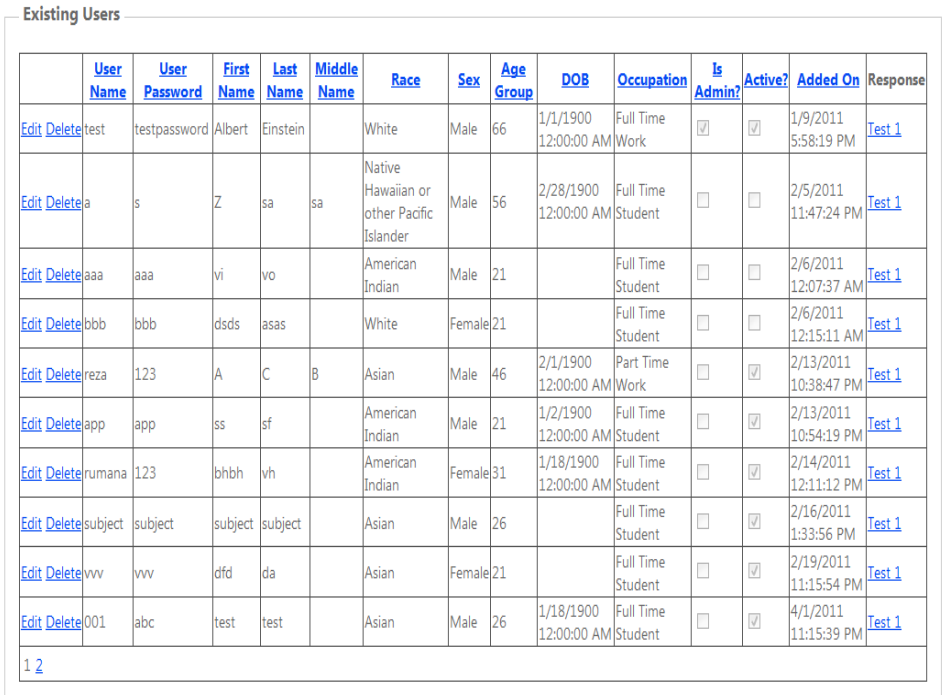


Figure 21. Post Test Stress Measurement Questionnaire

The individual test results can be exported as PDF or excel sheet into the local NDSU computer database for analysis. Figure 23 shows a snapshot of the export mechanism.



Existing Users

	User Name	User Password	First Name	Last Name	Middle Name	Race	Sex	Age Group	DOB	Occupation	Is Admin?	Active?	Added On	Response
Edit Delete	test	testpassword	Albert	Einstein		White	Male	66	1/1/1900 12:00:00 AM	Full Time Work	☑	☑	1/9/2011 5:58:19 PM	Test 1
Edit Delete	a	s	Z	sa	sa	Native Hawaiian or other Pacific Islander	Male	56	2/28/1900 12:00:00 AM	Full Time Student	☐	☐	2/5/2011 11:47:24 PM	Test 1
Edit Delete	aaa	aaa	vi	vo		American Indian	Male	21		Full Time Student	☐	☐	2/6/2011 12:07:37 AM	Test 1
Edit Delete	bbb	bbb	dsds	asas		White	Female	21		Full Time Student	☐	☐	2/6/2011 12:15:11 AM	Test 1
Edit Delete	reza	123	A	C	B	Asian	Male	46	2/1/1900 12:00:00 AM	Part Time Work	☐	☑	2/13/2011 10:38:47 PM	Test 1
Edit Delete	app	app	ss	sf		American Indian	Male	21	1/2/1900 12:00:00 AM	Full Time Student	☐	☑	2/13/2011 10:54:19 PM	Test 1
Edit Delete	rumana	123	bhbh	vh		American Indian	Female	31	1/18/1900 12:00:00 AM	Full Time Student	☐	☑	2/14/2011 12:11:12 PM	Test 1
Edit Delete	subject	subject	subject	subject		Asian	Male	26		Full Time Student	☐	☑	2/16/2011 1:33:56 PM	Test 1
Edit Delete	vvv	vvv	dfd	da		Asian	Female	21		Full Time Student	☐	☑	2/19/2011 11:15:54 PM	Test 1
Edit Delete	001	abc	test	test		Asian	Male	26	1/18/1900 12:00:00 AM	Full Time Student	☐	☑	4/1/2011 11:15:39 PM	Test 1

1 2

Figure 22. Participants Test Result Records

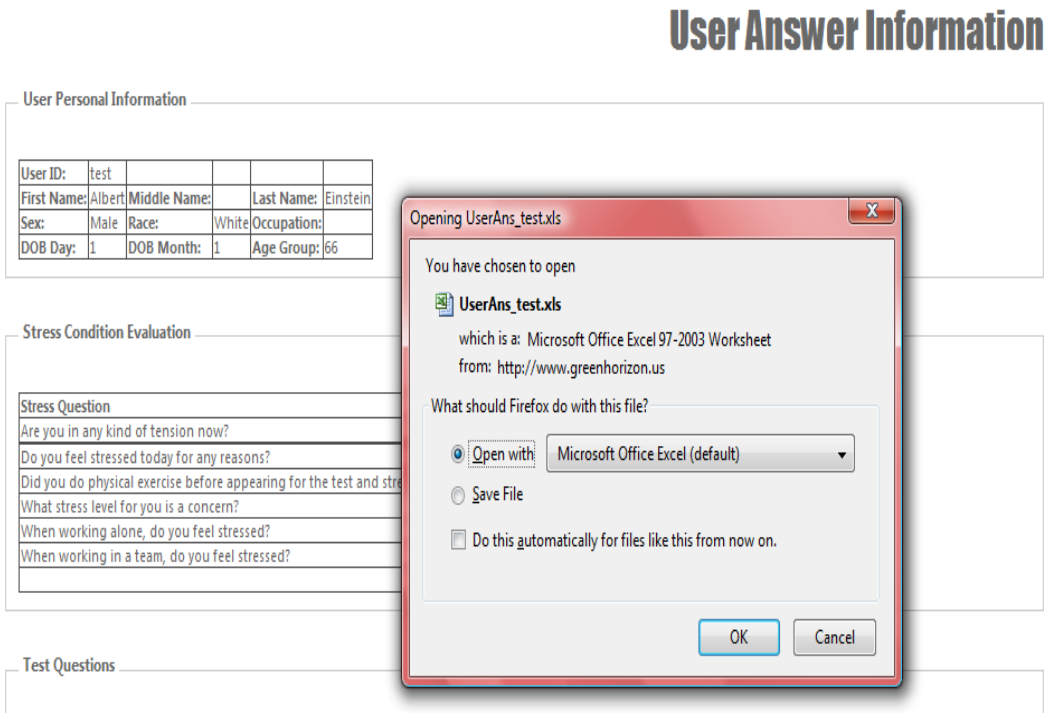


Figure 23. Individual Data Export Mechanism

6. TEST REPORT

The observation and subjects' comments on the test are tabulated in Appendix C6. From the report analysis and observation, during the test results, three subjects were identified as outlier. Since none of these three subjects completed the stress test at the desired level, or reported self rating on stress was above 10, which was considered the threshold value, were not considered for evaluation. Two other subjects did not appear for the second phase of the test.

Table 12 was required to be completed by the participants before beginning of the test. If the subject stated that he or she is ill or did not have enough sleep or their subjective rating was higher than the rating of 4, then the subject was asked to comeback in a later date for the computer test. From the analysis of the collected subjective statements it was confirmed that all the subjects were within the allowed protocol for the test.

Table 12. Report on Subjective State

(For Comfort: 1 = very rested, 7 = extremely exhausted For Temperature: 1 = very cold, 7 = very hot)

Are you ill today? ☐ Yes ☐ No
Did you have enough Sleep today? ☐ Yes ☐ No

Subjective Rating	1 (Normal)	2	3	4	5	6	7 (high)
Comfort							
Fatigue							
Sweating							
Temperature							

NASA-TLX rating principle was utilized and modified to develop a overall performance chart to be rated by each subject as shown in Table 13. It was required to be completed after the computer test. The purpose of the subjective rating chart was to

estimate subject's evaluation of the test in terms of mental demand, temporal demand, performance, effort and frustration level. The analysis of the report provides an overview for the test structure and the scope of future improvement to the test.

Table 13. Overall Performance Chart

Title	Endpoints (1-10) scale	Descriptions
Mental Demand	Low / High	How much mental and perceptual activity was required?
Temporal Demand	Low / High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?
Performance	Poor / Good	How much do you think you were in accomplishing the goals of the task set by the experimenter?
Effort	Low / High	How hard did you have to work (mentally) to accomplish your level of performance?
Frustration Level	Low / High	How stresses versus relaxed did you feel during task?

Table 14 summarizes the subjective rating after the completion of the test. It shows that the mental demand and temporal demand was around 62%, self rated performance was 90%, effort given was 53%, and frustration level was 27%. The evaluation of the subjective rating indicates participants were comfortable with how the questions were designed with a very low frustration level and a medium level of effort.

Table 14. Summary of Subjective Rating on Test

Type	Rating (1-5) Frequency	Rating (1-5) %	Rating (6-10) Frequency	Rating (6-10) %
Mental Demand	12	37.5	20	62.5
Temporal Demand	12	37.5	20	62.5
Performance	3	9.5	29	90.5
Effort	15	47	17	53
Frustration Level	20	62.5	12	27.5

A short survey form as shown in Table 15 was used to find how the subject felt about the test design. The form was completed by the subject after the test.

Table 15. A Short Survey on Computer Test

Computer Model	**Rate Satisfaction Level In Scale of 1to5***	**Comments**
Accessibility		
Navigation		
Readability		
Content Organization		
Time allocated for time dependent questions		
Total Time spent on participating in the test		
Stress measurement questions		

Table 16 summarized the participants rating of the test in terms of percentage. Evaluation of the results shows that majority of participant were comfortable with the test setup.

Table 16. Evaluation of Computer Test

Type	Rating (1-3) Frequency	%	Rating (4-5) Frequency	%
Accessibility	1	3	31	97
Navigation	0	0	32	68
Readability	3	9	29	91
Content Organization	2	6	30	94
Time allocated for time dependent questions	8	25	24	75
Total Time spent on participating in the test	8	25	24	75
Stress measurement questions	5	16	28	84

A total of 27 subjects completed the Phase I and Phase II test. 12 subjects completed the Phase I and 15 subjects completed the Phase II of the test. An online test was also conducted. 15 participants completed the Phase I test. Summary of the tests are shown in Table 17.

Table 17. Summary of Laboratory and Online Test

Test Type	Number of Subjects	Mean Accuracy	Standard Deviation
Online Test Average	15	78.44	6.02
Laboratory Test Without Stress (Phase I)	12	78.30	6.61
Laboratory Test Without Stress (Phase II)	15	71.10	6.79
Mena differences of phase I and phase II and average standard deviation	42	7.26	6.47

It is observed that the accuracy averages for the online test and the laboratory test without stress are very close. In addition, the standard deviations of the two tests are also very close. For the purpose of statistical analysis these two tests are combined and average of the two tests is considered as the test without stress.

As a part of the Delphi approach, questions were selected from literature sources that have been used in different test batteries. This reduced time required to design the initial set of questions. First, the subjects evaluated if the tasks cover the seven types of test instrument selected which included: Computation, SA, Three-dimensional review, Vocabulary, Pattern recognition, Comparison and Arithmetic reasoning.

The subjects were then asked to validate the questions in terms of significance of the task related to the job performance and usefulness. The results were plotted and if the majority of the points were not 6 or better (in the X-axis) then the questions were redesigned. Since the test is designed for students and professionals from different organizations, it is not expected that the usefulness in job performance (in the Y-axis) will have majority consensus. But this will be useful for any specific job environment.

The online test is conducted to validate the test construction. The participants were given the questionnaire after the test and were asked if the questions were evaluating the tasks selected and if they were relevant to evaluating the content validity with respect to general daily use. The study considers students and professionals as experts which includes subjects working as scientists, engineers, IT and university faculty members working in their respective fields geographically located in different continents and countries. A few graduates students also volunteered to participate in the content evaluation portion of the test. When there is a need to design a test for specific group of people then the expert level

could be modified accordingly. Summary of the analysis is shown in Table 18. Content Validity is summarized in Appendix C.7.

Table 18. Delphi Study on Questionnaire

Question #	Task Type	# of Subjects Agree	# of Subjects Disagree	Agree (%)
Question # 1	Compute	20	1	95
Question # 2	Compare	20	1	95
Question # 3	Analyze	20	1	95
Question # 4	Compare and Categorize	19	2	90
Question # 5	Compare and Categorize	20	1	95
Question # 6	Identify and Categorize	20	1	95
Question # 7	Compute and Short-memory	19	2	90
Question # 8	Identify, Analyze and Compare	20	1	95
Question # 9	Store and Short-memory	20	1	95
Question # 10	Category, Store and Short-memory	17	4	80
Question # 11	Compute	20	1	95
Question # 12	Category, Store and Short-memory	17	4	80
Question # 13	Compute	21	0	100
Question # 14	Identify	18	3	85
Question # 15	Store and Short-memory	19	2	90
Question # 16	Compare, Analyze and Plan	19	2	90
Question # 17	Compare and Analyze	19	2	90
Question # 18	Identify, Count and Short-memory	18	3	85
Question # 19	Search and identify	19	2	90

Table 18 (Continued)

Question #	Task Type	# of Subjects Agree	# of Subjects Disagree	Agree (%)
Question # 20	Search, Identify, Count and Short-memory	18	3	85
Question # 21	Identify, Interpret and Filter	18	3	85
Question # 22	Compute	19	2	90
Question # 23	Identify, Short-memory, Plan and Analyze	18	3	85
Question # 24	Identify	19	2	90
Question # 25	Compute and Analyze	18	3	85
Question # 26	Analyze and Plan	16	5	76
Question # 27	Compare and Analyze	18	3	85
Question # 28	Identify, Short-memory, Plan and Compute	18	3	85
Question # 29	Identify	18	3	85
Question # 30	Identify, Compute, Interpret and Short-memory	19	2	90

From the analysis of the literature, it was found that there are no specific criteria for determining the sample size for Delphi study. Some studies experimented with 15 subjects with 70% as consensus level. In this experiment 21 subjects responded as part of the Delphi study to validate the questionnaire. Table 18 shows that the number of subjects who agreed with the task description provided was well above 70%.

Content validity of the questions used for the test was analyzed by the online subjects. The subjects evaluated the nature (example: arithmetic, comparison, SA, etc.) of the questions. Table 19 shows that average values obtained from the content validity

evaluation of each subject. A summary of the individual content validity analysis is listed in the Appendix C.8.

Table 19. Average of Content Validity Evaluation

Question #	# of Subjects	How important the task is in daily life (1-9) Scale	How much the task is used in daily life (0-100)%
1	16	7.46	64.06
2	16	6.12	50.10
3	16	6.34	56.87
4	16	6.84	59.06
5	16	6.68	56.87
6	16	6.68	58.43
7	16	6.59	58.43
8	16	6.40	51.87
9	16	6.37	49.37
10	16	5.51	41.56
11	16	7.50	68.75
12	16	5.53	47.18
13	16	7.53	63.43
14	16	7.59	71.25
15	16	6.42	50.00
16	16	6.03	43.75
17	16	5.82	46.37
18	16	6.03	43.81
19	16	6.03	46.68
20	16	5.81	47.93
21	16	6.04	52.50
22	16	7.43	65.31
23	16	5.73	44.62
24	16	7.14	65.93
25	16	7.03	59.50
26	16	6.07	51.43
27	16	6.62	54.06
28	16	6.14	48.56
29	16	6.34	59.00
30	16	6.67	53.93

Figure 24 is a plot of content validity. A total sixteen people responded to this analysis. The initial expectation was to have a content validity rating of 6 and higher in defining 'How important the task is in daily life', but the plot indicates that some of the question ratings fall below 6. Since the subjects participating in the test are from a wide range of professions and some participated online, the variability is expected. The plot indicates that only ratings for a few questions fall between 5.6 and 6.

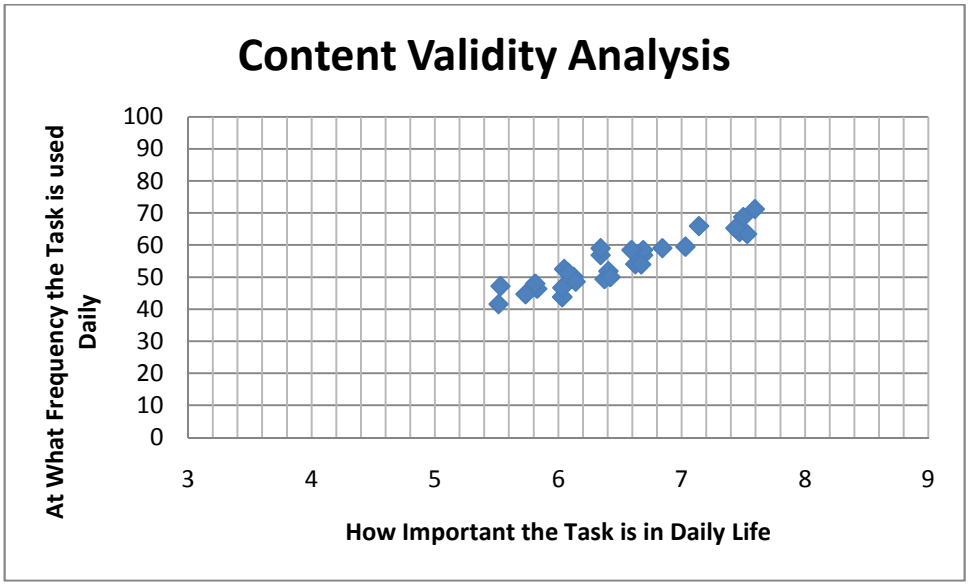


Figure 24. Content Validity Analysis

The test was conducted in a laboratory setting as well as on online environment. As mentioned earlier, the test subjects included undergraduate students, graduate students, professionals working in Fargo, North Dakota area and professionals working in different states in USA and other countries. The descriptions of the participants' gender participating via online or in a laboratory setting are classified in Table 20. The subjects who started the test but did not complete it are not included in this summary. Mean accuracy level of online and the laboratory test for Phase I are very close. A close relationship is expected between the results as both tests are taken in a quiet environment with the subjects alone. Three

subjects did not complete the Phase II of the experiment which included biking at a desired level of resistance and two subjects did not complete the test during a second attempt. To eliminate outliers these data set were removed from the database for statistical analysis. Different professional groups are summarized in Table 21. Age groups are summarized in Table 22.

Table 20. Summary of Participants

Type of Condition	Total Number of Subjects	Sex	
		Male	Female
Online Test	15	13	2
Computer Cluster Test	14	14	
Laboratory Test	32	28	4

Table 21. Professional Group Summary

Type of Condition	Total Number of Subjects	Occupation		
		Full-time Student	Part-time Student	Full-time Work
Online Test	15	1	1	13
Computer Cluster Test	14	14		
Laboratory Test	32	21		11

Table 22. Age Group Classification

Type of Condition	Total Number of Subjects	Age Group			
		21-25	26-30	31-35	36-40
Online Test	15		2	6	7
Computer Cluster Test	14	14			
Laboratory Test	32	6	14	7	5

Table 23. Evaluation of Each Question

Question #	Number of Subjects	Number of Accuracy	Percentage of Accuracy
Question # 1	61	56	92
Question # 2	61	61	100
Question # 3	61	22	36
Question # 4	61	55	90
Question # 5	61	57	93
Question # 6	61	45	74
Question # 7	61	51	84
Question # 8	61	53	87
Question # 9	60	35	58
Question # 10	60	42	70
Question # 11	60	52	87
Question # 12	60	50	83
Question # 13	60	43	72
Question # 14	60	53	88
Question # 15	59	54	92
Question # 16	57	31	54
Question # 17	56	36	64
Question # 18	55	34	62
Question # 19	54	49	91
Question # 20	53	33	62
Question # 21	51	16	31
Question # 22	50	38	76
Question # 23	49	41	84
Question # 24	49	36	73
Question # 25	49	45	92
Question # 26	49	23	47
Question # 27	49	30	61
Question # 28	49	25	51
Question # 29	49	38	78
Question # 30	49	41	84

A group of fourteen students from an engineering university participated in the computer test in a computer cluster after a regular class. The instructor requested the students to take the test and briefly explained the purpose of the test. A list of user

identification and corresponding passwords were provided to the instructor to be given to the subjects. The subjects willingly took the test. The answers obtained from the students were utilized for verifying the difficulty level of each questionnaire by combining the results for the subjects who completed the test. The analysis is shown in Table 23. The detail is provided in the appendix C.9. After combining the data sets for both trials, each question was evaluated as shown in Table 24.

Table 24. Evaluation of Each Question After Combining

	First Time Appearance Data Set		Second Time Appearance Data Set		Combined Data Set	
Question #	Number of Subjects	Number of Accuracy	Number of Subjects	Number of Accuracy	Total Number of Subjects	Number of Accuracy
Question # 1	61	56	27	25	88	81
Question # 2	61	61	27	27	88	88
Question # 3	61	22	27	15	88	37
Question # 4	61	55	27	24	88	79
Question # 5	61	57	27	27	88	84
Question # 6	61	45	27	21	88	66
Question # 7	61	51	27	21	88	72
Question # 8	61	53	27	26	88	79
Question # 9	60	35	27	24	87	59
Question # 10	60	42	27	19	87	61
Question # 11	60	52	27	23	87	75
Question # 12	60	50	27	23	87	73
Question # 13	60	43	27	23	87	66
Question # 14	60	53	27	23	87	76
Question # 15	59	54	27	26	86	80
Question # 16	57	31	27	12	84	43

Table 24 (Continued)

	First Time Appearance Data Set		Second Time Appearance Data Set		Combined Data Set	
Question #	Number of Subjects	Number of Accuracy	Number of Subjects	Number of Accuracy	Total Number of Subjects	Number of Accuracy
Question # 17	56	36	27	14	83	50
Question # 18	55	34	27	20	82	54
Question # 19	54	49	27	25	81	74
Question # 20	53	33	27	16	81	49
Question # 21	51	16	27	6	79	22
Question # 22	50	38	27	24	77	62
Question # 23	49	41	27	23	76	64
Question # 24	49	36	27	25	76	61
Question # 25	49	45	27	27	76	72
Question # 26	49	23	27	16	76	39
Question # 27	49	30	27	16	76	46
Question # 28	49	25	27	10	76	35
Question # 29	49	38	27	14	76	52
Question # 30	49	41	27	24	76	65

Table 25 summarizes individual accuracy levels, total times, mouse movement times and actual times for the response to the questionnaire for Phase I and Phase II. This table summarizes the results after each subject participated either in Phase I or Phase II of the experiment.

Table 25. Laboratory Test Results Summary

ID	Number of Correct Answer (%)	Total time (msec)	Movement time (msec)	Actual Time (sec)	Phase I (average)	Phase II (average)	Phase I (stdev)	Phase II (stdev)
ID	Number of Correct Answer (%)	Total time (msec)	Movement time (msec)	Actual Time (sec)				
3001	63.33	1182068	110651	1071.41				
3002	86.66	1138684	62095	1076.58				
3003	83.33	1209118	59104	1150.01	78.30		6.61	
3004	73.33	962838	40836	922.00				
3005	80	1067067	40389	1026.67				
3006	80	1006879	65640	941.23				
3007	73	762562	74295	688.26				
3008	76.66	854572	62359	792.21				
3017	83.33	893462	55945	837.51				
3019	76.66	1383306	109934	1273.37				
3021	76.66	1164001	70710	1093.29				
3022	86.66	898237	63174	835.06				
3009	70	1178804	44979	1133.82				
3010	70	824403	61343	763.06				
3011	60	755806	47161	708.64				
3012	66.66	977145	120299	856.84				
3013	63	799287	61878	737.40		71.10		6.79
3015	63.33	729816	39219	690.59				
3016	73.33	867753	51659	816.09				
3018	80	1061698	167101	894.59				
3020	73.33	998218	95422	902.79				
3023	83.33	946632	44997	901.63				
3024	73.33	1418092	110640	1307.45				
3025	63.33	675492	35608	639.88				
3026	77	1347512	74328	1273.18				
3027	73.33	1094345	96531	997.81				
3029	77	783929	62156	721.77				

Table 26 shows the results of Phase I and Phase II experiments in a laboratory setting in minutes.

Table 26. Time Spent on Test in Laboratory

ID	Total time (mins)	Movement time (mins)	Actual Time (Mins)
3001	19.703	1.84	17.85
3002	18.97	1.03	17.94
3003	20.15	0.98	19.16
3004	16.04	0.68	15.36
3005	17.78	0.67	17.11
3006	16.787	1.09	15.68
3007	18.14	1.23	16.90
3008	14.24	1.03	13.20
3017	14.89	0.93	13.95
3019	23.05	1.83	21.22
3021	19.40	1.17	18.22
3022	14.97	1.05	13.91
3009	19.64	0.74	18.89
3010	13.74	1.02	12.71
3011	12.59	0.78	11.81
3012	16.28	2.00	14.28
3013	13.66	1.30	12.35
3026	22.45	1.23	21.21
3015	12.16	0.65	13.60
3016	14.46	0.86	14.90
3018	17.69	2.78	15.04
3020	16.63	1.59	15.02
3023	15.77	0.74	15.02
3024	23.63	1.844	21.79
3025	11.25	0.59	10.66
3027	18.23	1.60	16.63
3029	13.06	1.03	12.02
Average	16.65	1.03	15.46

The average time of completion for Phase I type of tasks was 17.39 minutes and average time of completion for Phase II type of tasks was 16.06 minutes. Table 27 shows the results obtained from the online tests.

Table 27. Online Test Results

ID	Number of Correct Answer (%)	Total time (msec.)	Movement time (msec.)	Actual Time (sec)	Phase I (average)	Phase II (average)	Phase I (stdev.)	Phase II (stdev.)
201	70	1754116	156872	1597.24				
202	76.66	1852019	239344	1612.67				
208	86.66	799471	46187	753.28				
210	66.66	726310	101291	625.01	78.44		6.02	
211	90	997786	97264	900.52				
216	76.66	1818627	203136	1615.49				
218	76.66	1244091	53844	1190.24				
219	83.33	731536	80232	651.30				
221	80	1478746	105584	1373.16				
226	80	1158042	122128	1035.914				
217	83.33	968640	89299	879.341				
220	76.66	1558614	263703	1294.911				
203	76.66	2122525	78011	2044.514				
223	80	1490642	78148	1412.494				
227	73.33	1323954	45574	1278.38				

Tables 28 show the time taken for the online test in minutes. Summary of the results are shown in Table 29.

Comparing data presented in Table 26 and Table 28, it is observed that time taken to complete the tests is higher for the online test. The subjects take their time since they are in a more familiar environment taking the test at their own terms.

Total subjects who completed the tests combining online and laboratory setting are 42. A total of 15 subjects completed Phase II portion of the experiment and 27 subjects completed the Phase I portion and online test. The sample t-test is performed to find any statistical significance.

Table 28. Online Test Results in Minutes

ID	Total time (mins)	Movement time (mins)	Actual Time (Mins)
201	29.23	2.61	26.62
202	30.86	3.98	26.87
208	13.32	0.76	12.55
210	12.10	1.68	10.41
211	16.63	1.62	15.00
216	30.31	3.38	26.92
218	20.73	0.89	19.83
219	12.19	1.33	10.85
221	24.64	1.75	22.88
226	19.30	2.03	17.26
217	16.14	1.48	14.65
220	25.97	4.39	21.58
203	35.37	1.30	34.07
223	24.84	1.30	23.54
227	22.06	0.75	21.30
Average	22.25	1.95	20.29

Table 29. Summary Results

Test Type	Number of Subjects	Mean Accuracy	Standard Deviation
Online Test Average	15	78.44	6.02
Laboratory Test Without Stress (Phase I)	12	78.30	6.61
Laboratory Test With Stress (Phase II)	15	71.10	6.79

μ_1 =Phase I and laboratory results accuracy average

μ_2 = Phase II laboratory results accuracy average

Hypothesis Test:

Ho: $\mu 1=\mu 2$

H1: $\mu 1>\mu 2$

Sample size (n), Mean accuracy (y) and standard deviation (s) of Phase I (average of Lab and online) are 27, 78.37 and 6.3 respectively.

Sample size (n), Mean accuracy (y) and standard deviation (s) of Phase II are 15, 71.1 and 6.79 respectively.

$t_{calculated} = 3.48$ is calculated from the given data.

$t_{table} = 1.697$ is obtained from t-table

It is observed that $t_o > t_{table}$ indicating mean is different and it can be stated that low level physical stress has an effect on task performance. The ratio of Phase I (including online and lab) and Phase II is approximately 2:1. The difference in mean and standard deviation is 7.25 and 0.47 respectably.

Table 30 shows the results from the t-test SAS program for mean difference of 6 and 7 and standard deviation of 7 and 6. The SAS program considered at Power 0.8 and alpha 0.05. Since the mean difference and standard deviation calculated from lab and online experiments between 6 and 7, the average of N value from Table 30 is considered as total subjects required for the test which is approximately 40.

Table 30. SAS Results of t-Test

Computed N Total				
Index	Mean Diff	Std Dev	Actual Power	N Total
1	6	7	0.807	51
2	7	6	0.828	30

7. RESULTS AND DISCUSSION

Task Capacity Test analyzes the data by comparing the pre-test results with post-test results for each subject. The tool calculates the individual capacity in each category and translates that to 100 % task capacity scale index.

Accuracy (AC) - The accuracy is defined as the ratio of the correct task results divided by total number of tasks.

Response Time (RT) - The response time is calculated based on the time that each subject spends on each task from the time the task is displayed until the subject confirms his or her response and selects a confidence level.

The results based on overall accuracy level for either Phase I test or Phase II test is listed in Table 31. Each result is classified based on the type of stress of either With Stress or Without Stress, based on age type of either Age Group of (21-30) or Age Group of (31-40) and based on professional experience level of either having full-time Work Experience or having No previous Work Experience. Table 32 summarizes Factor classification for ANOVA test of the accuracy results.

Table 31. Factor Classification for ANOVA

Classification	Identification Used
Without Stress	1
With Stress	2
Age Group (21-30)	A
Age Group (31-40)	B
No Professional Work Experience	3
Professional Work Experience	4

Table 32. Overall Accuracy of Test

Serial #	Subject ID	Accuracy Results	Phase Type	Age Type	Professional Experience Type
1	3001	63	1	A	3
2	3002	87	1	A	4
3	3003	83	1	B	3
4	3004	73	1	A	3
5	3005	80	1	A	4
6	3006	80	1	A	4
7	3007	73	1	A	3
8	3008	77	1	B	3
9	3017	83	1	A	4
10	3019	77	1	B	4
11	3021	77	1	B	4
12	3022	87	1	A	4
13	3009	70	2	B	3
14	3010	70	2	A	3
15	3011	60	2	A	3
16	3012	67	2	A	3
17	3013	63	2	B	4
18	3015	63	2	B	3
19	3016	73	2	B	4
20	3018	80	2	A	3
21	3020	73	2	A	3
22	3023	83	2	B	4
23	3024	73	2	A	3
24	3025	63	2	B	3
25	3026	77	2	A	3
26	3027	73	2	B	4
27	3029	77	2	B	3

The ANOVA conducted based on a two level and fixed type of analysis is shown in Table 33.

Table 33. ANOVA Analysis: Phase Type, Age Type, Experience Type

Factor	Type	Levels	Values
Phase Type	Fixed	2	1, 2
Age Type	Fixed	2	A, B
Experience	Fixed	2	3, 4

Probability distribution shown in Figure 25 indicates the data set is normally distributed. Table 34 summarizes the ANOVA results. The P values of 0.007 for experience type indicate a significant effect on performance. P value analysis of Phase Type, Age Type and interactions between the three factors do not indicate significant impact on performance statistically. Though P value of Phase Type and Age Type interaction, and P value of Age Type and Experience Type interaction indicates that they have an effect on performance.

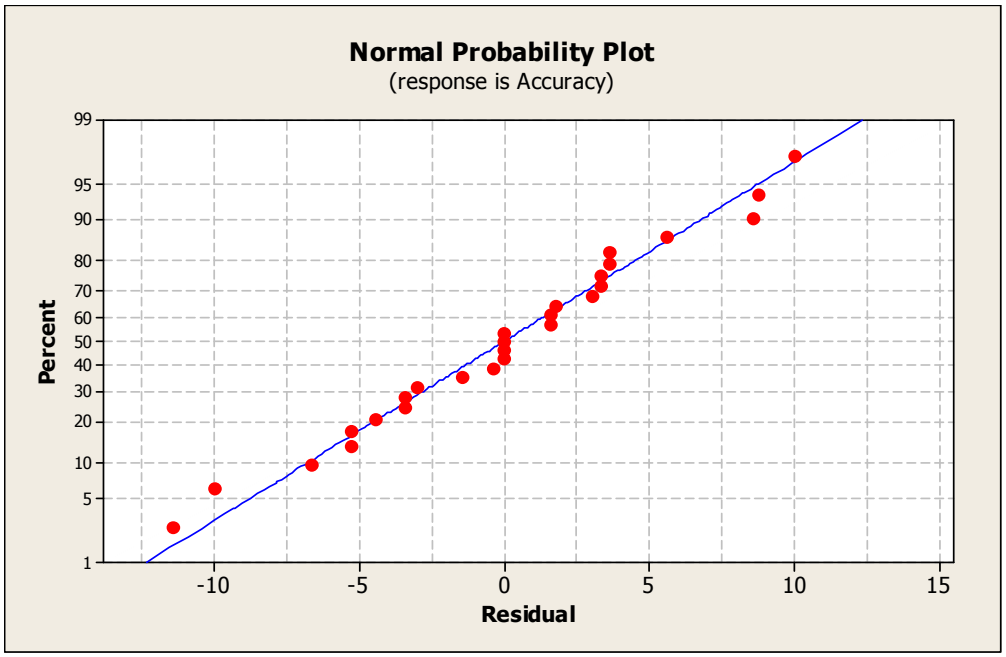


Figure 25. Normality Test for Accuracy Results

The main effect plot shown in Figure 26 indicates significant difference in Mean Experience Type as compare to Phase Type and Age Type. As professional experience increases performance level also increases when compared between subjects. Performance of Age group of 21-30 is higher than Age group of (31-40) significantly.

Table 34. Analysis of Variance for Accuracy

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Phase Type	1	358.52	4.09	4.09	0.11	0.742
Age Type	1	0.85	83.95	83.95	2.30	0.145
Experience Type	1	177.84	330.61	330.61	9.05	0.007
Phase Type*Age Type	1	37.23	148.89	148.89	4.08	0.057
Phase Type*Experience Type	1	11.80	40.04	40.04	1.10	0.308
Age Type*Experience Type	1	182.61	182.61	182.61	5	0.037
Error	20	730.33	36.52	36.52		
Total	26	1499.19				

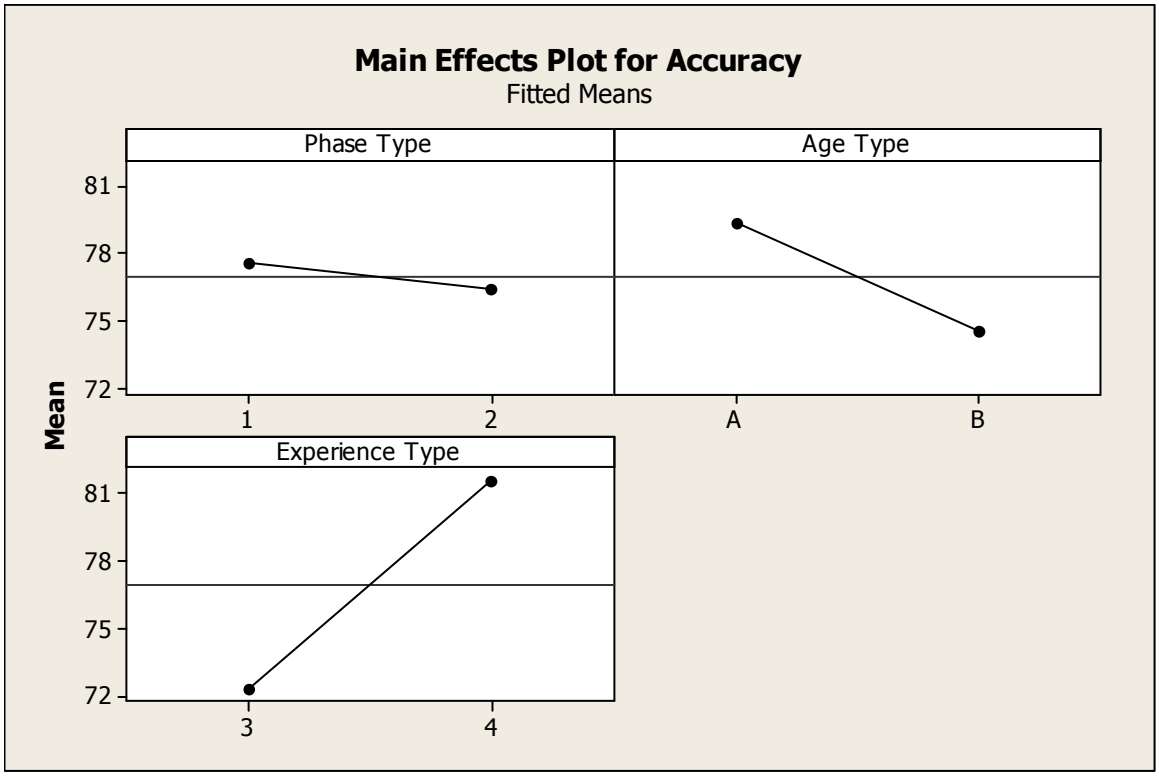


Figure 26. Main Effects Plot for Test Results

The interaction plot in Figure 27 indicates that performance level decreases due to stress when age group of 31-40 is considered and performance remains unchanged or

slightly improved when age group of 21-30 is considered. Performance curve is steeper when considering lower age group and no professional work experience compare to higher age group with professional experience. Experienced group performs better under stress compare to inexperienced group.

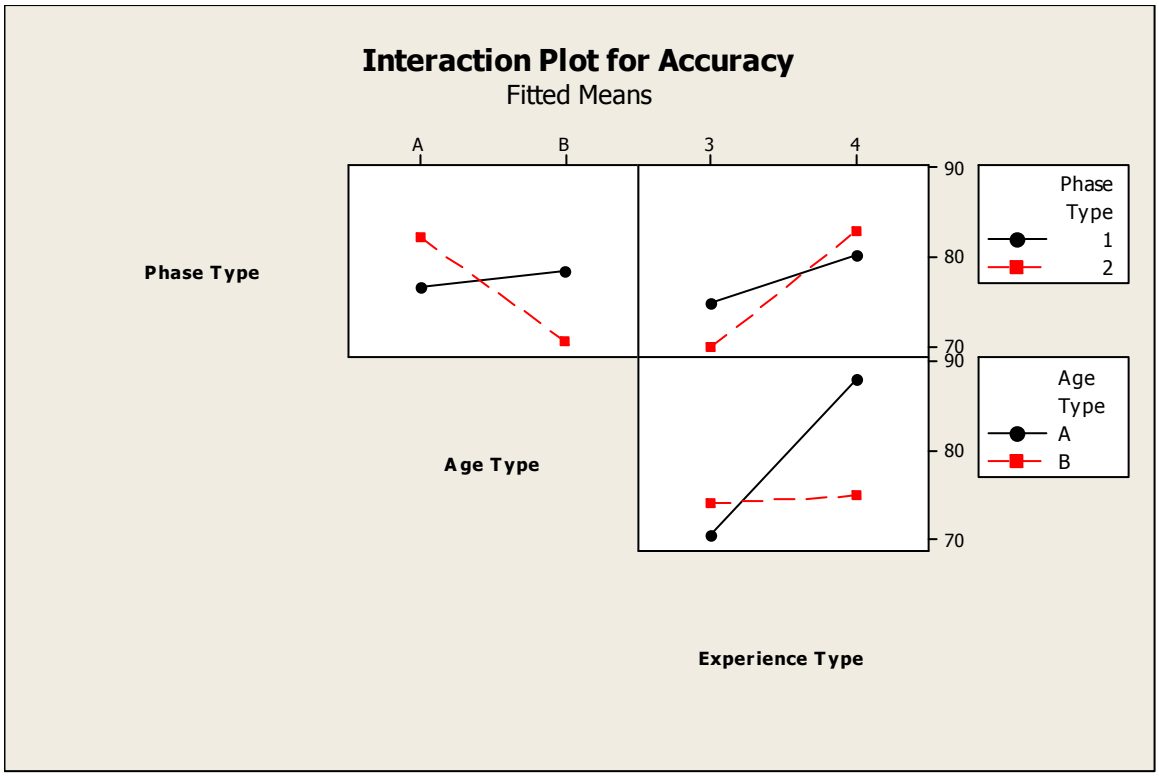


Figure 27. Interaction Plot for Accuracy Results

Table 35 summarizes IQ' performance measured in terms of accuracy and compared with phase type, age type, and experience type. Table 36 indicates that there is no statistically significant effect on the IQ' performance measured. Since the tasks performed in this category do not involve solving problems and there is no time pressure resulting in any significant change in the stress level of the subject. The task difficulty level is general life category and not very difficult, indicating that age and experience has little or no influence on performance. Figure 28 shows the main effect plots of Phase Type, Age Type

and Experience Type. There is an effect of stress on performance accuracy, though statistically it is not significant.

Table 35. IQ' Test Accuracy

Serial #	Subject ID	IQ' Accuracy	Phase Type	Age Type	Experience Type
1	3001	80	1	A	3
2	3002	90	1	A	4
3	3003	100	1	B	3
4	3004	90	1	A	3
5	3005	80	1	A	4
6	3006	90	1	A	4
7	3007	90	1	A	3
8	3008	90	1	B	3
9	3017	90	1	A	4
10	3019	90	1	B	4
11	3021	70	1	B	4
12	3022	100	1	A	4
13	3009	90	2	B	3
14	3010	80	2	A	3
15	3011	80	2	A	3
16	3012	80	2	A	3
17	3013	70	2	B	4
18	3015	90	2	B	3
19	3016	80	2	B	4
20	3018	90	2	A	3
21	3020	90	2	A	3
22	3023	80	2	B	4
23	3024	90	2	A	3
24	3025	70	2	B	3
25	3026	70	2	A	3
26	3027	80	2	B	4
27	3029	100	2	B	3

Figure 29 indicates that there are interaction between Age Type and Experience Type. Age group (21-30) with professional work experience performs better than age group (31-40) with professional work experience. Table 37 summarizes PSQ performance

measured in terms of Accuracy and compared with Phase Type, Age Type and Experience Type.

Table 36. ANOVA Table for IQ' Analysis

Source	DF	F	P
Phase Type	1	0.46	0.505
Age Type	1	0.37	0.548
Experience Type	1	0.61	0.444
Phase Type*Age Type	1	0.16	0.695
Phase Type*Experience Type	1	0.24	0.632
Age Type*Experience Type	1	3.11	0.093
Error	20		
Total	26		

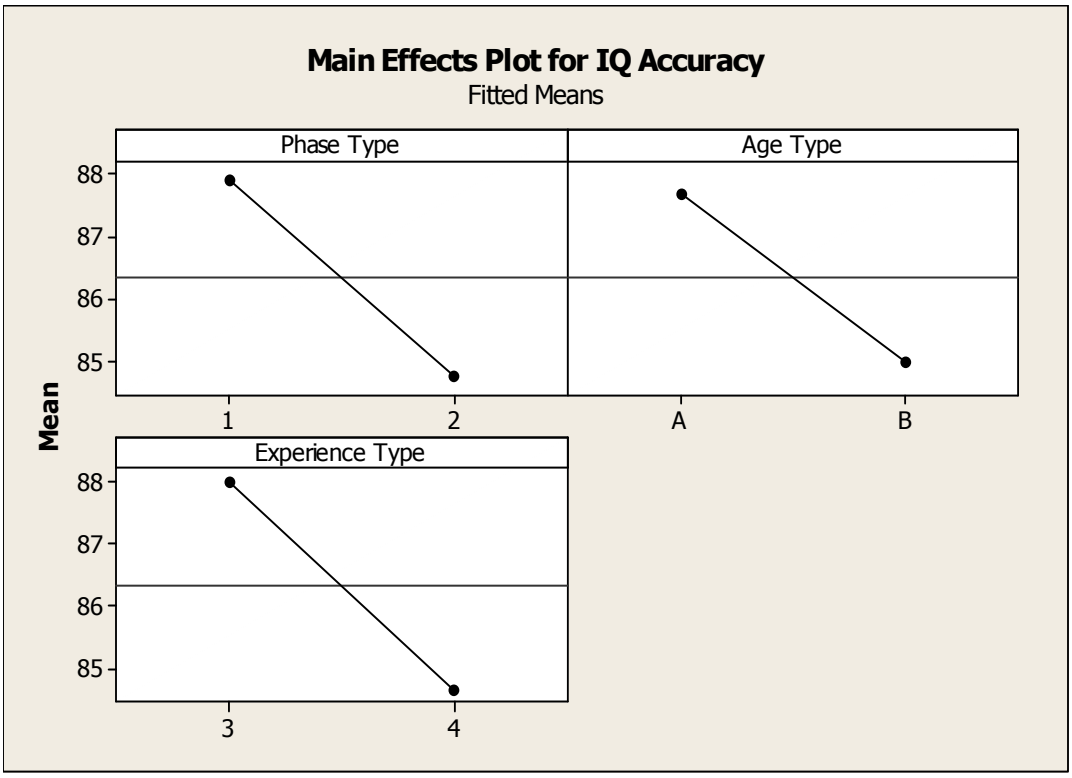


Figure 28. Main Effect for IQ' Test

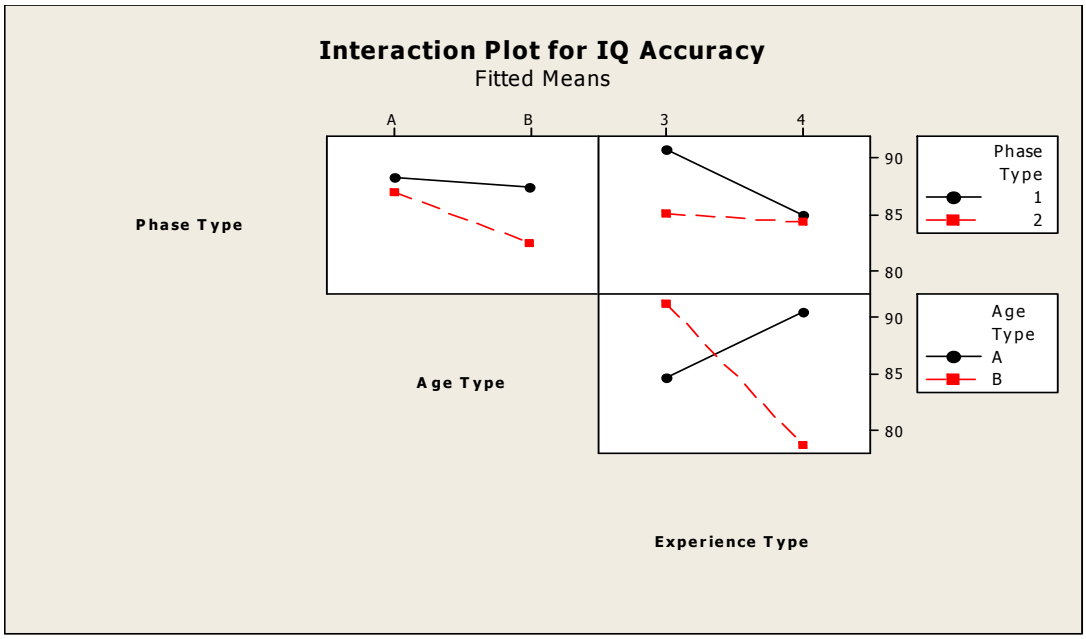


Figure 29. Interaction Plot for IQ' Accuracy

Table 37. PSQ Accuracy Test

Serial #	Subject ID	PSQ Accuracy	Phase Type	Age Type	Experience Type
1	3001	55	1	A	3
2	3002	85	1	A	4
3	3003	75	1	B	3
4	3004	65	1	A	3
5	3005	80	1	A	4
6	3006	75	1	A	4
7	3007	70	1	A	3
8	3008	70	1	B	3
9	3017	80	1	A	4
10	3019	70	1	B	4
11	3021	80	1	B	4
12	3022	80	1	A	4
13	3009	60	2	B	3
14	3010	65	2	A	3
15	3011	50	2	A	3
16	3012	60	2	A	3
17	3013	65	2	B	4
18	3015	50	2	B	3
19	3016	70	2	B	4
20	3018	75	2	A	3
21	3020	60	2	A	3
22	3023	70	2	B	4
23	3024	65	2	A	3
24	3025	60	2	B	3
25	3026	80	2	A	3
26	3027	70	2	B	4
27	3029	65	2	B	3

Table 38 indicates professional work experience has statistically significant effect in PSQ type of tasks. Similarly the interactions of Phase Type and Age Type, and interactions of Age Type and Experience Type have impact on PSQ performance.

Table 38. ANOVA Table for PSQ Analysis

Source	DF	F	P
Phase Type	1	0.05	0.825
Age Type	1	3.74	0.068
Experience Type	1	14.47	0.001
Phase Type*Age Type	1	4.02	0.059
Phase Type*Experience Type	1	1.59	0.222
Age Type*Experience Type	1	3.8	0.065
Error	20		
Total	26		

Figure 30 indicates professional work experience has higher PSQ accuracy compare to no professional work experience. Also age group (21-30) has higher level of performance than age group (31-40) when solving PSQ type of tasks. There is not a significant effect of stress on PSQ accuracy.

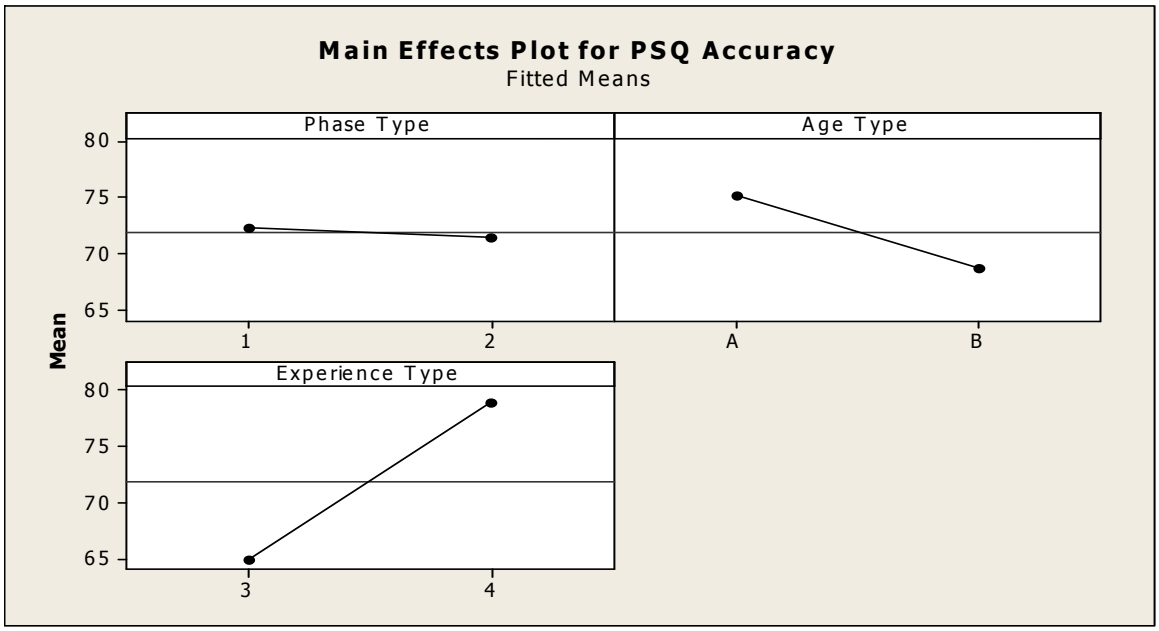


Figure 30. Main Effect Plot for PSQ Task Accuracy

Figure 31 indicates that PSQ performance decreases due to stress in the case of age group (31-40) and remains unchanged in the case of age group (21-30). Experience is a dominating factor when interaction is considered with stress level and age group. Table 39 summarizes SA performance measured in terms of accuracy and compared with Phase Type, Age Type and Experience Type.

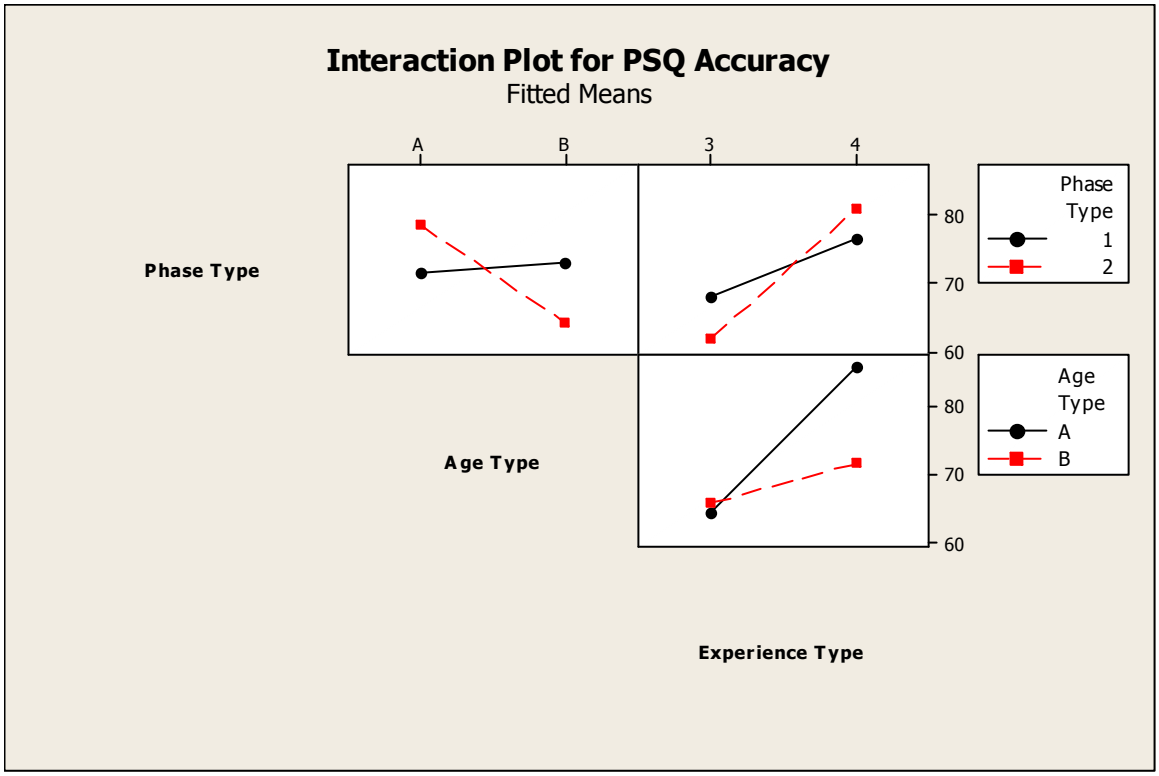


Figure 31. Interaction Plot for PSQ Task Accuracy

Table 40 indicates Experience Type impacts SA task performance. Stress, Age and interactions of these factors do not have any significant effect on SA task performance. Since the task under the category of SA involves time dependent questions, time pressure might be a dominating factor on participant's performance. Time pressure is beyond the scope of this research and may be considered in the future. Another potential reason for not detecting any significant change in result is that the stress levels applied might not be sufficiently high to observe any significant impact on SA task performance.

Table 39. SA Test Accuracy

Serial #	Subject ID	SA Accuracy	Phase Type	Age Type	Experience Type
1	3001	30	1	A	3
2	3002	100	1	A	4
3	3003	80	1	B	3
4	3004	90	1	A	3
5	3005	70	1	A	4
6	3006	90	1	A	4
7	3007	60	1	A	3
8	3008	70	1	B	3
9	3017	80	1	A	4
10	3019	80	1	B	4
11	3021	90	1	B	4
12	3022	90	1	A	4
13	3009	70	2	B	3
14	3010	80	2	A	3
15	3011	60	2	A	3
16	3012	70	2	A	3
17	3013	50	2	B	4
18	3015	50	2	B	3
19	3016	90	2	B	4
20	3018	100	2	A	3
21	3020	60	2	A	3
22	3023	90	2	B	4
23	3024	60	2	A	3
24	3025	70	2	B	3
25	3026	90	2	A	3
26	3027	100	2	B	4
27	3029	100	2	B	3

Figure 32 indicates experience level is a dominating factor as compared to the Stress Type and Age Type on SA task performance. Subject's SA performance increases when under stress as compare to when there is no stress. Age group (21-30) performs better compare to age group (31-40) as expected.

Table 40. ANOVA Table for SA Accuracy Analysis

Source	DF	F	P
Phase Type	1	0.34	0.569
Age Type	1	0.02	0.886
Experience Type	1	3.72	0.068
Phase Type*Age Type	1	0.68	0.419
Phase Type*Experience Type	1	0.00	1
Age Type*Experience Type	1	0.50	0.490
Error	20		
Total	26		

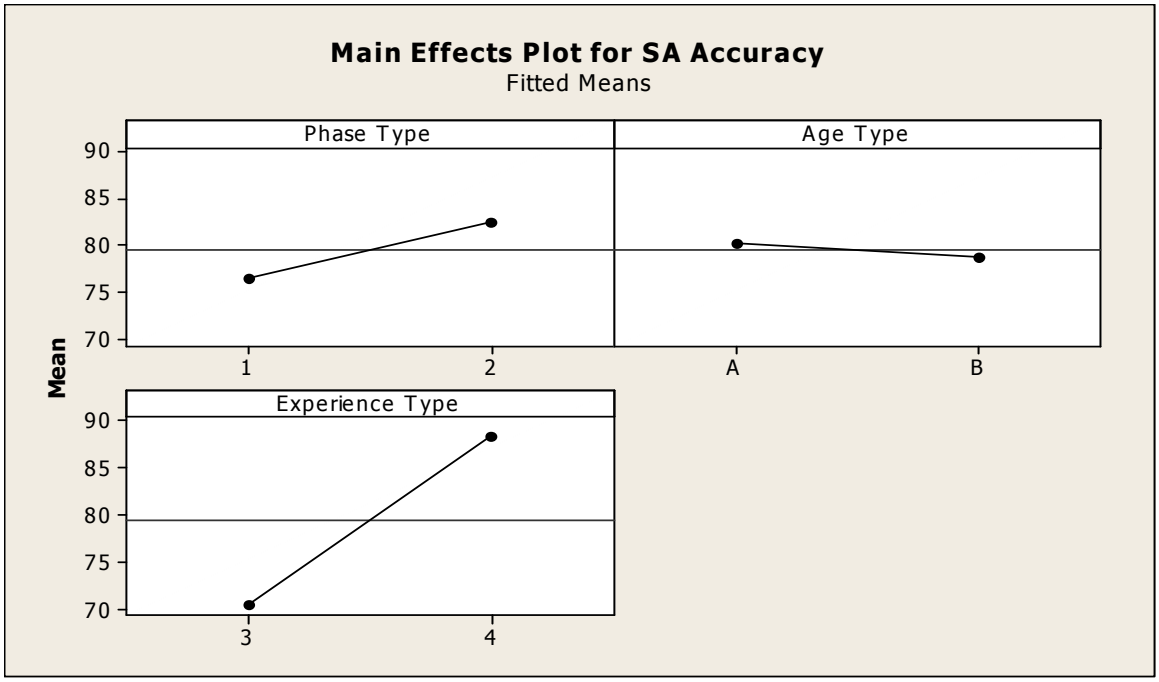


Figure 32. Main Effect Plot for SA Accuracy

Figure 33 indicates that there are interaction effects between age group and experience. Age group (21-30) has steeper accuracy line when the subjects have professional work experience as compare to with no work experience. There are no interactions observed when stress and experience factors are considered.

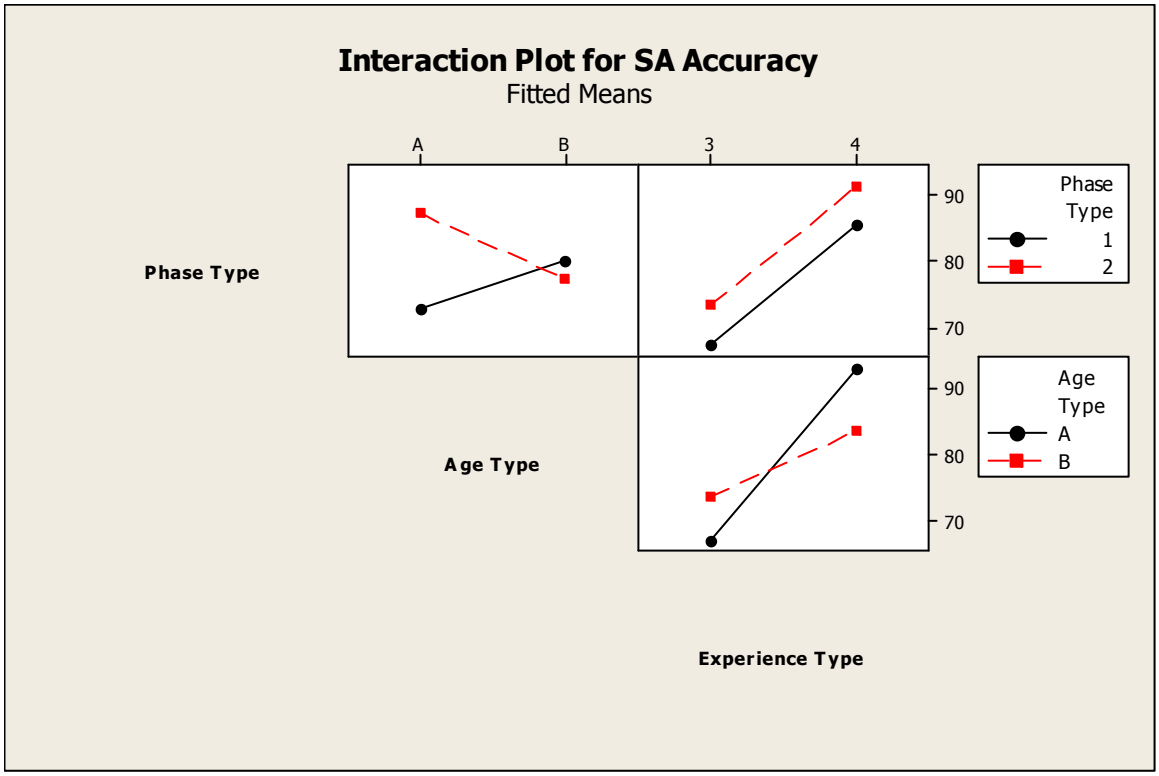


Figure 33. Interaction Plot for SA Accuracy

The ANOVA was performed on overall task accuracy, IQ', PSQ and SA. The analysis was done with subjects appearing for the first time to take the test, either for Phase I or for Phase II. It is observed that professional work experience is a dominating factor on task performance when all factors and interactions are considered simultaneously. The initial objective was set to study the effect of stress on task performance with the same subject appearing for the second time. The ANOVA was conducted considering three factors with twenty seven subjects completing either Phase I task or Phase II task. The distribution of number of subjects in different age group, experience group and Phase group was not uniformly proportionate for ANOVA analysis. There were fifteen subjects in age group A, twelve subjects in age group B, sixteen subjects in experienced group 3, eleven subjects in experienced group 4, twelve subjects in Phase group 1 and fifteen subjects in phase group 2. Since the number of subjects was not sufficient for ANOVA

given three factors simultaneously, further investigation was conducted to determine if stress has any effect on task performance when the same subject is considered as a control and takes the test a second time with or without stress.

In the next section the descriptive analysis of the test results is presented considering Phase I and Phase II type performance of the same subject. The analysis considered the effect of stress effect on Age Group, Experience Group, IQ' Type Task, PSQ Type Task, SA Type Task, completion time and performance confidence level. Table 41 summarizes accuracy level of subjects who completed both Phase I and Phase II.

Total subjects who completed both the Phase I and Phase II part of the test is 27. The paired t-test is performed to find any statistical significance.

μ_1 =Phase I and laboratory results accuracy average

μ_2 = Phase II laboratory results accuracy average

μ_d = Differences in mean

Hypothesis Test:

Ho: $\mu_d = \mu_1 - \mu_2 = 0$

H1: $\mu_1 \neq \mu_2$

Corr. = 0.59

Sample size (n), Mean (y) and Standard Deviation (s) for Phase I (average of Lab and online) are 27, 77 and 6.66 respectively, and for Phase II 27, 73 and 7.14 respectively.

$$t_0 = d_{bar} / (S_d/\sqrt{n}) \quad (10)$$

Where t_0 is the calculated value for t-test, d is the differences of score of Phase I and Phase II of the same subject, d_{bar} is the average of paired differences (d), S_d is the standard deviation of d and n is the number of subjects.

Table 41. Summary of Accuracy for Subjects Completed Both Phase I and Phase II

Serial #	Subject ID	Laboratory						
		First Phase I				First Phase II		Difference (Phase I - Phase II)
		Type	Phase I	Phase II	Type	First Phase II	Second Phase I	
1	3001	X	63	67				-3
2	3002	X	87	80				7
3	3003	X	83	73				10
4	3004	X	73	77				-3
5	3005	X	80	77				3
6	3006	X	80	83				-3
7	3007	X	73	60				13
8	3008	X	77	77				0
9	3017	X	83	83				0
10	3019	X	77	70				7
11	3021	X	77	73				3
12	3022	X	87	83				3
13	3009				Y	70	80	10
14	3010				Y	70	80	10
15	3011				Y	60	63	3
16	3012				Y	67	67	0
17	3013				Y	63	76	13
18	3015				Y	63	77	13
19	3016				Y	73	87	13
20	3018				Y	80	73	-7
21	3020				Y	73	70	-3
22	3023				Y	83	77	-6
23	3024				Y	73	80	7
24	3025				Y	63	70	7
25	3026				Y	77	87	10
26	3027				Y	73	73	0
27	3029				Y	77	77	0
Total			940	903		1067	1136	
Average			78	75		71	76	
Standard Deviation			6.6135	7.1714222		6.7937	6.7004699	

$$d_{bar} = (1/n)*\sum d_j \quad (11)$$

Where j = 1 to n

$$S_d = [(\sum d_j^2 - (1/n)*(\sum d_j)^2) /(n-1)]^{1/2} \quad (12)$$

From Equation (11) $d_{bar} = 4$ and from Equation (12) $S_d = 7.44$.

From Equation (10) $t_0 = 2.74$

$t_{table} = 2.05$

$t_0 > t_{calculated}$

The null hypothesis is rejected and there is evidence that the mean accuracy measured is different due to stress. It can be stated that low level physical stress has an effect on task performance. Table 5 confirms that sample size considered satisfies the statistical requirement.

The classification of subjects based on professional work experience is listed in Table 42. The subjects who worked within one year for at least two years are considered in the category of Full-time work classification. There are twenty subjects identified in the category of having no professional work experience and twelve subjects are identified in the category of having professional work experience. Two subjects were unable to complete the two phases of the test. Three subjects were unable to perform to the designed termination protocol due to leg pain and discomfort while biking. Data for twenty seven subjects who completed both Phase I and Phase II were considered for analysis.

Table 43 summarizes the % accuracy of subjects having no professional work experience and manages to complete both phase I and Phase II of the experiment. The results indicate that low level stress has an effect on performance. Table 44 summarizes % accuracy of subjects having professional work experience and completed both Phase I and Phase II of the experiment. Comparing Tables 44 and 45, one can see that subjects with work experience performs better in both Phase I and Phase II compare to subjects with no

work experience. Also it is observed that performance decreases for both classifications of subjects when stress factor is considered.

Figure 34 confirms that the trend is similar when comparing no work experience group with experienced group and stress is a significant factor.

Table 42. Classification of Subjects Based on Work Experience

ID #	No Professional Work Experience	Professional Work Experience
3001	X	
3002		Y
3003	X	
3004	X	
3005		Y
3006		Y
3007	X	
3008	X	
3009	X	
3010	X	
3011	X	
3012	X	
3013		Y
3014	X	
3015	X	
3016		Y
3017		Y
3018	X	
3019		Y
3020	X	
3021		Y
3022		Y
3023		Y
3024	X	
3025	X	
3026	X	
3027		Y
3028	X	
3029	X	
3030		Y
3031	X	
3032	X	

X-No Work Experience, Y-Professional Work Experience

Table 43. Summary of Accuracy % with No Work Experience

		Phase I	Phase II
1	3001	63	67
2	3003	83	73
3	3004	73	77
4	3007	73	60
5	3008	77	77
6	3009	80	70
7	3010	80	70
8	3011	63	60
9	3012	67	67
10	3015	77	63
11	3018	73	80
12	3020	70	73
13	3024	80	73
14	3025	70	63
15	3026	87	77
16	3029	77	77
	Average	75	70

Table 44. Summary of Accuracy % with Work Experience

		Phase I	Phase II
1	3002	87	80
2	3005	80	77
3	3006	80	83
4	3013	76	63
5	3016	87	73
6	3017	83	83
7	3019	77	70
8	3021	77	73
9	3022	87	83
10	3023	77	83
11	3027	73	73
	Average	80	76

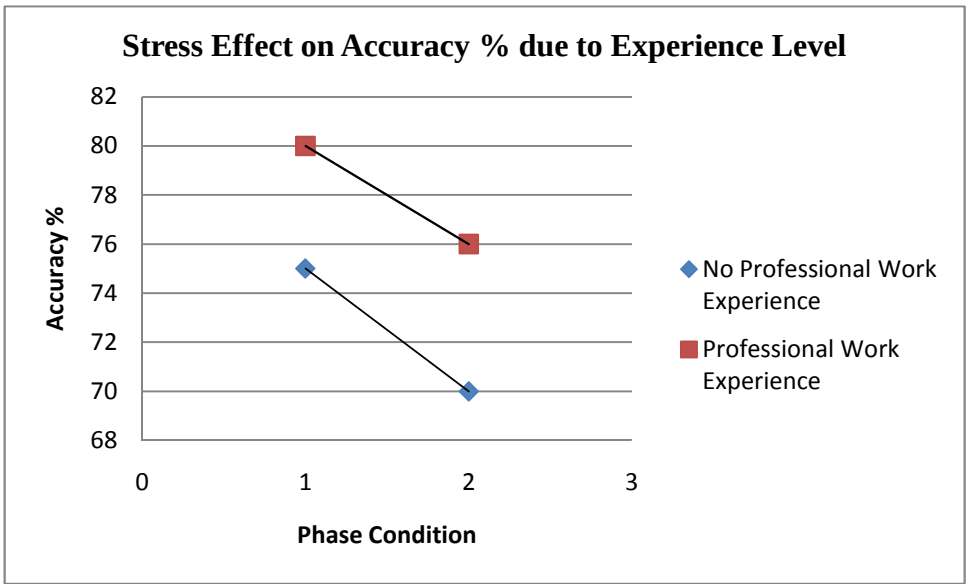


Figure 34. Stress Effect on Performance Due to Experience Level

Figure 35 was constructed from combining Phase I and Phase II depicting percent accuracy for both experienced and not experienced groups. It shows a shift in accuracy towards right for subjects with work experience. Also dispersion is higher for subjects having no work experience.

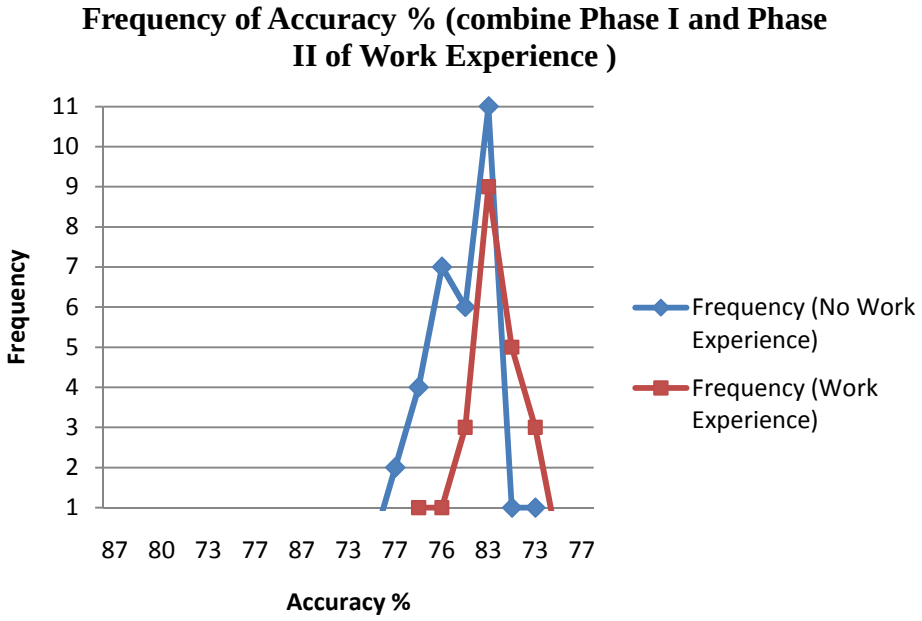


Figure 35. Dispersion of Accuracy Due to Experience Level

Figure 36 also shows that there is a similarity pattern when same subject is performing the test with and without stress. Overall it indicates that there is a drop in performance level due to stress no matter whether the subject is taking the Phase I or Phase II test first.

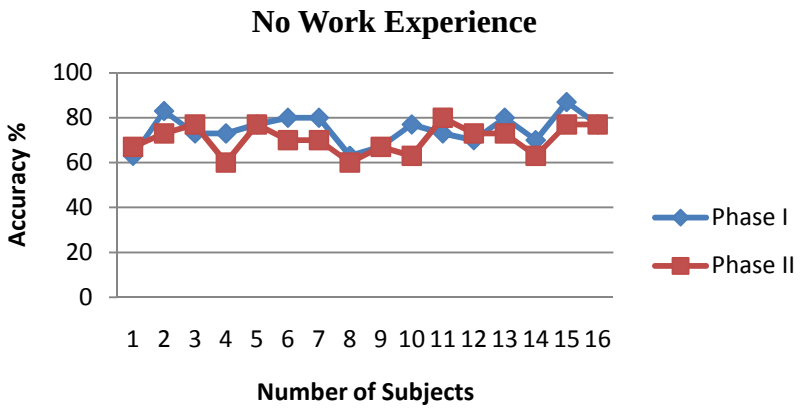


Figure 36. Stress Effect on Subjects With No Professional Experience

Similarly, Figure 37 shows that there is less dispersion on accuracy when comparing Phase I and Phase II for subjects with work experience though pattern is similar for the same subject performing Phase I and Phase II test.

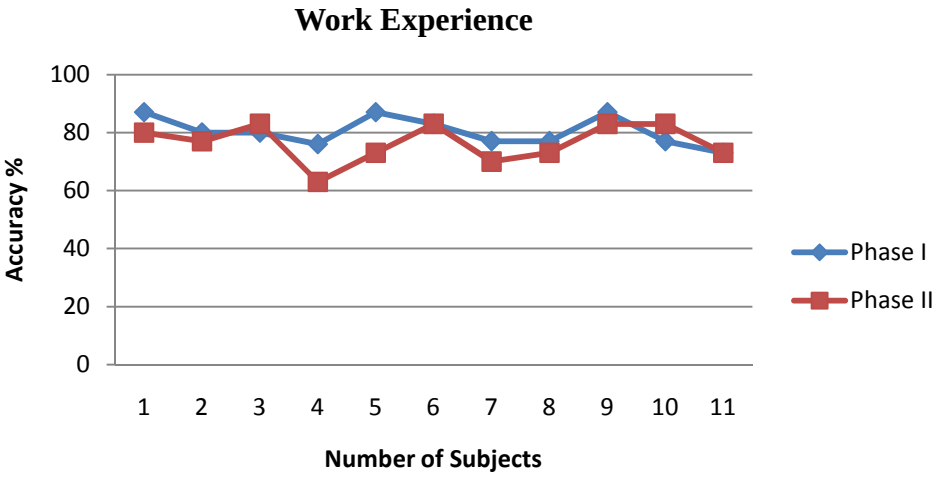


Figure 37. Pattern on Stress Effect on Subjects With Work Experience

Table 45 shows the classification of subjects based on age groups. There were six subjects in the Age Group of 21-25, thirteen subjects in the Age Group 26-30, eight subjects in the Age Group of 31-35 and five subjects in the Age Group of 36-40. To perform statistical analysis and in order to obtain balanced distribution of subjects, age groups 21-25 and 26-30 were combined as one group, and age groups 31-35 and 36-40 were combined as another group. As described earlier, data for the twenty seven participants who completed both the Phase I and the phase II part of the experiment were analyzed statistically.

Table 45. Classification of Subjects Based on Age Group

ID #	21-25	26-30	31-35	36-40
3001		1		
3002		1		
3003			2	
3004		1		
3005	3			
3006		1		
3007		1		
3008			2	
3009			2	
3010		1		
3011	3			
3012		1		
3013			2	
3014			2	
3015			2	
3016				4
3017		1		
3018		1		
3019				4
3020	3			
3021				4
3022		1		
3023				4
3024		1		
3025				4
3026	3			
3027			2	
3028		1		
3029			2	
3030		1		
3031	3			
3032	3			

Table 46 shows the effects of stress on Age Group 21-30. There is a clear decrement in performance due to the stress. Table 47 shows the effect of stress on age group 31-40. Table 48 summarizes the effect of stress on the two classified age group.

Table 46. Stress Effect on Age Group 21-30

Serial #	21-30 Age Group	Phase I	Phase II
1	3001	63	67
2	3002	87	80
3	3004	73	77
4	3005	80	77
5	3006	80	83
6	3007	73	60
7	3010	80	70
8	3011	63	60
9	3012	67	67
10	3017	83	83
11	3018	73	80
12	3020	70	73
13	3022	87	83
14	3024	80	73
15	3026	87	76
	Average	76	74

Table 47. Stress Effect on Age group 31-40

Serial #	31-40 Age Group	Phase I	Phase II
1	3003	83	73
2	3008	77	77
3	3009	80	70
4	3013	76	63
5	3015	77	63
6	3016	87	73
7	3019	70	77
8	3021	77	73
9	3023	83	77
10	3025	70	63
11	3027	73	73
12	3029	77	77
	Average	78	72

Table 48. Stress Effect on Age Group

	Phase I	Phase II
Age Group (21-30)	76	74
Age Group (31-40)	78	72

Figure 38 displays that the performance decrement rate is higher for age group 31-40. The plot indicates that stress is a concern on overall performance when considering higher age group.

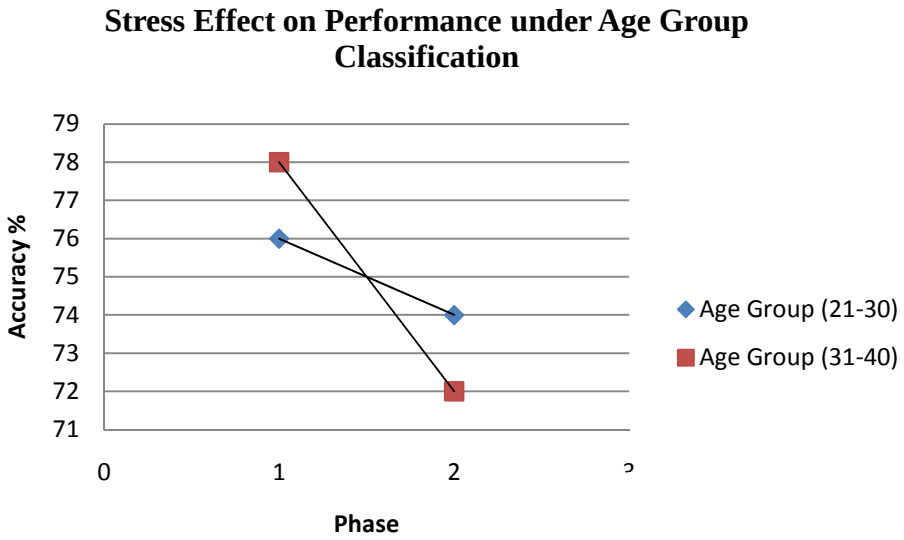


Figure 38. Stress Effect on Different Age Group

Figure 39 shows the frequency plot for both age groups combined, with and without stress performance. The plot indicates that there is a similarity in performance pattern for both age groups. Dispersion is slightly higher for age group 21-30 as compared to age group 31-40. From the plot it is clear that similar performance is observed from both age groups.

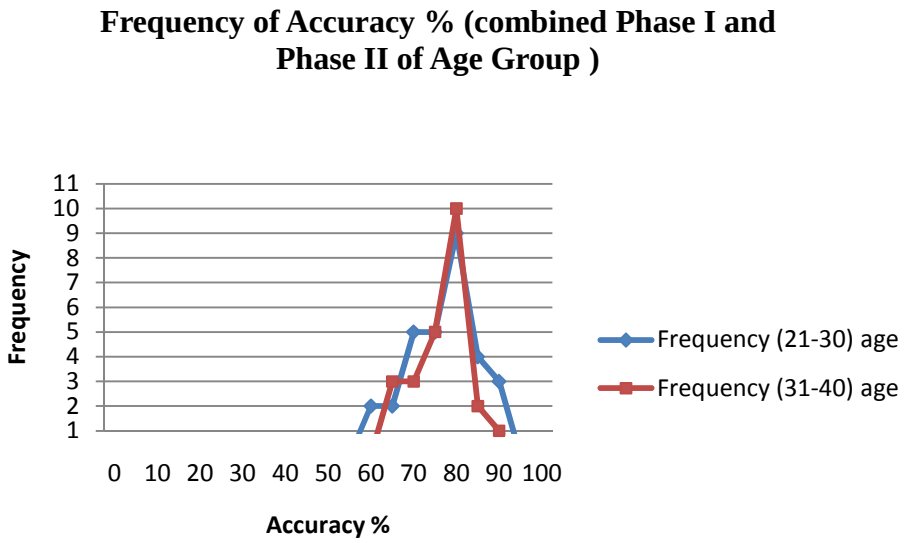


Figure 39. Dispersion of Accuracy Due to Age Classification

Figure 40 shows performance measured in terms of accuracy for each subject for both Phase I and Phase II tests for the Age Group of 21-30. The performance level decreased slightly but the pattern of accuracy is very consistent for each subject.

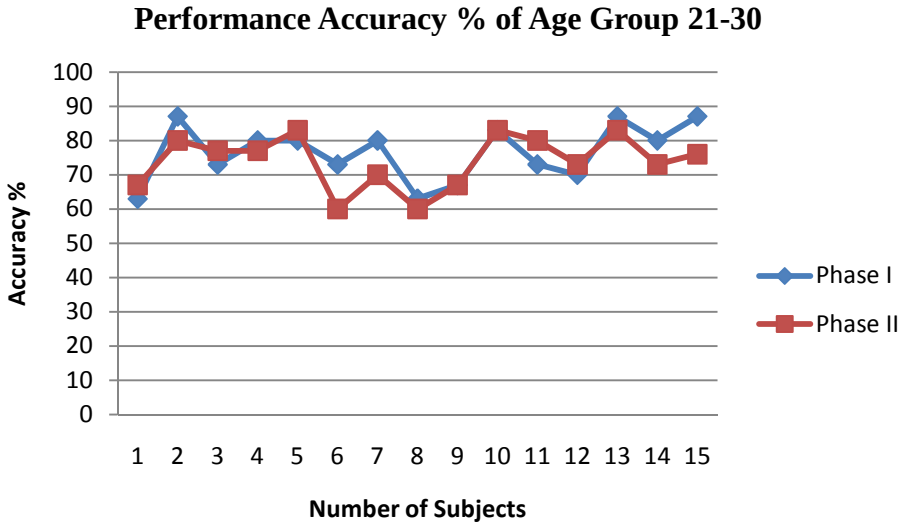


Figure 40. Performance Accuracy % for Age Group 21-30

Figure 41 shows the performance accuracy for the Age Group 31-40 considering Phase I and Phase II of the test. Similarly, a pattern exists when considering the same subject. The accuracy level decreases with stress.

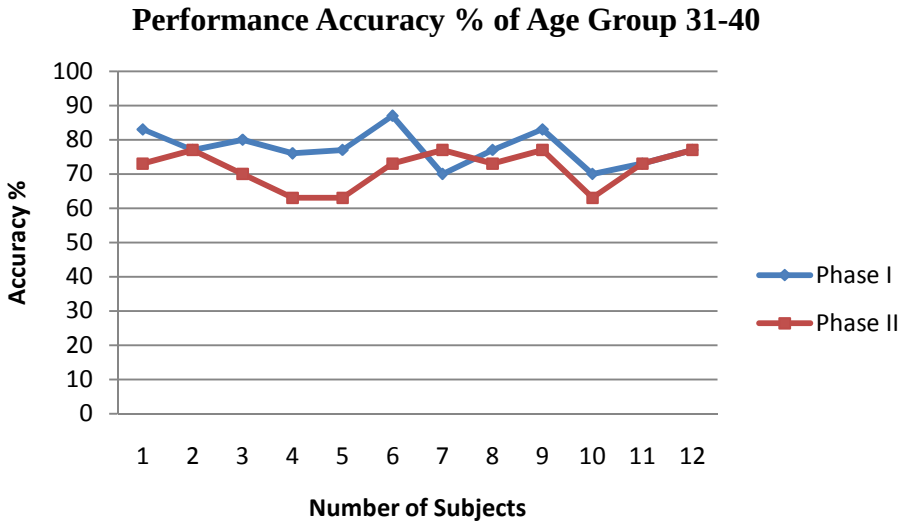


Figure 41. Performance Accuracy % of Age group 31-40

Figure 42 shows the stress effect on task performance when Age Type is considered for subjects having professional work experience and subjects having no professional work experience. The plot indicates in all cases accuracy level decreased due to stress. Subjects having work experience, and fallen under Age Group A performed well in compare to other groups.

Table 49 shows the effect of stress on subjects' performance. It is observed that performance improved for six subjects, performance remained unchanged for five subjects and performance decreased for sixteen subjects due to the added stress. From the analysis one can see that the percentage of subjects' whose performance decreased is significant, and certainly application of low level stress to the subjects contributed significantly to the decreased performance levels.

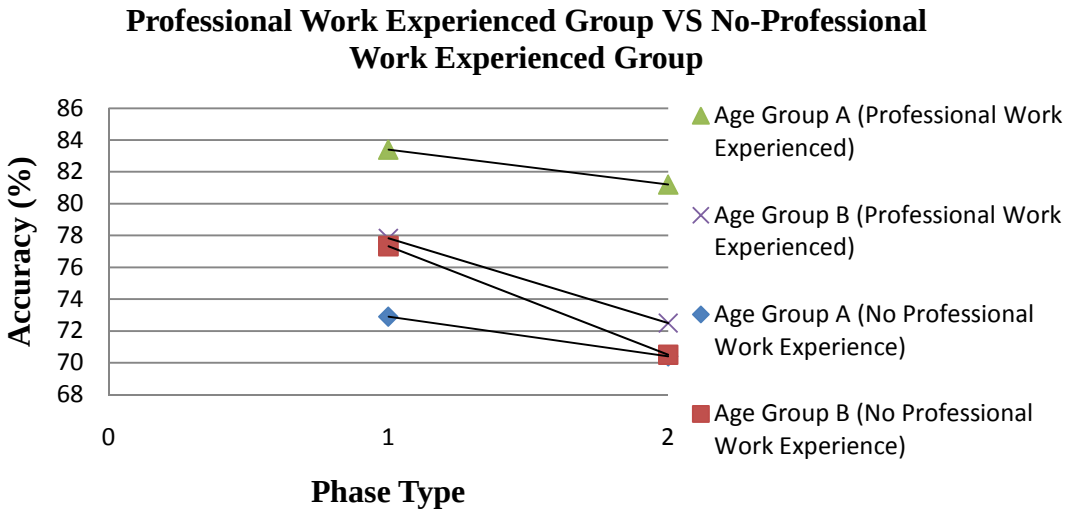


Figure 42. Professional Work Experienced Group VS No Professional Experienced Group

Table 49. Stress Effect on Performance

Stress Effect on Performance	Number of Subjects	% of Subject
Performance Improved	6	22.23
Performance Unchanged	5	18.52
Performance Decreased	16	59.25

Figure 43 shows the percentage distribution of subjects' performance.

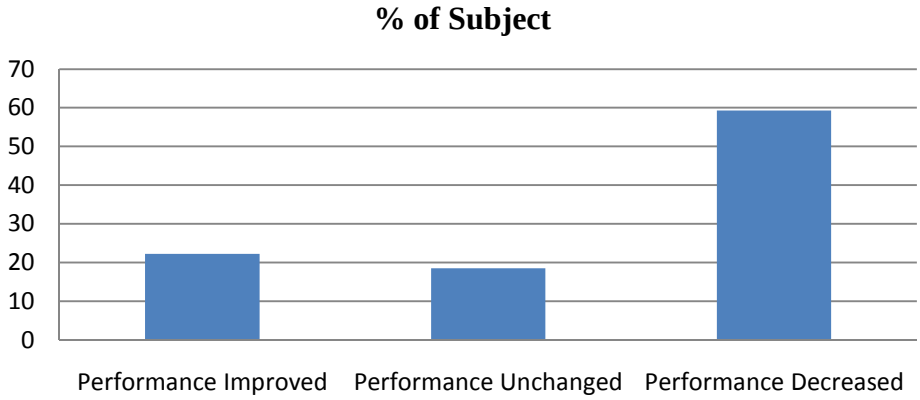


Figure 43. Percentage Distribution on Performance

Table 50 shows the percent average score for the subjects who started Phase I first and then completed Phase II, and for subjects who started Phase II first and then completed Phase I.

Table 50. Percentage Average of Phase I and Phase II

	Phase I	Phase II
First Time	78	71
Second Time (Reversed)	75	76

Figure 44 shows that there is a high fluctuation in terms of accuracy when subjects start Phase I first and then complete Phase II. But when the same subjects participated for the second time starting with Phase II and then Phase I respectively, there is little fluctuation is accuracy.

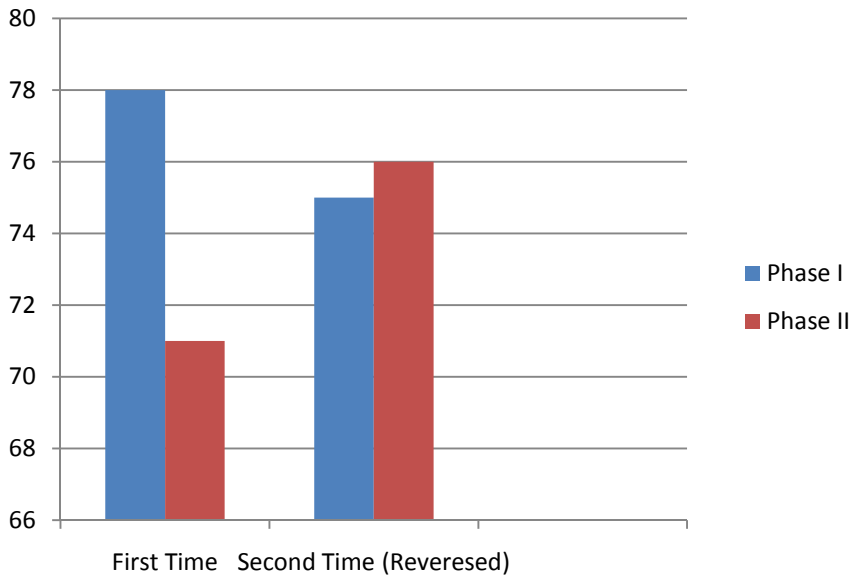


Figure 44. First Phase I and Then Phase II VS First Phase II and Then Phase I

Table 51 shows the total time taken when each subject completes either Phase I or Phase II with average time taken to complete the test.

Table 51. Time Taken for Phase I and Phase II

ID	Total time (msec)	Movement time (msec)	Actual Time (sec)	Phase I (average)	Phase II (average)	Phase I (stdev)	Phase II (stdev)
3001	1182068	110651	1071.41				
3002	1138684	62095	1076.58				
3003	1209118	59104	1150.01				
3004	962838	40836	922.00	975.63		168.95	
3005	1067067	40389	1026.67				
3006	1006879	65640	941.23				
3007	762562	74295	688.26				
3008	854572	62359	792.21				
3017	893462	55945	837.51				
3019	1383306	109934	1273.37				
3021	1164001	70710	1093.29				
3022	898237	63174	835.06				
3009	1178804	44979	1133.82				
3010	824403	61343	763.06				
3011	755806	47161	708.64				
3012	977145	120299	856.84				
3013	799287	61878	737.40				
3015	729816	39219	690.59				
3016	867753	51659	816.09				
3018	1061698	167101	894.59		889.70		207.35
3020	998218	95422	902.79				
3023	946632	44997	901.63				
3024	1418092	110640	1307.45				
3025	675492	35608	639.88				
3026	1347512	74328	1273.18				
3027	1094345	96531	997.81				
3029	783929	62156	721.77				

Table 52 summarizes average time taken to complete the test when the subject performs online for the Phase I and Phase II conditions along with the tabulating the standard deviation. It is observed that under very relaxed conditions, when the test is completed online, time taken to complete the test is high and the variability of time to complete the test is high. The results also indicate that when the test is completed under

stress, time taken to complete the test decreases and the variability of time taken to complete the test is lower compare to the other two conditions.

Table 52. Summary of Time Taken in Different Setup

Test Type	Number of Subjects	Time Taken	Standard Deviation
Online Test Time	15	1217.63	409.73
Laboratory Test Time (Phase I)	12	975.63	168.95
Laboratory Test Time (Phase II)	15	889.70	207.35

Figure 45 shows a bar chart presenting the average time taken by the subjects to complete the test.

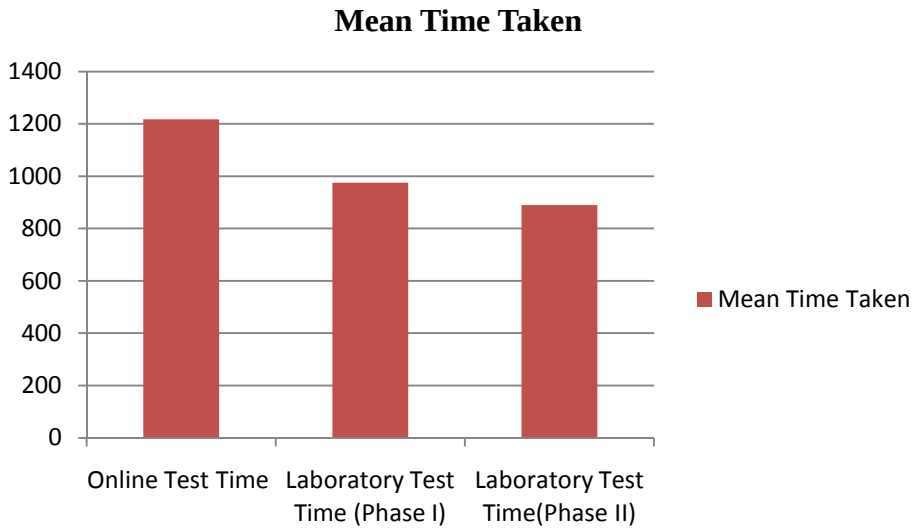


Figure 45. Mean Time Taken

Table 53 shows the statistical analysis performed to test if the mean time taken to complete the test in Phase I and Phase II is the same. Student t-test calculated value is higher than the t-table value, concluding statistically that stress has an effect on performance time. Subjects completed the test faster when under stress with lower accuracy rate as discussed earlier. The time comparison shown in the table is for subjects who completed either Phase I or Phase II of the test.

Table 53. Statistical Analysis on Total Time Comparing Phase I and Phase II

Ho:	μ1=μ2		
H1:	μ1>μ2		
Alpha	0.05		
Phase	Mean (y)	Sample Size (n)	Standard Deviation (s)
Phase I (average of Lab and online)	1096	27	289
Phase II	831	15	207.36
t-calculated	3.13	t-table (ν)	1.68

Table 54 summarizes the data when the same subjects switched to their respective alternative test. Table 55 summarizes average completion time for all subjects who completed both the Phase I and Phase II of the test.

Table 54. Second Time Data Summary

Test Type	Number of Subjects	Actual Time (Seconds)	Standard Deviation
Laboratory Test With Stress (Phase II)	12	727.12	128.83
Laboratory Test Without Stress (Phase I)	15	831.19	144.16

Table 55. Data Average When Subject Performs Second Set

Type	Actual Time (Seconds) Phase I	Actual Time (Seconds) Phase II
First Set	975.64	889.71
Second Set	727.12	831.19

Figure 46 shows the variation in time needed to complete the test when a subject switches from Phase I to Phase II and Phase II to Phase I. The first set shows average of

accuracies of subjects who completed Phase I and then Phase II; and second set shows average of accuracies of subjects who completed the Phase II and then Phase I respectively.

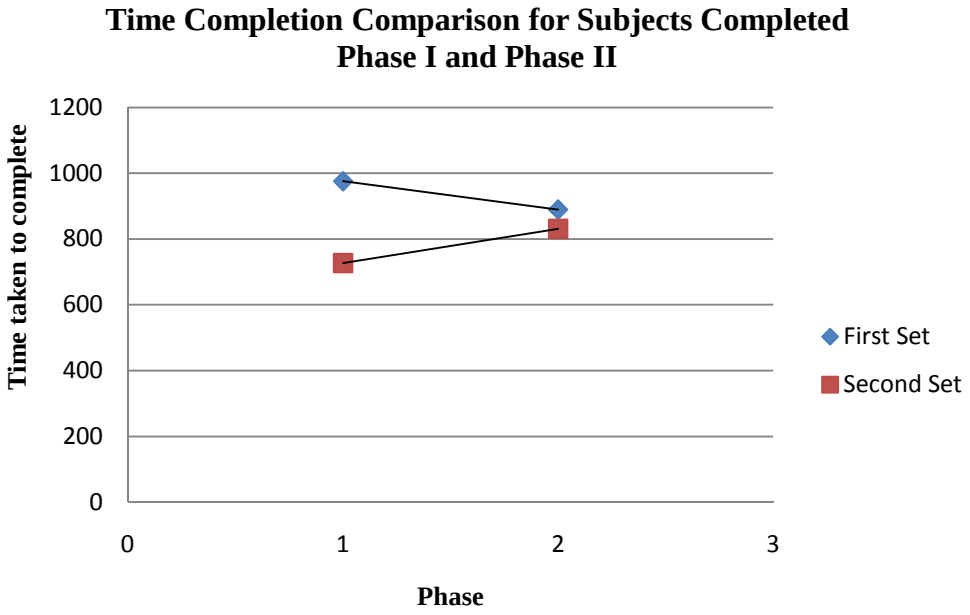


Figure 46. Plot Showing Magnitude Difference

Table 56 compares scores of task capacity and situational awareness accuracy. There were twenty task capacity related questions and ten situational awareness related questions. In this Table, First Time Appearance means subjects who completed either Phase I or Phase II at first. Similarly, Second Time Appearances means subjects who completed either Phase I or Phase II in the second appearance for the test.

Figure 47 shows the scores for first time appearance of task capacity and for first time appearance of situational awareness capacity. The plot indicates pattern of task capacity performance and situational awareness is not similar. In other words, there is less probability of having any linear relationship.

Table 56. Task Capacity VS Situational Awareness

	First Time Appearance		Second Time Appearance	
Serial #	Task Capacity %	Situation Awareness %	Task Capacity %	Situational Awareness %
1	80	30	60	80
2	80	100	75	90
3	85	80	70	80
4	65	90	70	90
5	85	70	75	80
6	75	90	85	80
7	75	70	60	60
8	80	70	75	80
9	70	70	85	70
10	65	80	75	90
11	60	60	60	70
12	65	70	70	60
13	85	60	85	60
14	70	50	75	80
15	65	90	80	100
16	85	80	85	80
17	70	100	70	80
18	75	80	65	80
19	65	80	60	90
20	70	90	75	70
21	85	90	80	90
22	65	90	80	70
23	80	60	75	90
24	60	70	70	70
25	70	90	85	90
26	60	100	70	80
27	65	100	80	100

Figure 48 shows scores for second time appearances for the test. The pattern of subjects' score also shows no specific relation between task capacity and situational awareness.

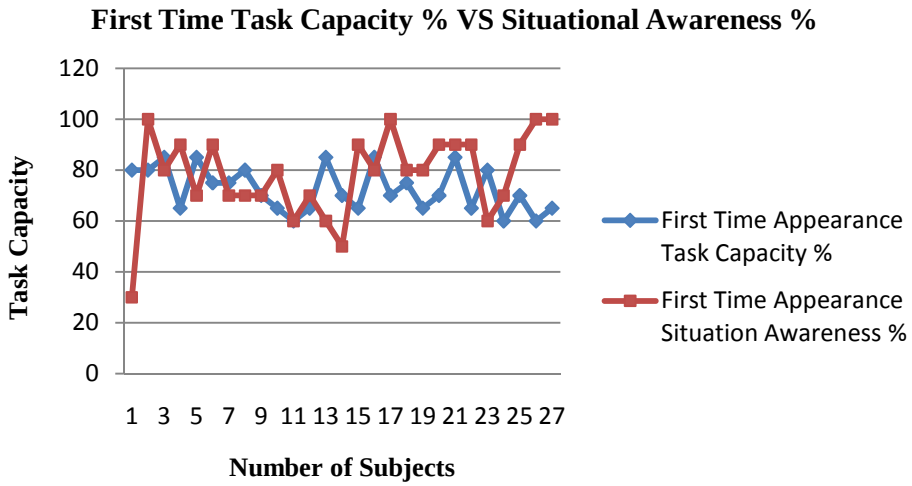


Figure 47. Plot of First Time: Task Capacity VS Situational Awareness

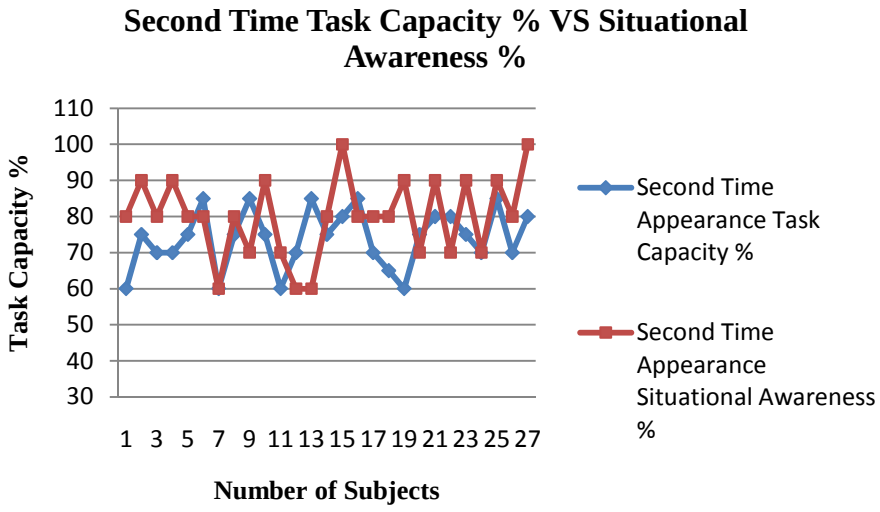


Figure 48. Second Set: Task Capacity VS Situational Awareness

When the data is plotted for all subjects comparing only task capacity as shown in Figure 49, a pattern emerges. When comparing only situational awareness tasks, Figure 50 shows that there is a higher fluctuation in scores and there is no similarity in pattern. Also the fluctuation of score was higher when the subjects appeared for the first time but when appeared for the second time score improved and variability decreased.

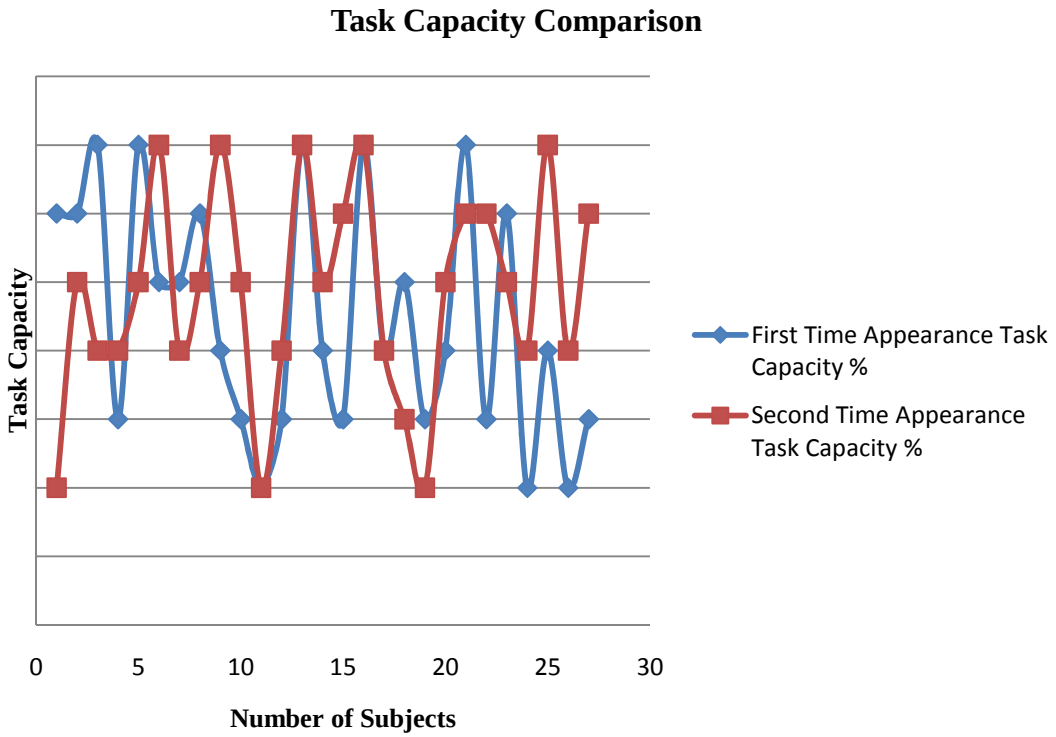


Figure 49. Task Capacity Comparison

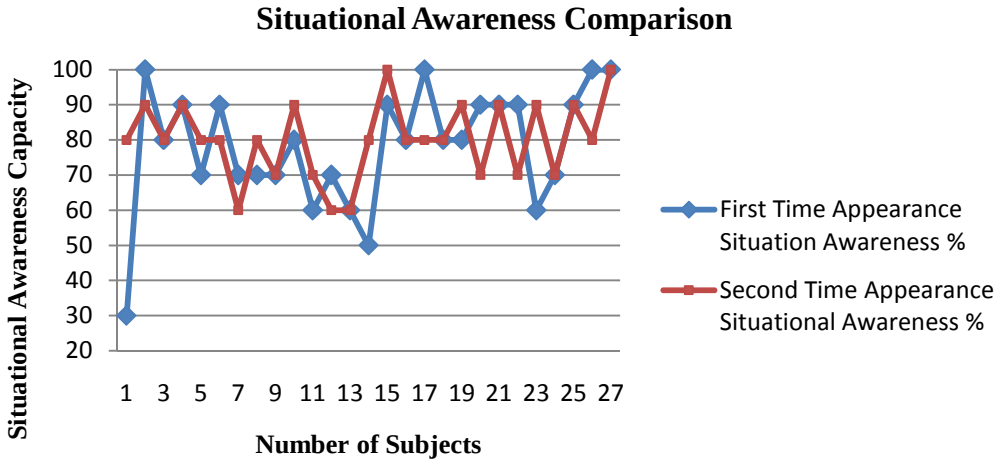


Figure 50. Situational Awareness Comparison

Table 57 summarizes Task Capacity results for subjects who completed the Phase I first and then Phase II. Figure 51 shows the Phase I and phase II pattern for each subject. There is a performance decrement when same subject appears for Phase II test. The variability between the two performances is low.

Table 57. Task Capacity Analysis for Phase I First

Phase I	Phase II
Task Capacity %	Task Capacity %
80	60
80	75
85	70
65	70
85	75
75	85
80	75
85	85
75	65
70	75
85	80

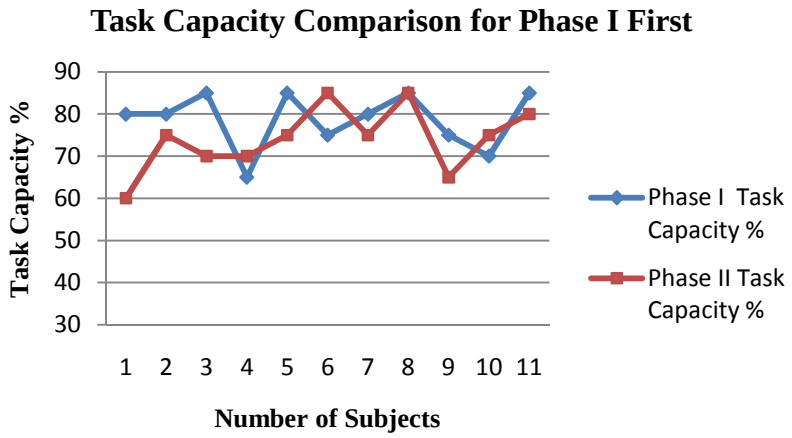


Figure 51. Task Capacity Comparison for Phase I First

Table 58 shows task capacity results for subjects who completed Phase II first and then Phase I. Figure 52 show that performance increment rate is higher when subject first completed Phase II and then Phase I. There is a significant performance improvement. Table 59 shows situational awareness capacity results for subjects who completed Phase I first and then Phase II.

Table 58. Task Capacity Analysis for Phase II First

Phase II	Phase I
Task Capacity %	Task Capacity %
60	75
70	85
65	75
60	60
65	70
85	85
70	75
65	80
70	70
65	60
80	75
60	70
70	80
60	80
65	85
65	70

Task Capacity % Comparison for Phase II First

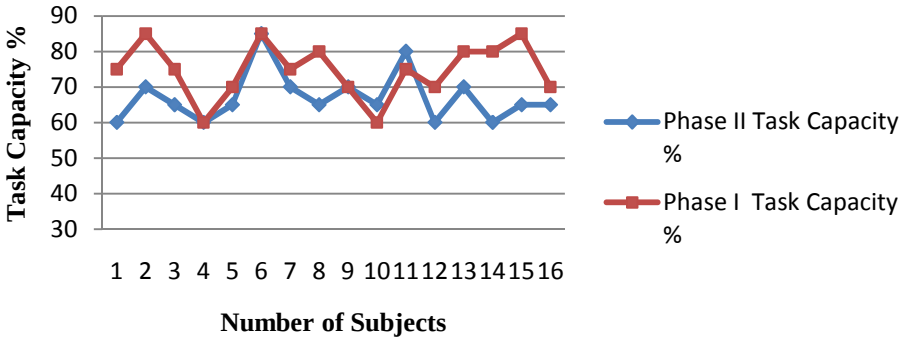


Figure 52. Task Capacity Comparison for Phase II First

Figure 53 shows the Phase I and phase II patterns for each subject. There is not much performance decrement when same subjects appear for Phase II test. The variability between the two performances is low. Table 60 shows situational awareness capacity results for subjects who completed Phase II first and then Phase I.

Table 59. Situational Awareness Capacity Analysis for Phase I First

Phase I	Phase II
Situational Awareness %	Situational Awareness %
30	80
100	90
80	80
90	90
70	80
90	80
70	80
80	80
80	80
90	70
90	90

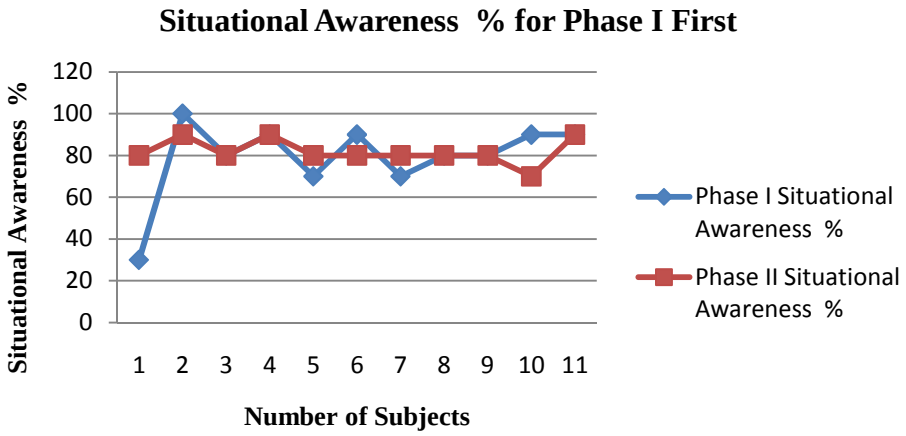


Figure 53. Situational Awareness Comparison for Phase I First

Figure 54 shows the Phase II and phase I patterns for each subject. There is a performance improvement when same subjects appear for Phase I test. The variability between the two performances is low.

Appendix C10 shows the individual task capacity and situational awareness accuracy for the subjects who started Phase I first and Phase II next. Similarly Appendix C11 lists the subjects who started Phase II first and then Phase I.

Table 60. Situational Awareness Capacity Analysis for Phase II First

Phase II	Phase I
Situational Awareness %	Situational Awareness %
60	70
70	70
80	90
60	70
70	60
60	60
50	80
90	100
100	80
80	90
60	70
70	90
90	70
100	90
100	80
90	100

Table 61 shows the Task Capacity accuracy when comparing the effect of stress on subjects who completed Phase I and then Phase II. The difference is much larger when the subject completed the test under stress first and then completed the test with no stress.

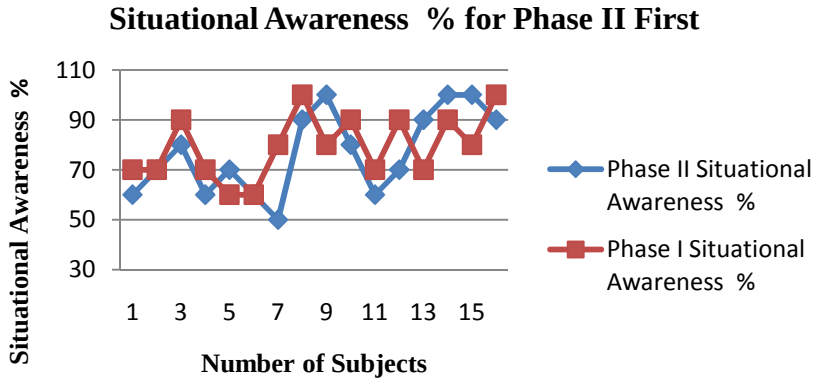


Figure 54. Situational Awareness Comparison for Phase II First

Table 61. Task Capacity and Stress Effect

Task Capacity %	Accuracy (%) Phase I	Accuracy (%) Phase II
First Phase I	79 (First)	74 (Second)
First Phase II	75 (Second)	67 (First)

Figure 55 displays the magnitude difference of Task accuracy. It is only 4% when comparing results for the subjects who first completed Phase I tasks and then Phase II tasks. The difference is almost doubled to 7% when comparing results for the subjects who first completed Phase II and then Phase I.

Table 62 shows the SA accuracy when comparing the effect of stress on subjects who completed Phase I test and then Phase II test. Magnitude difference is higher when the subject completing the test under stress first and then completed the test without stress.

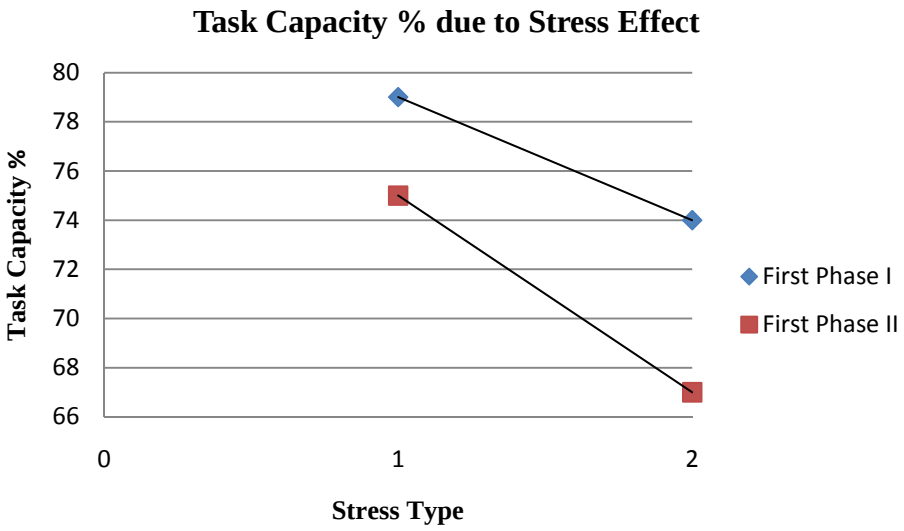


Figure 55. Task Capacity and Stress Effect

Table 62. SA Capacity and Stress Effect

Situational Awareness Capacity %	Accuracy (%) Phase I	Accuracy (%) Phase II
First Phase I	79 (First)	82 (Second)
First Phase II	79 (Second)	77 (First)

Figure 56 displays the magnitude difference of SA accuracy. It is 2% when compared to without stress conditions for subjects first completing Phase I task and second Phase II tasks. Similarly it is 3% when comparing with stress conditions to first Phase II task to second Phase I task.

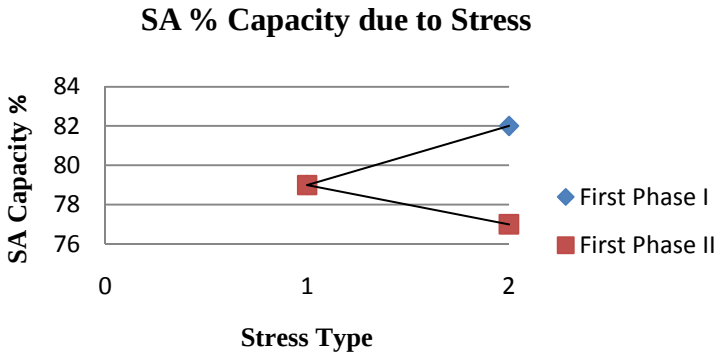


Figure 56. SA Capacity and Stress Effect

Table 63 shows the Task accuracy and SA accuracy when compared to two stress conditions. Figure 57 shows the Task accuracy and SA accuracy when compared to two stress conditions. Situational awareness remained unchanged during the two stress conditions. But task capacity decreased.

The confidence level is categorized as Very High, Moderate, High, Low and Very Low. Table 64 was used to compare Phase I and Phase II accuracy levels. Here the 'Known' and 'Unknown' factors were used from the confidence level. If the subject selects high, moderate and very high confidence levels then it was considered as Known and if the

subject selects low and very low confidence levels then it was considered as Unknown. Similarly the stress tools used in this experiment compared between Phase I and Phase II.

Table 63. Task Capacity and SA on Stress Effect

Task Type %	Accuracy (%) Phase I	Accuracy (%) Phase II
Task Capacity %	76	70
Situational Awareness %	79	79

Table 65 shows the confidence level for performing the test accurately under Phase I and Phase II test conditions. One of the subjects who completed both phase of the test but did not complete the accuracy rating properly was eliminated for analysis purposes. The subject used “very low” confidence rating for answering all the questions. It is observed from the table that at Phase I performance, confidence level was higher as compared to Phase II performance. Figure 58 shows there is a relationship between confidence levels rating and answering each question, when compared to with and without stress condition performance.

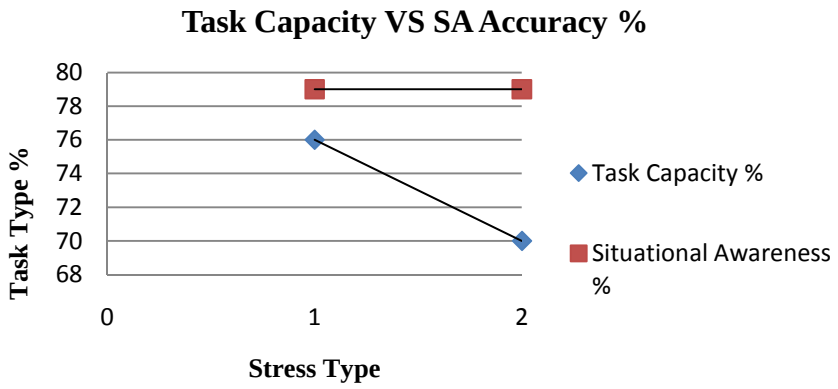


Figure 57. Task Capacity and SA on Stress Effect

Table 64. Four Possible Outcomes of Accuracy

	Correct	Wrong
Known	Hit	Miss
Unknown	False Alarm	Correct Rejection

Table 66 summarizes IQ' accuracy percentage values for subjects who completed Phase I task first and then Phase II task, and also for subjects who completed Phase II task first and then completed Phase I task.

Table 65. Confidence Level and Accuracy Level Due to Stress

Serial #	Id #	Phase I		Phase II	
		Confidence Level (%)	Accuracy (%)	Confidence Level (%)	Accuracy (%)
1	3001	80	63	87	67
2	3002	97	87	80	80
3	3003	100	83	73	73
4	3004	73	73	67	77
5	3005	100	80	77	77
6	3006	93	80	90	83
7	3007	80	73	73	60
8	3008	77	77	77	77
9	3009	90	80	93	70
10	3010	90	80	97	70
11	3011	90	60	90	63
12	3012	83	67	73	67
13	3015	100	77	90	63
14	3016	93	87	83	73
15	3017	100	83	97	83
16	3018	90	73	80	80
17	3019	93	77	93	80
18	3020	77	70	70	70
19	3021	90	77	100	80
20	3022	100	87	100	83
21	3023	77	77	90	83
22	3024	83	80	80	73
23	3025	93	70	93	63
24	3026	87	87	77	77
25	3027	93	73	90	73
26	3029	87	87	97	77
	Average	89	77.25	85	73.75

Figure 59 shows magnitude difference is 4% when second completed data set is compared and the difference is almost doubled to 7% when comparing first completed data set. Table 67 summarizes PSQ accuracy percentage values for subjects who completed

Phase I task first and then Phase II task, and also for subjects who completed Phase II task first and then completed Phase I task.

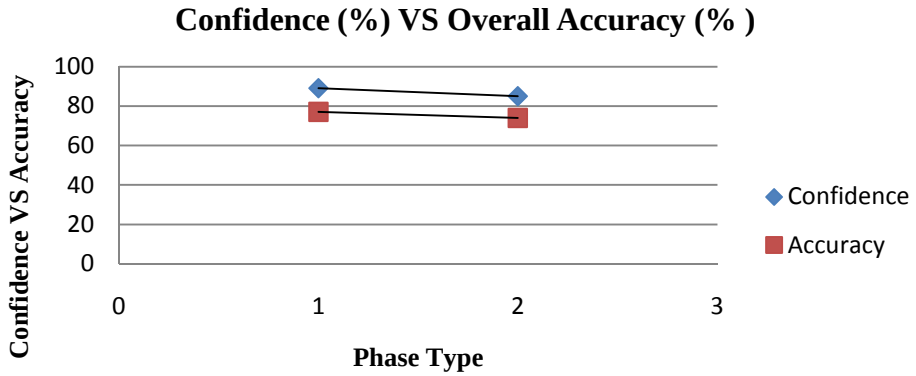


Figure 58. Confidence Level and Stress Relationship

Figure 60 shows magnitude difference is 2% when second completed data set is compared and it jumps almost five times to 9% when comparing first completed data set. It is evident that PSQ accuracy is mostly affected due to stress compared to IQ' and SA accuracy affects due to stress.

Table 68 shows IQ' accuracy is not that much affected compare to PSQ accuracy when performing under stress conditions. There is a sharp drop in performance when solving PSQ type of problems under stress. Figure 61 shows that IQ' average is higher than PSQ average. There exists a linear relationship between IQ' and PSQ. Table 69 shows the combined result of subjects who completed both Phase I and Phase II. The ANOVA was conducted considering three factors: Phase Type, Age Type and Experience Type.

Table 66. IQ' Accuracy Due to Stress

IQ' Level	Accuracy (%) Phase I	Accuracy (%) Phase II
First Phase I	88 (First)	92 (second)
First Phase II	88 (Second)	81 (First)

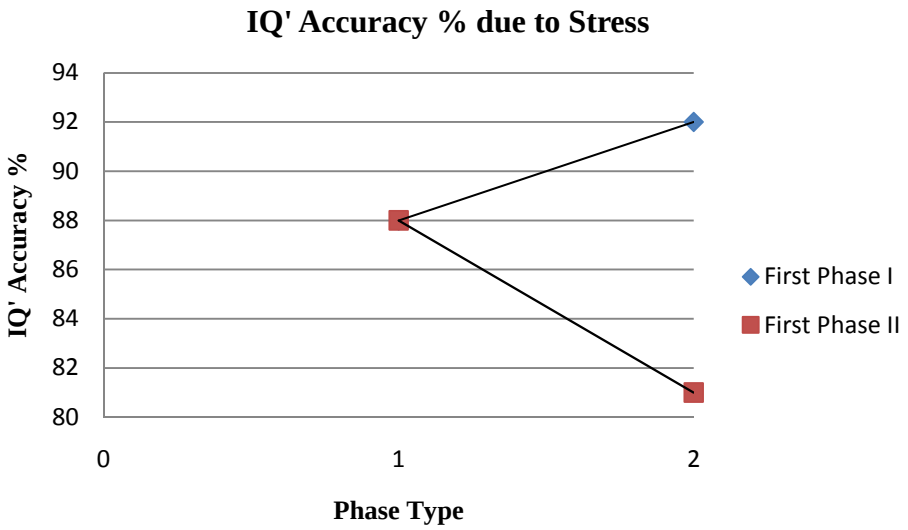


Figure 59. Overall IQ' Comparison

Table 67. PSQ Accuracy Due to Stress

PSQ Level	Accuracy (%) Phase I	Accuracy (%) Phase II
First Phase I	74 (First)	69 (Second)
First Phase II	71 (Second)	65 (First)

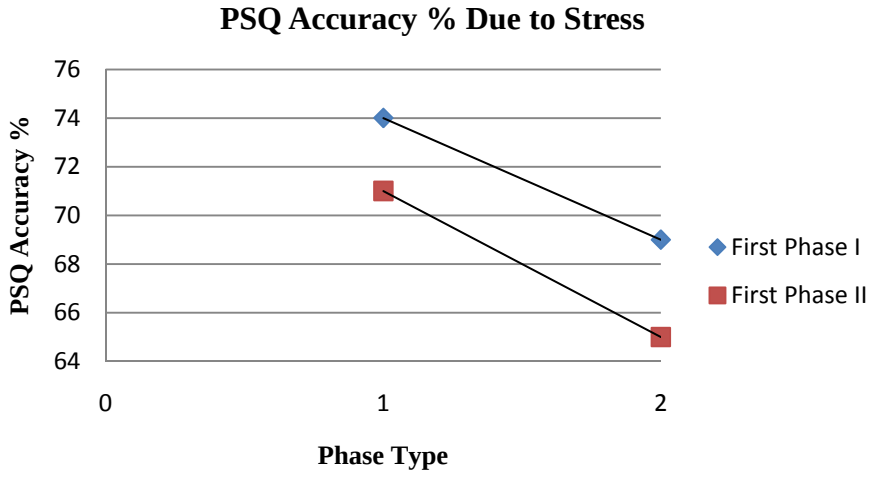


Figure 60. PSQ Task Capacity Comparison

Table 68. IQ' VS PSQ Accuracy Due to Stress

Type of Task	Accuracy (%) Phase I	Accuracy (%) Phase II
IQ' Accuracy	88	86.5
PSQ Accuracy	72.5	67

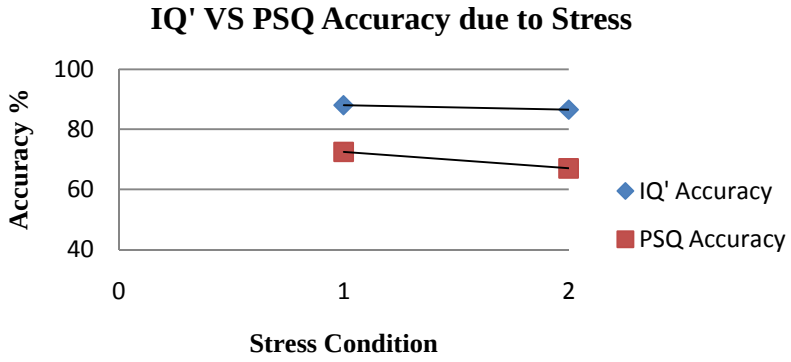


Figure 61. IQ' VS PSQ Task Capacity Interaction

Table 69. Combined Result of Phase I and Phase II for ANOVA

Subject ID	Accuracy	Phase Type	Age Type	Experience Type
3001	63	1	A	3
3002	87	1	A	4
3003	83	1	B	3
3004	73	1	A	3
3005	80	1	A	4
3006	80	1	A	4
3007	73	1	A	3
3008	77	1	B	3
3017	83	1	A	4
3019	77	1	B	4
3021	77	1	B	4
3022	87	1	A	4
3009	70	2	B	3
3010	70	2	A	3
3011	60	2	A	3
3012	67	2	A	3
3013	63	2	B	4
3015	63	2	B	3

Table 69 (Continued)

Subject ID	Accuracy	Phase Type	Age Type	Experience Type
3016	73	2	B	4
3018	80	2	A	3
3020	73	2	A	3
3023	83	2	B	4
3024	73	2	A	3
3025	63	2	B	3
3026	77	2	A	3
3027	73	2	B	4
3029	77	2	B	3
3001	67	2	A	3
3002	80	2	A	4
3003	73	2	B	3
3004	77	2	A	3
3005	77	2	A	4
3006	83	2	A	4
3007	60	2	A	3
3008	77	2	B	3
3017	83	2	A	4
3019	70	2	B	4
3021	73	2	B	4
3022	83	2	A	4
3009	80	1	B	3
3010	80	1	A	3
3011	63	1	A	3
3012	67	1	A	3
3013	76	1	B	4
3015	77	1	B	3
3016	87	1	B	4
3018	73	1	A	3
3020	70	1	A	3
3023	77	1	B	4
3024	80	1	A	3
3025	70	1	B	3
3026	87	1	A	3
3027	73	1	B	4
3029	77	1	B	3

Table 70 shows the ANOVA results for the above Table 69. It reflects Experience Type is a dominating factor, though Phase Type and, interaction of Age Type and Experience Type are statistically significant factors.

The main effect plot is shown in Figure 62. Experience Type from the ANOVA represents a significant contributing factor for the accuracy in comparison to Phase Type and Age Type.

Table 70. ANOVA Results for Phase I and Phase II Combined

Source	DF	F	P
Phase Type	1	6.35	0.015
Age Type	1	2.11	0.153
Experience Type	1	12.60	0.001
Phase Type*Age Type	1	1.34	0.253
Phase Type*Experience Type	1	0.07	0.796
Age Type*Experience Type	1	7.86	0.007
Error	47		
Total	53		

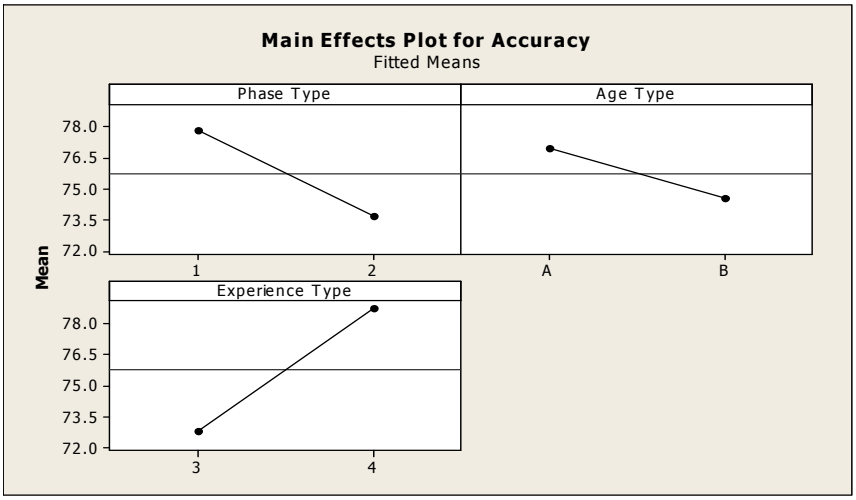


Figure 62. Main Effect Plot for Phase I and Phase II Combined

Figure 63 shows the interaction plot of the three factors combining Phase I and Phase II. The plot indicates only Age Type and experience Type has a significant interaction.

The reliability and sensitivity analysis of the test is shown in Table 71. The reliability is measured in terms of ratio of correct answers to incorrect answers for each question. In the laboratory, there were twenty seven subjects who completed both phases of the test. Reliability evaluates each question. Reliability value can be from zero to infinity. An infinite value means accuracy rate is 100% and reliability value of zero means what subjects were unable to answer any question because of the difficulty level. The reliability index measures the difficulty level of each question. Ideally it is expected to design test questions such that it is not too easy or too difficult. The two extreme cases of difficulty level are not sensitive enough to capture any variability from any external stress sources. Reliability values calculated are used to measure sensitivity of each question. Sensitivity value is measured by deducting the difference between percentage of accurate answer and percentage of inaccurate answers from 100%. If the sensitivity % is close to 100%, it means that the test is sensitive enough to show any affect of stress on performance.

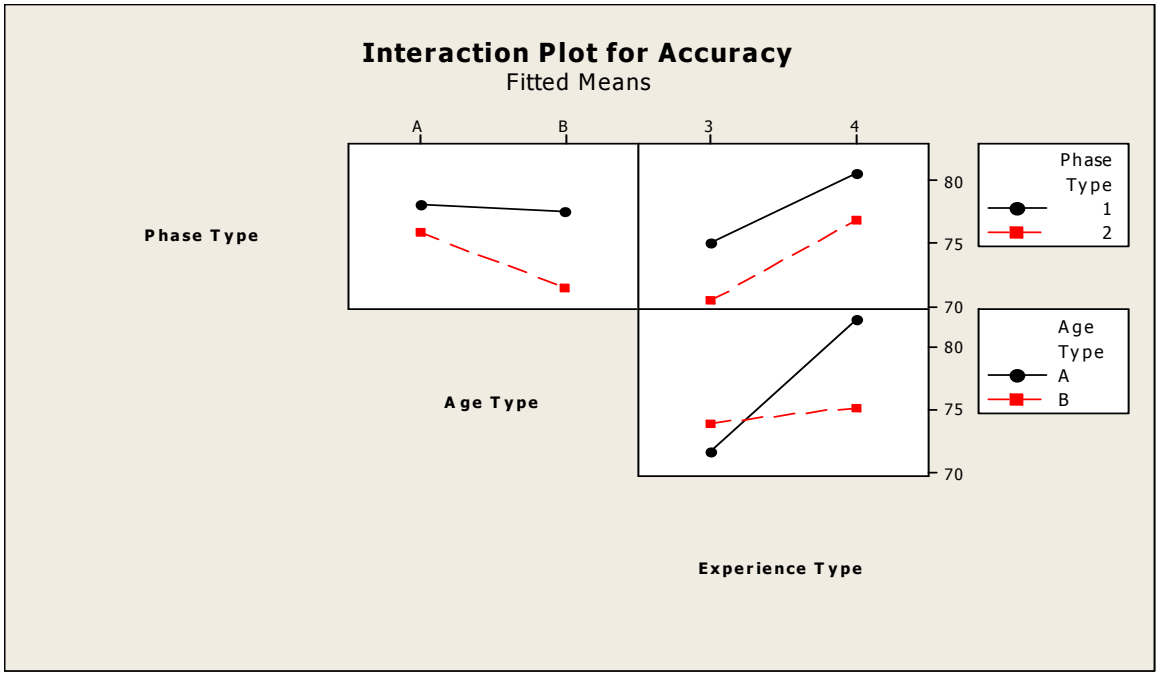


Figure 63. Interaction Plots for Phase I and Phase II Combined

When designing a task capacity measurement tool, it is expected to design a tool with a sensitivity of more than 50%. When a comprehensive test is designed, it combines a mixture of difficulty levels in the test to simulate a real world picture. The current setup in the test considered a combination of low difficulty level with high difficulty level of questions.

Table 71. Test Reliability and Sensitivity Analysis

Question #	Combined # of Subjects	Combined # of Accuracy	Percentage Accuracy	Reliability Index	Percentage Correct	Percentage Incorrect	Sensitivity of Test % (Laboratory)
1	54	51	94	17	94	6	11
2	54	53	98	53	98	2	4
3	54	24	44	1	44	56	89
4	54	48	89	8	89	11	22
5	54	52	96	26	96	4	7
6	54	38	70	2	70	30	59
7	54	41	76	3	76	24	48
8	54	50	93	13	93	7	15
9	54	42	78	4	78	22	44
10	54	35	65	2	65	35	70
11	54	47	87	7	87	13	26
12	54	45	83	5	83	17	33
13	54	39	72	3	72	28	56
14	54	46	85	6	85	15	30
15	54	51	94	17	94	6	11
16	54	28	52	1	52	48	96
17	54	30	56	1	56	44	89
18	54	37	69	2	69	31	63
19	54	50	93	13	93	7	15
20	54	29	54	1	54	46	93
21	54	11	20	0	20	80	41
22	54	45	83	5	83	17	33
23	54	45	83	5	83	17	33
24	54	45	83	5	83	17	33
25	54	53	98	53	98	2	4
26	54	26	48	1	48	52	96
27	54	31	57	1	57	43	85
28	54	24	44	1	44	56	89
29	54	34	63	2	63	37	74
30	54	48	89	8	89	11	22

8. CONCLUSION

The focus of this research is on standardizing the task functions needed to evaluate individual task capacity and to determine if low level physical stress has any effect on task performance. Stress effects were analyzed on overall task performance, IQ' type performance, PSQ type performance, SA type performance, test completion time, and performance confidence level. The relationship between cognitive performance and situational awareness under different stress conditions was compared. Response time and accuracy were also measured for statistical analysis. ANOVA was performed to evaluate performance considering three factors: stress, age, and professional work experience. Delphi method, which is usually applied in social and public health policy issues, was utilized as a research tool. Human task performance analysis is a complex process and it became evident that there were no specific tools designed to measure task performance found in literature. Tools previously developed were used to serve a specific need or to evaluate a particular objective. The Delphi technique utilizes combined individual judgment to address any issue related to an incomplete state of knowledge. Individual input is very important when designing a task capacity measurement tool allowing the flexibility of incorporating input from a wide range of views. Delphi method was used to establish the consensus on the designed test at 70% level and validation showed consensus was reached above 70% with eighteen subjects who completed the evaluation. Sixteen subjects responded to the content validity analysis for each question. The subjects participating in the content validity were from a wide range of professions. The consensus level achieved was about 6 and above, in terms of “how important the task is in daily life.”

The developed tool is flexible in nature to apply in any specific field of application. It has the feature to design test materials in any combinations of IQ', PSQ and SA, and any task can be activated or deactivated as per requirement. Number of questions can be changed as per need. Time allocations for SA questions can be changed depending on the type of tasks are analyzed. Test can be featured in a random order or it can be in a specific order.

The developed test instrument measured human overall task performance when tasks are cognitive in nature and require situational awareness. The computer tool simulated human task capacity performance in a predefined task module. Task capacity of a subject was measured before and after exposure to low levels of physical exercise. The levels of stress of the subjects were measured using questionnaires before at the start of the test. From the analysis of the collected subjective statements, it was confirmed that all the subjects were physically in good condition before the experiment.

An overall performance chart was completed by each subject after the test. The subjective rating chart estimated mental demand, temporal demand, performance, effort and frustration levels experienced by each subject while completing the test. The mental demand and temporal demand for the test was approximately 62%, which indicates that the test scenarios constructed were not too easy or too difficult. Since the responses to 33% of the questions were tracked for duration or time required to respond, it resulted in a subjective rating above 50% time demand when performing the test. Effort rating was around 53%, which is close to the mental demand rating by the subjects. Frustration level was 27%, which explains that subjects volunteered to participate in the test without any

benefit and provided maximum attention required to complete the test. The analysis of the report gives an overview of the test structure and scope for future improvements of the test.

The participants who completed the test in the laboratory and online provided feedback on the computer test site based on their experience to start the site, navigation throughout the test, readability of the questions, content organization, time allocation for time dependent questions, total time spent on the test and stress measurement questions. The analysis of the evaluation indicates satisfaction level was above 75% for most of the cases except navigation which was 68%. Since there is a mixture of questions in random order, and some questions require situational awareness and some questions only required IQ' and PSQ solving skills, a number of subjects rated navigation lower than 75%.

When the computer test was designed for the experimental conditions, the total time allocated for Phase I was thirty five minutes, and the total time allocated for Phase II was forty five minutes. The time was calculated based on how much time it would take a subject from the time he or she entered the laboratory to the time they actually left the laboratory. From the analysis of the time values, it was found that the average time taken to complete the test for the first time appearance was fifteen and half minutes and time taken to complete the test for the second appearance was thirteen minutes. This shows that time allocation was within the acceptable range and there is less time taken to complete the test when the subjects appeared for the second time.

It was found that online and laboratory results without stress were very close to 78.4%. The reason was that in both scenarios the subjects were relaxed before the test. On the other hand, laboratory results with stress were close to 71%. There is more than a 7% performance decrease due to stress when comparing a group of subjects who only

completed Phase I to another group who completed Phase II of the test. The average accuracy was 75% combining online and laboratory participants, indicating the difficulty level was moderate.

The developed tool was able to detect any effect of stress on task performance successfully and efficiently. The statistical analysis of the result satisfied the sample size considered for the test.

The ANOVA analysis showed professional work experience impacted task performance significantly compared to stress and age group. Three factors with results of twenty-seven subjects completing either Phase I task or Phase II task were used to conduct the ANOVA. Another ANOVA analysis was conducted with three factors along with twenty-seven subjects completing both Phase I and Phase II of the test. The result indicates professional work experience is a major significant factor on performance, though stress is also a statistically a significant factor on performance. It is suspected that since the number of subjects in each group was not uniform, we were not able to capture the effect of stress on performance. A t-test was conducted with subjects completing either Phase I test or Phase II test and results confirmed statistically that stress is a concerning factor. Similarly, a paired t-test was conducted when the same subjects participated a second time either in Phase II or Phase I respectively. The results also confirm stress effects task performance.

The ANOVA analysis also showed when IQ' type of task is considered, none of the three factors was statistically significant. The IQ' task is in the general life category with no time pressure. Professional work experience, stress, interactions of phase type, age type, interactions of age type, and experience type affects the PSQ. SA is affected by professional work experience.

Subjects with work experience perform better in both Phase I and Phase II compared to subjects with no work experience. Performance decreased at a higher rate for the age group 31-40. When a histogram is plotted for the Professional work group with the no work experience group, there is a shift of mean values towards higher accuracy for the experienced group. Variability of accuracy is higher for the non professional experience group. The pattern of accuracy for the same subject completing Phase I type test and Phase II type test is similar but when the stress factor is considered accuracy rate is lower. In all cases whether the subjects have professional work experience or have no professional work experience, subjects' accuracy level decreased due to stress. Subjects having work experience in Age Group A performed well in compare to other groups.

There is no linear relationship between task capacity and situational awareness. The performances on time dependent questions were improved when the same subject appeared for the next test. Confidence level is higher when performing without stress as compared to performing with stress.

Out of twenty-seven subjects, six subjects improved their performance level; five subjects remained in the same performance level and sixteen subjects' performance level decreased due to stress. The analysis indicates low level stress effects task performance, significantly.

In today's industry, tasks are becoming more cognitive in nature. Low level stress is neglected when the tasks are cognitive in nature. The low level stress becomes a challenge on cognitive task performance under pressure when repetitive tasks are performed. The method developed in this research is expected to differentiate the type of task functions that are affected significantly when stress is a concern. Self-rated stress measurement examines

what type of tasks may be considered as a stressor to individuals. The current research indicates that low level stress is a concern. In reality, stress is an unavoidable factor in life. When designing a system that involves cognitive tasks, the stress effect on performance needs to be considered.

8.1. Limitations And Future Research Scope

The test is designed with general types of work. It creates a wide range of views even with the same type of questions. In the Delphi study the subjects participated from a different professional working area. It was a challenge to obtain a high level of consensus on designed questions.

There were subjective rating tools implemented in this research which was used to evaluate the present physiological conditions of a subject, but there was a difficulty to know the mental state of the same subject. It was also difficult to have any control on subject's relaxation state before the test.

Current research limited duration of low level stress to ten minutes. In future research, duration of stress may be increased by certain intervals to find a cut-off line or threshold when task performance will decrease significantly.

The current research is considered a complete test with a set of task covering IQ', PSQ and SA. The scope of the research may be changed to include all IQ' types and PSQ types in order to determine which type of task is more affected as a result of stress.

From the study, it was observed that some subjects enjoyed physical stress and some showed concern. To further review and investigate if stress is independent of individual preference will be an interesting approach. Two different groups of subjects can be tested: one group who enjoys working under stress and the other group who does not.

A test scenario can be developed to see if low level stress, which is performed before starting a task with multiple subtasks, has any effect on the task performance at the early portion of the test or at the later portion of the test. A test scenario can be considered for comparing group performance results with that of individual performance after stress.

REFERENCES

Adler, Paul S. (2000). *Time-and-Motion Regained*. Harvard Business Review, January-February 1993.

Aks, D. J., 1998. Influence of exercise on visual search: Implications for mediating cognitive mechanisms. Perceptual and Motor Skills, 87, 771-783.

Arcelin, R., Brisswalter, J., and Delignierres, D., 1997. Effects of physical exercise duration on decision-making performance. Journal of Human Movement Studies, 32, 123-140

Basahel, A. M., Young, Mark and Ajovalasit. 2010. *Impacts of Physical and Mental Workload Interaction on Human Attentional Resources Performances*. Proceedings of ECCE 2010 Conference, 25-27 August 2010, Delft, The Netherlands. 215-217.

Borer KT., 2003. Exercise Endocrinology. Human Kinetics. Champaign, IL.

Borg GA, 1982. *Psychophysical bases of perceived exertion*. Med Sci Sports Exerc. Volume 14. 377–381

Buck, James R. and Wang, Jay-Hone, 1998. *A partial theory and an Engineering Model Predicting Human Performance of Information Seeking Tasks*. Proceedings, Industrial Engineering Research ’98 Conference, Alberta, Canada.

Buckle, P. et al. (2006). *Patient safety, systems design and ergonomics*. Applied Ergonomics / 37 / 491-500.

Cox-Fuenzalida, Luz-Eugenia (2007). Human Factors**,** Vol. 49, No. 2, pp. 277-291.

Delbecq, A. L., Van de Ven, A. H., and Gustafson, D. H., 1975. *Group techniques for program planning: a guide to nominal group and Delphi processes*. Glenview, IL: Scott Foresman and Company.

Edgar, G. K., et al., (2000). *QUASA: Quantifying and Analyzing Situational Awareness.* Paper presented at the IMCD people in digitized command and control symposium. Shrivenham, UK: RMCS.

Edwards, W. (1962). *Dynamic decision theory and probabilistic information processing*. *Human Factors, 4*, 59-73.

Endsley, Mica R. (1995). *Direct Measurement of Situational Awareness in Simulations of Dynamic Systems: Validity and use of SAGAT.* Presented in the International Conference on Experimental Analysis and Measurement of Situational Awareness, Daytona Beach, Florida.

Endsley, Mica R. (1995a). *Measurement of Situational Awareness in Dynamic Systems.* Human Factors, 37(1), 65-84.

Endsley, Mica R., et al., (1998). *A comparative analysis of SAGAT and SART for evaluations of Situational Awareness.* Paper presented for 42nd annual meeting of the Human Factors and Ergonomics Society. Chicago, IL, Santa Monica, CA: HFES.

Endsley, Mica R. et al., (2000). *Situational Awareness in air traffic control: Enhanced displays for advanced operations. DOT/FAA? CT-TN00/01.* Atlantic City, NJ: Federal Aviation Administration.

F., Faul et al., 2007. *G*Power 3: a flexible statistical power analysis program for the social, behavioral and biomedical sciences*. Behavioral Research Methods, 175-191.

Farahmand, Kambiz, Karim, Reza, et al., 2011. *LEAN Enterprise Principles in Healthcare – How to Apply*. The International Journal of Engineering Research and Innovation (IJERI), (in press).

Farahmand, Kambiz, Karim, Reza, et al., 2011. *Clinic Space Design Using Discrete Event Simulation*. Proceedings of the 2011 Industrial Engineering Research Conference, May 21-25, 2011, Reno, Navada.

Fletcher, Gerald F. et al., 2001, *Exercise Standards for Testing and Training: A Statement for Healthcare*. Circulation: Journal of the American Heart Association. 2001.104, 1694-1740

Gawron, V. J., French, J., and Funke, D., 2001. An overview of fatigue. In P. A. Hancock & P.A. Desmond (Eds.), Stress, workload and fatigue. Mahwah, NJ: Lawrence Erlbaum. 581-595.

Gonzalez, Cleotilde (2005). *Task Workload and Cognitive Abilities in Dynamic Decision*. Human Factors**,** Vol. 47, No. 1, pp. 1-10.

Goodman, Ckaire et al. (1987). *The Delphi Technique: a critique*. Journal of Advanced Nursing 12:729-734.

Gopher, D. and Donchin, E. (1986). *Workload – An examination of the concept. Handbook of Perception and Human Performance*. Volume 2. Cognitive Processes and Performance. K.R. Boff, L. Kaufman and J.P. Thomas, John Wiley and Sons, Inc: 41-1:41-49.

Hancock, S. and McNaughton, L. (1986). *Effects of fatigue on ability to process visual information by experienced orienteer*. Perceptual & Motor Skills, 62, pp. 491-498

Hartigan, John A., and Wigdor, Alexandra K. (1989). *Fairness in Employment Testing: Validity Generalization, Minority Issues, and the General Aptitude Test Battery.* National Academy Press, Washington, D.C., pp. 113-116.

Hasson, Felicity et al. (2000). *Research Guideline for the Delphi Survey technique*. Journal of Advanced Nursing 32 (4):1008-1015.

Holding, D. H., 1983. Fatigue. In G. R. J. Hockey (Ed.), 1983. Stress and fatigue in human performance. New York: John Willey and Sons.

Jones, D. G. and Endsley M. R., 2004. Use of real-time probes for measuring situational awareness. The International Journal of Aviation Psychology. 14, 343-367

Joyce, Jennifer et al., 2009. *The time course effect of moderate intensity exercise on response execution and response inhibition*. Brain and Cognition, 71. 14-19.

Jung, Hwa S. and Jung, Hyung-Shik, 2001. Establishment of overall workload assessment technique for various tasks and workplaces. International Journal of Industrial Ergonomics, 28, 341-353.

KABER, D.B., RILEY, J.M., LAMPTON, D. and ENDSLEY, M.R. (2005). *Measuring situation awareness in a virtual urban environment for dismounted infantry training*. In Proceedings of the 1st International Conference on Virtual Reality (CD-ROM), Las Vegas, NV, 22–27 July.

Kroemer, Karl, Kroemer, Henrike and Kroemer, Katrin (2003). *Ergonomics: How to Design for Ease and Efficiency*. Prentice Hall, 2nd Edition.

Lan, Li and Lian, Zhiwei, (2010). *Application of Statistical power analysis- How to determine the right sample size in human health, comfort and productivity research*. Journal of Building and Environment, 45, 1202-1213.

Lazarus, Richard S., 1990. *Theory-Based Stress Measurement*, Psychological Inquiry, Vol. 1, No. 1, pp. 3-13.

Lee, J. D., (1999). *Measuring Driver adaptation to in-vehicle information systems: disassociation of subjective and objective situation awareness measures.* Paper presented for 43nd annual meeting of the Human Factors and Ergonomics Society. Houston, Texas, Santa Monica, CA: HFES.

Lichaz, F. M. J., (2008). *Augmenting understanding of the relationship between situation awareness and confidence using calibration analysis.* Ergonomics, 51, 1489-1502.

McGuinness, B., (2004). *Quantitative Analysis of Situational Awareness (QUASA): Applying signal detection theory to true/false probes and self-ratings.* 2004 command and control research and technology symposium.

McGuinness, B., (2007). S*ignal detection theory and the assessment of situational awareness.* In: M. Cook, J. Noyes and Y. Masakowski, eds. Decision making in complex environments. Aldershot, UK: Ashgate Publishing Ltd., 299-310.

McKenna, Hugh et al. (1994). *The Delphi Technique: a worthwhile research approach for nursing?* Journal of Advanced Nursing 19:1221-1225.

McKillip, J, *Case studies in job analysis and training evaluation*, 2001. International Journal of Training and Development, Vol. 5, No. 4. 283-289.

McMorris, Terry et al., 2011. *Acute, intermediate intensity exercise, and speed and accuracy in working memory tasks: A meta-analytical comparison of effects*. Physiology & Behavior 102. 421-428.

Miller, Robert B. 1974. *A Method for Determining Task Strategies*. American Institutes f or Research in the Behavioral Sciences, Silver Spring, MD. Report number APHRL-TR-74-26.

Mozrall, J. R. and Drury, C. G., 1996. *Effect of physical exertion on task performance in modern manufacturing: A taxonomy, a review, and a model*. Ergonomics, 39 (10), 1179-1213.

Muckler, Fredrick A. 1992. *Selecting Performance Measures: Objective versus Subjective Measurement.* Human Factors, 1992, 34 (4), 441-455.

Paas, F. G., and Adam, J., 1991. *Human information processing during physical exercise*. Ergonomic 34 (11). 1385-1397.

Perry, et al., (2008). *Effect of Physical workload on cognitive task performance and situational awareness*. Theoretical Issues in Ergonomics Science. Vol 9, No. 2, March-April, 95-113

Powell, Catherine (2003). *The Delphi technique: myths and realities*. Journal of Advanced Nursing 41(4):376-382.

Reilly, T. and Smith, D. (1986). *Effect of work intensity on performance in a psychomotor task during exercise*. Ergonomics, 29, pp. 601-606.

Rousseau, Robert et al. (2010), *The Role of Metacognition in the relationship between objective and subjective measures of situation awareness.* Theoretical Issues in Ergonomics Science, Vol 11, Nos 1-2, January-April, pp 119=130.

Rubio, Susana et al., 2004. *Evaluation of Subjective Mental Workload: A comparison of SWAT, NASA-TLX and Workload Profile Methods*. Applied Psychology: An International Review, 53 (1), 61-86.

Salmon, Paul (2006), *Situational awareness measurement: a review of applicability for C4i environments*. Applied Ergonomics, Volume 37, issue 2, pp. 225-238.

Sanders, Mark S. and McCormick, Ernest J. (1993). *Human Factors in Engineering and Design*, McGraw-Hill, 7th edition.

Silver, M.P. et al. (2004). Improving *Healthcare systems performance: A Human Factors approach.* American journal of medical quality 19(3).

Shah, H. A. and Tillman, Tracy S., 2008. *An international Lean Certification Role Delineation Delphi Study Applied to Develop Graduate-level Curriculum in Lean Manufacturing.* The Technology Interface Journal/IAJC-IJME Conference, Fall 2008.

Soemes Job, R. F. and Dalziel, J., 2001. Defining fatigue as a condition of the organism and distinguishing in from habituation, adaptation, and boredom. In P. A. Hancock and P. A. Desmond (Eds.), Stress, workload, and fatigue. Mahwah, NJ: Lawrence Erlbaum. 466-475.

Spear, M.E. (2002). *Ergonomics and Human Factors in healthcare settings*. Annals of emergency medicine 40(2)/213-216.

Srikaew, Twin (1999). *Mental Capacity Testing and Measurement of the Effect of Stress and Environment on Mental Performance*. Texas A&M University-Kingsville.

Taylor, R. M., 1990. *Situational Awareness Rating Technique (SART): The development of a tool for aircrew systems design*. Situational awareness in aerospace operations. AGARD-CP-478 Neuilly-sur-Seine, France: NATO-AGARD, 3/1-3/17

Tomporowski, P. D., & Ellis, N. (1986). *Effects of exercise on cognitive processes: A review*. Psychological Bulletin, 99(3), 338–346.

Tomporowski, P.D., (2003). Effects of acute bouts *of exercise on cognitive.* Acta Psychologica, 112, 297-324.

Trent, Warren C., 1985. *Understanding and Selecting Personnel*. Tyler: Gateway Press, Texas.

Usher, J. M. and Kaber, D. B. (2000). *Establishing information requirements for supervisory controllers in a flexible manufacturing system using GTA*. Human Factors and Ergonomics in Manufacturing, 10, pp. 431–452.

Villiers, Mariet et al. (1987). T*he Delphi Technique in Health Sciences Education Research*. The Journal of Psychology 113:73-80.

Weimer, Jon (1995). *Research techniques in human engineering.* Englewood Cliffs, N.J: Prentice Hall.

Weiss, Elisabeth M. et al., 2003. Sex differences in Cognitive Functions. Personality and Individual Differences, 35, 863-875

Yerkes, R. M., and Dodson, J. D., 1908. *The relation of strength of stimulus to rapidity of habit formation.* Journal of comparative neurology and psychology, vol 18. 459-482.

Young, M.S. and Stanton, N. A. 2002. *Malleable attentional resources theory: a new explanation for the effects of mental underload on performance*. Human Factors, 44. 365-375.

APPENDIX A

Appendix A.1. SAS Program Code For Paired t-Test

```
Title1 'Sample Size Calculations for Paired T-test';
*Title2 'Uses SD=10, Power=.8, Varying Corr. for Common Standard Deviation';
proc power;
  pairedmeans
  test=diff
  corr=.5 to .7 by .1
  meandiff = 2, 3, 4
  stddev=5, 6, 7, 8,
  npairs = .
  Power = 0.8;
  Plot x=power min=.5 max=1
      xopts= (ref=0.8 crossref=yes)
      Vary (color)
      Markers = nice;
  run;
```

Appendix A.2. SAS Program Code For t-Test

The program code:

```
Title1 'Sample Size Calculations for Simple Two Sample T-test';

proc power;

 twosamplemeans

 meandiff=5, 6, 7, 8

 stddev=5, 6, 7, 8

 groupweights= (1 1)

 power=.8

 ntotal=.;

 plot x=power min=.5 max=1

     xopts=(ref=0.8 crossref=yes)

 Vary (color)

 Markers=nice;

 title2 "Task Capacity Uses SD=5, 6, 7, 8 and Power=.8 for Common Standard Deviation";

 run;
```

Appendix A.3. PAR-Q

Physical Activity Readiness Questionnaire: PAR-Q

Note: the PAR-Q must be completed before you can move on to the next assessment.

Regular physical activity is fun and healthy, and increasingly more people are choosing to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor first.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

- ☐ Yes
- ☐ No

Do you feel pain in your chest when you do physical activity?

- ☐ Yes
- ☐ No

In the past month, have you had chest pain when you were not doing physical activity?

- ☐ Yes
- ☐ No

Do you lose your balance because of dizziness or do you ever lose consciousness?

- ☐ Yes
- ☐ No

Do you have a bone or joint problem that could be made worse by a change in your physical activity?

- ☐ Yes
- ☐ No

Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

- ☐ Yes
- ☐ No

Do you know of any other reason why you should not do physical activity?

- ☐ Yes
- ☐ No

Physical Activity Readiness Questionnaire (PAR-Q) and You

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly:

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of any other reason why you should not do physical activity?

If you answered:

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed use of the PAR-Q: Reprinted from ACSM's Health/Fitness Facility Standards and Guidelines, 1997 by American College of Sports Medicine

APPENDIX B. INSTITUTIONAL REVIEW BOARD APPROVAL FORMS

Approval Notice:

NDSU NORTH DAKOTA STATE UNIVERSITY

Institutional Review Board
Office of the Vice President for Research, Creative Activities and Technology Transfer
NDSU Dept. 4000
1735 NDSU Research Park Drive
Research 1, P.O. Box 6050
Fargo, ND 58108-6050

701.231.8995
Fax 701.231.8098
Federalwide Assurance #FWA00002439

June 28, 2011

Kambiz Farahmand
Dept. of INdustrial and Manufacturing Engineering
Rm 202 CIE

IRB Expedited Review of: "**The Effect of Stress on Task capacity and Situational Awareness**", Protocol **#EN11285**
Co-investigator(s) and research team: **Reza Karim**
Research site(s): **NDSU** Funding: **n/a**

The protocol referenced above was reviewed under the expedited review process (category # 4, 7) on **6/22/2011**, and the IRB voted for: ☐ approval ☒ approval, contingent on minor modifications. These modifications have now been accepted. IRB approval is based on the original submission, with revised: protocol and consent form (received – 6/27/2011).

Approval expires: 6/21/2012 **Continuing Review Report Due: 5/1/2012**

Please note your responsibilities in this research:

- All changes to the protocol require approval from the IRB prior to implementation, unless the change is necessary to eliminate apparent immediate hazard to participants. Submit proposed changes using the *Protocol Amendment Request Form*.
- All research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others must be reported in writing to the IRB Office within 72 hours of knowledge of the occurrence. All significant new findings that may affect risks to participation should be reported in writing to subjects and the IRB.
- If the project will continue beyond the approval period, a continuing review report must be submitted by the due date indicated above in order to allow time for IRB review and approval prior to the expiration date. The IRB Office will typically send a reminder letter approximately one month before the report due date; however, timely submission of the report is your responsibility. Should IRB approval for the project lapse, recruitment of subjects and data collection must stop.
- When the project is complete, a final project report is required so that IRB records can be inactivated. Federal regulations require that IRB records on a protocol be retained for three years following project completion. Both the continuing review report and the final report should be submitted according to instructions on the *Continuing Review/Completion Report Form*.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB regulations.

Thank you for cooperating with NDSU IRB policies, and best wishes for a successful study.

Sincerely,
Kristy Shirley
Kristy Shirley, CIP, Research Compliance Administrator

Last printed 6/28/2011 12:03:00 PM

IRB Protocol Form:

Institutional Review Board …for the protection of human participants in research

Date Received

North Dakota State University
Sponsored Programs Administration
1735 NDSU Research Park Drive
NDSU Dept #4000
PO Box 6050
Fargo, ND 58108-6050 231-8995(ph) 231-8098(fax)

IRB Protocol #:

IRB PROTOCOL FORM

Application to Conduct Research Involving Human Participants

1.Title of Project: **The Effect of Stress on Task capacity and Situational Awareness**

2. Principal Investigator: **Dr. Kambiz Farahmand** Dept. name: **Industrial and Manu. Engg.**

(PI must be an NDSU faculty or staff member; graduate students must list their advisor as PI)

Campus address/phone: **Room 202 Civil & Industrial Engg. Bldg.**

Email address: **Kambiz.Farahmand@ndsu.edu**

Specify role in this research: **direct/supervise research Supervise Research**

Highest earned degree and field of study: **Ph.D. in Industrial Engg.**

3. Co-Investigator(s): **Reza Karim** Dept. name: **Industrial & Manufacturing Engg.**

Campus address/phone: **202 Civil & Industrial Engg. Bldg.**

Email address: **Reza.Karim@ndsu.edu**

Specify role in this research: **direct/supervise research Direct Research**

Highest earned degree and field of study: **M.S. in Mechanical Engg.**

4. Research team: *List all NDSU students, faculty or staff who will assist in the project (project design/oversight, recruiting participants, obtaining informed consent, intervening or interacting with participants to obtain information/data, and/or handling identifiable information for research purposes). May provide as a separate attachment.*

Name, dept. or affiliation: Specify role in research: Training date (IRB office only)

Reza Karim, IME	Project Design, recruit participan obtain consent, interacting with participant to obtain data, handle identifiable information for researc purposes, collect data, data analysi	

Please Note: *Investigators and all members of the research team are required to complete a course in the protection of human research participants prior to protocol review. This training must be current (within the last 3 years). Refer to the 'Training' page of the IRB website for information and links to online training sessions.*

5. Project dates: indicate the anticipated start and end dates for research procedures involving human subjects: *(Note that start date should allow sufficient time for IRB*

review and approval; no research procedures involving human participants may begin prior to obtaining notification of IRB approval.)

Anticipated start date: After IRB approval

Anticipated end date: December 15, 2011

6. Requested review category: *(final determination will be made by the IRB)*

☒ Expedited review *(*Include the Expedited Review Categories attachment)*

☐ Full board review

Project Description

Use plain language, avoiding technical terms or jargon, unless explained. The description should be understandable to any person unfamiliar with the area of research. Include a brief summary of the pertinent literature with citations, if applicable.

1. Purpose and goals of the research:

The research is designed to find the effect of stress on task performance. The test methodology that is developed here, measures cognitive task performance capacity, and situational awareness. Cognitive task capacity and situational awareness of a subject is measured before and after doing a low level of physical exercise. The individual response is obtained in the form of true or false response with confidense level of individuals of doing each task. The task battery developed will compare task capacity among different age and sex group. Response time, accuracy and repeatability are measured for statistical analysis. It compares pre and post stress effects on task performance. A stress

level is measured of the subject before participating on the test using a questionnaire. A group of students age 21 and above from NDSUand professionals working in different fields is considered as test subjects for the task measurement. The physical stress is expected to play a major role on the variability of task performance.

2. Method and procedures: *Explain in detail what subjects will be asked to do or what information will be collected about them. Specify when or how often research procedures will be conducted. Provide a timeline or schedule of events, if applicable. May be provided as a separate attachment, with numbered pages.*

Subject will participate in a computer test. The test is designed to cover human task capacity and situational awareness in the following area:

- Computation
- Three-dimensional review
- Vocabulary
- Pattern recognition
- Comparison
    - Arithmetic reasoning

The information collected about the subject in the computer test will be sex, race, occupation. Name and date of birth (excluding year) will only be stored in the paper records. The user name and password will be saved in the paper record. This user ID and password will be given to the participant, so he or she can log-in and put all other information described earlier in computer test.

The informed consent will be obtained from participants after the participants verbally agree to participate and shows up for the test in the Human Factor Lab of IME, NDSU. The participant will be shown the arrangement of the test site, and explained the procedure of the test at the time of participation and if participant wants to continue to do the computer test, the consent form will be signed.

Please provide additional information regarding the physical activity to be performed in Session 2. For instance, how intense will the exercise be? Is there any research to support the length of time chosen for the activity/physical stressor intervention?

Please see attachment saved as #2 for detail information.

Borg Scale rating will be used as a subjective rating of the participant's stress level and verbal expression will be used to rate the scale to utilize sensory rating rather than cognitive frame expression (Borg GA, 1982, "Psychophysical bases of perceived exertion," Medicine and Science in Sports and exercise, Vol 14, pp 377-381). The verbal rating will reduce the Borg Scale review differences from person to person. And also to reduce variability among participants we are using 'Physically fit' factor and PAR-Q checklist to physical condition. We are looking at the stress rating of 11 or below from the Borg scale while gives us a

better deterministic factor of the low level stress.

Guideline for Workload:

Step 1: Warm-up time for 2-3 minutes with a resistance of 0 Kg and RPM of 50.

Step 2: 1st stage workload of for 3-4 minutes at 150 kg.m/minute (=25 Watt).

[Workload=Resistance (Kp) X Revolution /min (RPM) X Flywheel Travel Distance (m.rev-1)]

In this stage 0.5 Kg weight is considered)

Step 3: 2-3 minutes at 600 Kg.m/minute (=100 Watt)

Step 4: Verbally Borg stress rating will be asked to the subject

Limiting Traveling Distance of biking = (50 rpm X 6 m.rev-1) X 10 min =3000 m = 1.86 miles ~ 2 miles (approximately).

This study is broken into two phases performed sequentially. The time gap between two phase test is at least one week and could be a month depending on the avaialability of the subject.

Phase I:

It will be conducted to determine task capacity and situational awareness simultaneously with a set of tasks in the form of questions. The subject will come at the test site in Human Factor Lab of Industrial Engg. Dept.The subject will sit infront of the computer and adjust chair to a comfortable position. The subject is given a user name and a password to enter into the test site

(www.greenhorizon.us) in the computer. There will be thirty experimental questions for each subject in Phase I test. Subjects in phase I will perform approximately thirty minutes per test. The room air temperature and relative humidity is not altered from the central set value. Subject will be provided the description of the test followed by a tutorial on what type of questions to expect and how to select the answers. Subjects will answer six stress level measurement questions before starting the test. And after completing the test subject will be asked to complete another stress meaasurement questionnaire . The detail of the test is attached and specified as" Methods and Procedures".

Phase II:

Subject will appear in the test site (Human Factor Lab of Industrial Engg. Dept.) and perform 10 minutes of biking. Right after completing the biking the subject will appear in the test. The test materials and setup of the test is same as phase I.

3. Project/performance site(s): *Specify where the research will be conducted.*

The test site will be Human Factor Lab of Industrial Engg. department, NDSU. This is a regular room and it is chosen to provide a quite environment to the participant.

4. Research design and analysis plan: *If applicable, describe the sampling plan, the size of the sample or study group(s), and the power of the planned statistical tests.*

☐ N/A

Sixteen subjects are desired with a minimum of eight able to complete both the two phases of experiment. This sample size provides a statistical power (Montgomery, 2001), 1-β, of 0.95 when using an analysis of variance to compare mean task capacity of at least eight individuals participating in the experiment assuming the study detects task capacity differences of 15% between phase I and phase II with a standard deviation of 7. The goal is to have a balanced experimental design for subsequent statistical analysis. It is desired that the same eight subjects participate in both experimental phases. However, if subject drops out after completing phase I they will not be replaced by other volunteers during phase II. Instead, phase I will be participated by more than minimum desired volunteers.

5. Additional materials: Will the research involve use of data, documents, records or specimens that have already been collected (pre-existing) from individuals, or will be collected solely for non-research purposes?

☒ No

☐ Yes: a. Complete the *'Additional Materials' attachment.*

b. If the research will be *limited* to use of these pre-existing materials, or materials collected solely for non-research purposes *(research will not involve interaction, intervention or observation of human research participants),* then skip to the 'Risks and Benefits' section. Also complete the *'Informed Consent Waiver or Alteration Request'* if the requirement for informed consent is requested to be waived.

Recruitment

Selection of research participants must consider the following: research setting, equitable recruitment potential for coercion or undue influence, and vulnerable groups.

1. Research participants and recruitment methods: Describe participants, including approximate #, age-range, or any other relevant characteristics. Also describe in detail how they will be selected, identified contacted or approached to participate in the research:

Approximately 16 subjects are desired to complete both the two phases of experiment. Age range from 21 to 40. The selection process is random, anyone who is physically fit will be able to participate in the test. Physically fit means the subject does not have any limitations using mouse, and as well biking.

Physically fit means the subject does not have any limitations using mouse, and as well biking a stationary bike. A Monark Ergometer (Cardio Care 827E) at the workload of 100 watts (low level) will be used for biking. Physical Activity Readiness Questionnaire (PAR-Q) to assess whether potential participants have any risk factors for participating in physical exercise (attached).The original copyrighted PAR-Q form obtained from IRB office will be used . If the subject responses 'YES' to any of the PAR-Q question then the subject will be requested not to continue the test. This form will be given to the subject before the Phase I test and before signing the consent form.

NDSU listserve will be used to email students as well faculties of NDSU to participate in the test. Individual apporoach (through contacts) using e-mail will be conducted to recruit subjects working in other facilities around Fargo area.

Please find attached a copy of "script" which will be e-mailed to recruit subjects.

Attach a copy of any oral script, advertisement, announcement or preliminary invitation that will be used.

2. Describe any inclusion/exclusion criteria that will be used for subject selection, if applicable: ☒N/A

Anyone who is physically fit can participate in the test. Physically fit means the subject does not have any limitations using mouse, and has no physical limitation in biking. Please find attached PAR-Q form that would be used to determine the physical fitness of the subject.

3. Vulnerable populations: Indicate if individuals from any of the following groups will be specifically targeted:

☐ minors (under age 18) - *also complete the 'Children in Research Attachment' form.*

☐ prisoners - *also complete the 'Prisoners in Research Attachment' form.*

☐ pregnant women, fetuses or neonates

☐ cognitively impaired individuals – may require consent of a legally authorized representative

☐ economically disadvantaged persons

☐ educationally disadvantaged persons

☒ N/A - None of these groups will be specifically recruited

If any vulnerable populations will be recruited, indicate what additional safeguards will be included to protect participants' rights and welfare:

N/A

4. Compensation: Will participants or others are offered incentives for the research (i.e., gifts, payment, reimbursement, services, extra course credit, or other forms of compensation)? *Compensating participants for their time and effort is appropriate, although the amount of compensation must not cause undue influence to participate in a study. Any compensation should also be pro-rated, rather than awarded only on completion of the study. If research will involve compensating students with extra credit, specify the amount of extra credit, and what non-research alternatives (equal in time and effort) are available to the students for earning extra credit.*

☒ No

☐ Yes - provide details of the compensation scheme :

5. Alternatives to research participation: Describe any alternative procedures available to those who choose not to participate, if applicable.

☒ N/A

N/A

6. Dual relationships*: Does the investigator, co-investigator, any member of the research team, or anyone else assisting with the research has an authority relationship (e.g.,

instructor/student, employer or supervisor/employee, physician/patient, or other) with potential participants?

☒ No

☐ Yes - describe the relationship, and indicate how the research will be conducted to avoid undue influence on participants:

7. Will any aspect of the research be conducted in a classroom setting during class time?

☒ No

☐ Yes - describe what those who choose not to participate will be doing, and provide justification for use of class time for research (Attach course syllabus):

Informed Consent

Potential subjects must be provided with complete and easily understandable information about the study, fully informed of the voluntary nature of their choice, and given sufficient opportunity to consider participation in an environment that is free of coercion or undue influence. Participants cannot be made to waive any of their rights, or release the investigators, sponsor or institution from responsibility for any research-related harms.

1. Informed consent*: Explain procedures for obtaining informed consent from participants, their parent/guardian, or legally authorized representative. Be specific regarding who will obtain informed consent, and in what setting/time frame:

Reza karim will obtain informed consent from the participant. The consent will be obtained if the participant decides to participate in the test. This will be done at Human Factor lab of IME department prior to appearing at the test. The test schedule is flexible whenever the participant has time will be conducted. All participant age appearing for the test will be 21 and 40. Consent Form attached

Attach as applicable: informed consent form, parent/guardian permission form, child/youth assent forms to be used. Templates may be found on the IRB website 'Forms' page. *(Alternatively, a short form written consent document may be used, along with an oral presentation of the elements of informed consent. See IRB Standard Operation Procedures 9.2 Documentation of Informed consent.)*

2. Will all adult participants have the capacity to consent? *Individuals who lack the capacity to consent (as a result of either a permanent or transient condition) may participate in research only if a legally authorized representative (LAR) gives consent on their behalf. For more information, please see the National Institutes of Health guidance at: http://grants.nih.gov/grants/policy/questionablecapacity.htm Also, please see Standard Operating Procedure 10.3 Other Vulnerable Groups.*

☒ Yes

☐ No - explain how legally authorized consent will be sought:

3. Will all participants (and their parents/guardians or legal representatives, as applicable) be fluent in English?

☒ Yes

☐ No - explain how informed consent will be obtained, and provide a copy of the translation to be used:

4. Will the research be conducted at an international site(s)?

☒ No

☐ Yes - indicate site(s) and investigators' familiarity with the culture/cultural norms, whether or not the different cultural context presents any problems or risks that need to be addressed, and how those issues will be handled:

5. Withholding information from participants, or use of deception: Will the research involve purposely withholding some or all information about the research from participants prior to their involvement, or involve any use of deception?

☒ No

☐ Yes - Attach the '*Informed Consent Waiver or Alteration Request*.'

6. Is a waiver of the signature requirement requested? *Participants will be provided with full information about the research, but their signature will not be required. Agreement will be obtained in another manner*.

☒ No

☐ Yes - Attach the '*Informed Consent Waiver or Alteration Request'*.

Risks and Benefits

Risks to subjects must be minimized by using sound research design, procedures that do not unnecessarily expose subjects to risk, or procedures that are already being performed on subjects for diagnostic or treatment purposes. Risks must be reasonable in relation to any anticipated benefits.

1. Risks: Indicate all potential risks of harm/discomfort to subjects or others in this research:

☒ Privacy

☐ Psychological

☐ Social

☐ Legal

☐ Economic

☒ Physical

☐ Dignitary

☒ Other -

There is no other information about the participant except name and age group, sex, occupation, race and only month & day of date of birth will be obtained. The mentioned information will not be able to identify the participant. Besides given USER NAME will be used to evaluate data. Only Reza karim will have access to the database where USER NAME relates information about the participant.

During biking if the participant feels discomfort the test will not be done on that day. The type of bike which will be used has no open exposure of moving parts resulting there is no possibility of getting injured.

2. Protection against risks: Describe each possible risk of harm/discomfort, including the probability and magnitude, as well as the steps that will be taken to minimize these risks for subjects or others:

There is no other information about the participant except name and age group, sex, occupation, race and only month & day of date of birth will be obtained. The mentioned information will not be able to identify the participant. Besides given USER NAME will be used to evaluate data. Only Reza karim will have access to the database where USER NAME relates information about the participant.

During biking if the participant feels discomfort the test will not be done on that day. The type of bike which will be used has no open exposure of moving parts resulting there is no possibility of getting injured.

3. Describe what steps will be taken if participants experience serious injury, distress, discomfort or decompensation during research participation:

☒ N/A

4. Risk category: Categorize the level of risk you consider appropriate for the research: *Federal regulations define 'minimal risk' as the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.*

☒ No more than minimal risk

☐ A minor increase over minimal risk*

☐ More than a minor increase over minimal risk*

4a. Indicate what provisions will be taken to monitor the data collected to ensure the safety of subjects, and report unanticipated problems involving risks to subjects or others.

N/A

5. Benefits and risk-benefit analysis: *Describe any potential benefits to participants and/or society in general. Explain why the risks should be considered reasonable in relation to any anticipated benefits and/or in relation to the importance of the knowledge that is expected to result.*

The potential benefits to the society: The current research focuses on standardizing the task functions to measure individual task capacity. In a dynamic and complex work environment to measure Cognitive Capacity and Situational Awareness simultaneously using a single tool expected to be a useful application in manufacturing industries. The low level stress becomes a challenge on cognitive task performance when repetitive tasks are performed. The method developed in this research is expected to differentiate

the type of task functions that are affected significantly when stress is a concern. Self-rated stress measurement examines what type of tasks may be considered as a stressor to individuals.

6 Clinical trial: *NIH defines a clinical trial as a prospective biomedical or behavioral research study of human subjects that is designed to answer specific questions about biomedical or behavioral interventions (drugs, treatments, devices, or new ways of using known drugs, treatments, or devices). Behavioral studies involving an intervention to modify behavior (diet, physical activity, cognitive therapy, etc.) also fit the definition of a clinical trial.*

☒ No

☐ Yes - indicate what provisions will be taken to monitor the data collected to ensure the safety of subjects, and report unanticipated events involving risks to subjects or others: (*may provide as an attachment)*:

Data and safety monitoring information:

http://grants2.nih.gov/grants/policy/hs/data_safety.htm *) Clinical trial registration requirement: Federal law requires pre-registration of clinical trials involving FDA-regulated drugs, biologics and devices. See FAQs at: http://prsinfo.clinicaltrials.gov. Also note that some journals and sponsors may require registration for all clinical trials, including those involving only social or behavioral interventions.*

7. Use of human blood, tissues, or specimens:

☒ No

☐ Yes – Project also requires review/approval from the Institutional Biosafety Committee.

If an NDSU employee will handle human blood/tissues/specimens, participation in NDSU's Bloodborne Pathogen Program is also required; contact the University Police and Safety Office for more information.

8. Investigational use of a drug, biological product, medical device, or other product regulated by the FDA:

☒ No

☐ Yes - Attach additional information regarding risks and FDA approval status.

Instrument(s)

Provide the list of survey, interview or focus group questions, or oral history objective (may be provided as a separate attachment)

Privacy and Confidentiality

When appropriate, there must be adequate provisions to protect the privacy of subjects and maintain the confidentiality of data.

1. Confidentiality: Describe whether or not participants will be promised confidentiality of their responses or information. Include who will have access to individual data, and how results will be reported:

Yes, participant will be promised confidentiality. Reza Karim (Co-investigator) will have access to the data. Results will be published in pdf format and handed to the

individual participant if participants desires to have results after completion of the tests. Only the individual result will be handed to the participant. Only the user name (here user name is the code number 01, 02, 03 and so on given to the partcipant before appearing at the test) given to the participant will be reported in publication.

2. Identifiable information: Will any information be collected, even temporarily, that could potentially identify an individual? *(This would include not only names, personal ID #s, address, video or audio recordings, or other direct identifiers, but also may include certain demographic or unique information that would enable an individual's identity to be deduced.)*

☐ No

☒ Yes:

2a. Describe use of any identifying information, including codes, or linkages to identifiers; and indicate why these are necessary for the research:

Numbering code (such as 01, 02 etc.) will be used to identify each participant. This is necessary because same participant is expected to appear in phase II experiment, so the person can login using the same user name and password.

2b. Indicate whether these identifiers, codes or linkages will be retained after data collection, and if they will be removed at some point:

Only code will remain for data analysis purpose.

2c. Would identification of subjects or their responses place them at risk of: ☐ criminal liability, ☐ civil liability, or be damaging to their: ☐ financial standing, ☐ employability, ☐ insurability, ☐ reputation, or be ☐ stigmatizing?

☒ N/A

3. Video/audio tape recording*: Will participants be recorded (e.g., audio, video)?

☒ No

☐ Yes - describe the type of recordings and specify how they will be used, stored/secured, and their final disposition *(also provide this information to participants on the consent document)*:

**Note that recordings are considered individually identifiable.*

4. Data safeguarding procedures (hard-copy records): Specify the physical security procedures that will be used to prevent a breach of confidentiality of participants' information during data collection, transfer, analysis and storage:

☒ N/A

Advisor office (PI) will be used to store the paper document which is locked when the advisor is not at the office. Name and date of birth (excluding year) will only be stored in the paper records. The user name and password will be saved in the paper record. This user ID and password will be given to the participant, so he or she can log-in and put all other information described earlier in test.

5. Data safeguarding procedures (electronic records): Specify the electronic security procedures that will be used to prevent a breach of confidentiality of participants' information during data collection, transfer, analysis and storage (*i.e., password authentication, use of unique log-ins, data encryption, secure server, firewall, latest anti-virus protection, etc. Research data should be stored on computers maintained by NDSU ITS, or that conform to NDSU ITS standards)*: ☒ N/A

All the electronic records will only be accessed by Reza karim. No other person will have access to the database. Initially the data will be collected in the database (www.greenhorizon.us). Then it will be downloaded in the IME, NDSU computer in Reza Karim's Z drive. Only the coded name data (example 01, 02, 03 etc.) will be saved in the computer Z drive. All the data security, firewall, latest anti-virus provided by IME/ITS of NDSU is applicable here. The site (www.greenhorizon.us) administrator is Reza karim. He will only access to the database.

1. Go daddy server database security provided by the server itself.
2. Asp.net is used to develop the input forms, security is provided by the Asp.net, and where user ID and password is used to protect the data form.
3. While downloading from the server to local computer at NDSU: Antivirus (McAfee) + Firewall.
4. Local server security where the data is downloaded is provided by the local NDSU server provider.

6. Mandated reporting responsibility: Is there is a possibility that certain information will be obtained in the course of the research that you will be legally obligated to disclose to the proper authorities (e.g., child abuse, or other abuse, or threats of harm)?

☒ No

☐ *Yes –describe:

* This must also be disclosed to participants in the consent document.

***Note**: For some studies involving sensitive data collection, a Certificate of Confidentiality may be obtained from the National Institutes of Health to protect an individual participant's information from involuntary disclosure. Visit the NIH website for more information.*

Other Information

1. Conflict of Interest: does the Principal Investigator, Co-Investigator, or other key personnel have a conflict of interest (financial or other conflict) in the results of this project? *Note: A significant conflict may require disclosure to participants in the informed consent form.*

☒ No

☐ Yes:

1a. Identify the individual and explain the nature of the potential conflict of interest :

1b. Explain how this potential conflict will be managed:

2. Funding: Will external funds be used for the project?

☒ No

☐ Yes*- indicate the name of the agency, title of proposal, and funding status:

Sponsor agency:

Proposal title:

Funding status:

***Note**:

- **Attach a copy of final grant application, agreement or contract with this application.**
- The IRB is required to review funding applications to federal agencies and must receive a copy of the final proposal in order to verify consistency between the IRB protocol and the grant application.
- If external funds will be used for the project, the Sponsored Programs Administration requires internal approval of the proposal. Consult the SPA website (http://www.ndsu.edu/research/spa/index.php) for more information.

3. Other institution(s): Are any outside entities engaged in this research (e.g., receiving a direct award, grant or contract to perform research, directing or supervising the research, intervening and/or interacting with participants for research purposes, obtaining informed consent, obtaining private identifiable information or specimens from any source for research purposes, or utilizing private information or human specimens for FDA regulated research)? For additional information, please see the 'NDSU Collaborative, Multi-Site or Off-site Research Worksheet' available on the 'Forms' page of the IRB website.

☒No – *skip all remaining questions*

☐ Yes – name entity or institution, contact person(s), and describe their role in the research:

Name of outside entity or institution: **Contact person:** **Their role in the research:**

3a. Other IRB review: Has/will this project be submitted to another IRB for review?

☐ Yes* - name of IRB and status of the application:

*Attach a complete copy of the protocol reviewed and the IRB's determination. *(if not immediately available, may be forwarded upon receipt)*

☐ No: provide either:

- a letter of permission/cooperation stating:
  - a brief description of the entity's role in the research that appropriate training will be completed prior to involvement of human subjects
  - the project will be conducted according to the approved protocol and NDSU policies for protecting research subjects.

***NOTE**: If letter(s) or approval(s) from sites or collaborator(s) are not immediately available, the IRB may approve the protocol provided that:*
1) all other requirements are met, and
2) the documentation from the site(s) will be forwarded to the IRB prior to initiating research at each site.

Investigator's Assurance

The signature(s) below certify that:

- information provided in this application is complete and accurate*
- the principal investigator has the ultimate responsibility for the protection of the rights, safety and welfare of human subjects and the ethical conduct of this research

- each individual listed as principal, co-investigator, or research team member has received the required human research protections education
- each individual listed as an investigator or member of the research team possesses the necessary experience for conducting research activities in their assigned role, and is aware of and will abide by NDSU policies and procedures for the protection of research participants
- no research procedures with human subjects will be initiated until documented approval has been obtained from the IRB Office
- the research will be conducted according to the protocol approved by the IRB, in accordance with NDSU policies and procedures

_____

Principal Investigator signature, date

_____

Co-investigator (s) signature, date

The signature below certifies that:

- the research is scientifically valid;
- the investigator(s) and their team are qualified to conduct the project;
- facilities, equipment, and personnel are adequate; and
- continued guidance will be provided as appropriate.

_____

Chair, Dean or Director* signature, and date:

** If PI is Dept. Chair, College Dean must sign*

* Carefully review the application to ensure it is complete, contains sufficiently detailed responses to all questions, and all attachments. Incomplete applications will be returned without IRB review or approval, potentially delaying the research. Contact the IRB Office for questions or assistance at: 231-8995 or 231-8908.

Expedited Review Form:

Institutional Review Board …for the protection of human participants in research

North Dakota State University

Date of Receipt

IRB Protocol #:

Attachment: Expedited Review Categories

Include this attachment with the protocol form if the project is eligible for expedited review.

Title of Project: **The Effect of Stress on Task capacity and Situational Awareness**

Principal Investigator*: **Dr. Kambiz Farahmand**

*(*must be an NDSU faculty or staff member)*

Applicability Criteria

Federal regulations allow certain categories of research to be reviewed via an expedited review procedure (as described in 45 CFR 46.110 and 21 CFR 56.110). The categories listed here apply regardless of the age of subjects, except as noted. The standard requirements for informed consent (or waiver or alteration of consent) apply for both expedited and full board review.

Research is eligible for expedited review only if all the following conditions are true:

☒ **True** ☐ **False:** The research will involve no more than minimal risk* to human subjects *('Minimal risk' means the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests)*

☒ **True** ☐ **False:** The only involvement of human subjects will be in one or more of the following categories.

☒ **True** ☐ **False:** The research is *not* Federal Classified Research involving human subjects. Federal classified research is defined as, research where knowledge of the procedures and results of which, is restricted to individuals with United States government security clearance.

☒ **True** ☐ **False:** The research will implement reasonable and appropriate protections to ensure that risks related to invasion of privacy and breach of confidentiality will be no more than minimal if identification of subjects or their responses would reasonably place the subjects at risk of criminal or civil liability or be damaging to their financial standing, employability, insurability, reputation, or be stigmatizing.

Expedited Review Categories

Check all categories that apply to the research.

☐ **Category #1: Clinical studies of drugs and medical devices only when:**

(a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or

decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review.), or
(b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

☐ **Category #2: Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture:**

(a) from healthy, non-pregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or

(b) from other adults and children, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

☐ **Category #3: Prospective collection of biological specimens for research purposes by noninvasive means.**

Examples:
(a) hair and nail clippings in a nondisfiguring manner;
(b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction;
(c) permanent teeth if routine patient care indicates a need for extraction;
(d) excreta and external secretions (including sweat);
(e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue;
(f) placenta removed at delivery;
(g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor;
(h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques;
(i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings;
(j) sputum collected after saline mist nebulization.

☒ **Category #4: Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves.** *(Where medical devices are employed,*

they must be cleared/approved for marketing. Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)

Examples:
(a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy;
(b) weighing or testing sensory acuity;
(c) magnetic resonance imaging;
(d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography;
(e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

☐ **Category #5: Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for non-research purposes (such as medical treatment or diagnosis).** *(NOTE: Some research in this category may qualify under exemption category #4)*

☐ **Category #6: Collection of data from voice, video, digital, or image recordings made for research purposes.**

☒ **Category #7: Research on individual or group characteristics or behavior** *(including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior)* **or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.** *(NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. This listing refers only to research that is not exempt.)*

(Categories 8 and 9 are only applicable to continuing review.)

☐ **Category #8: Continuing review of research previously approved by the convened IRB where:**

(a) The research is permanently closed to the enrollment of new subjects, **a**ll subjects have completed all research-related interventions, and **t**he research remains active only for long-term follow-up, OR

(b) No subjects have been enrolled and no additional risks have been identified, OR

(c) The remaining research activities are limited to data analysis.

☐ **Category #9: Continuing review of research,** *(not conducted under an investigational new drug application or investigational device exemption)* **where categories two (2) through eight (8) do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified.**

Adult Consent Form:

NDSU North Dakota State University
Industrial & Manufacturing Engineering Department
Room 202 Civil and Industrial Engineering Building
Fargo, ND 58108-6050
701-231-7287

Title of Research Study: The Effect of Stress on Task capacity and Situational Awareness

This study is being conducted by: Reza Karim, Graduate student, Industrial & Manufacturing Engineering department, E-mail address: Reza.Karim@ndsu.edu, Phone: 701-231-5290. Advisor name: Dr. Kambiz Farahmand, Professor, Industrial & Manufacturing Engineering, E-mail address: Kambiz.Farahmand@ndsu.edu, Phone: 701-231-7287

You are invited to participate in this research because you are physically fit and age is 21-40 and above. Approximately 16 participants will be recruited for the research.

What is the reason for doing the study: The purpose of the study is to examine how human task capacity and situational awareness is affected by doing a physical exercise such as biking.

What will I be asked to do? The research will consist of two phases.

- During Session 1, you will give some basic demographic information such as your name, sex, race, occupation and date of birth. You will also be asked to perform a computer test which will measure: computation, three-dimensional review, vocabulary, pattern recognition, comparison and arithmetic reasoning. The first session will take approximately 30 minutes.
- Session 2 will take place at least one week later from first session. And the time difference between two sessions could go more than a month depending on your availability for participating in the session. During this session, you will be asked to bike on a stationary bike for approximately 10 minutes at low level (approximately 1.75 miles). Right after biking you will appear on the computer test. The test material will be same as of the first session. This session will take approximately 40 minutes.

Where is the study going to take place and how long will it take? The study will take place in the Human Factor Lab (Room 212) in Industrial Engineering Department at NDSU. Session 1 will take approximately 30 minutes, and session 2 will take approximately 40 minutes.

What are the risks and discomforts? It is not possible to identify all potential risks in research procedures, but the researcher(s) have taken reasonable safeguards to minimize any known risks to the participant. Potential risks to you are minimal and may include the

possibility of certain changes occurring during the biking portion of the study. This may include increased heart rate and breathing rate, and in rare instances fainting.

What are the benefits to me? You are not expected to get any benefit from being in this research study.

What are the benefits to others? Your participation will help to determine the effect of stress on people working in the industries and doing repetitive jobs daily that involve physical labor.

Do I have to take part in the study? Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time.

There is no cost involved in participating in the test. Instead of being in this research study, you can choose not to participate.

Who will see the information that I give? We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private.

Numbering code (such as 01, 02 etc.) will be used to identify each participant. This is necessary to match data collected from you in Session 1 to data collected during Phase 2.

What if I have questions? Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researcher, Reza Karim at 701-231-5290 or my advisor Dr. Kambiz Farahmand at 701-231-5694.

You have rights as a participant in research. If you have questions about your rights or complaints about this research or to report a research-related injury, you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8908
- Email: ndsu.irb@ndsu.edu
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/research/irb .

Documentation of Informed Consent:
You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

You will be given a copy of this consent form to keep.

_____ _____
Your signature Date

_____
Your printed name

_____ _____
Signature of researcher explaining study Date

Reza Karim
_____
Printed name of researcher explaining study

APPENDIX C

Appendix C.1. Personal Data Collection Sheet

The Effect of Stress on Task capacity and Situational Awareness

For Record

Personal Data Collection Sheet (Paper Portion)

Name: (First/Last) _____

Date of Birth: (Day/month)_____

User ID: _____

Password: _____

----------Detach here ----------

The Effect of Stress on Task capacity and Situational Awareness

For User
User ID: _____

Password: _____

Appendix C.2. Tutorial On Task Capacity And Situational Awareness

The test is designed to cover human task capacity and situational awareness in the following area:

- **Computation**
- **Three-dimensional review**
- **Vocabulary**
- **Pattern recognition**
- **Comparison**
- **Arithmetic reasoning**

Some of the questions are **TIME INDEPENDENT** and some of the questions are **TIME DEPENDENT.**

Following sections demonstrates the TEST setup:

Your Personal information is recorded in this section.

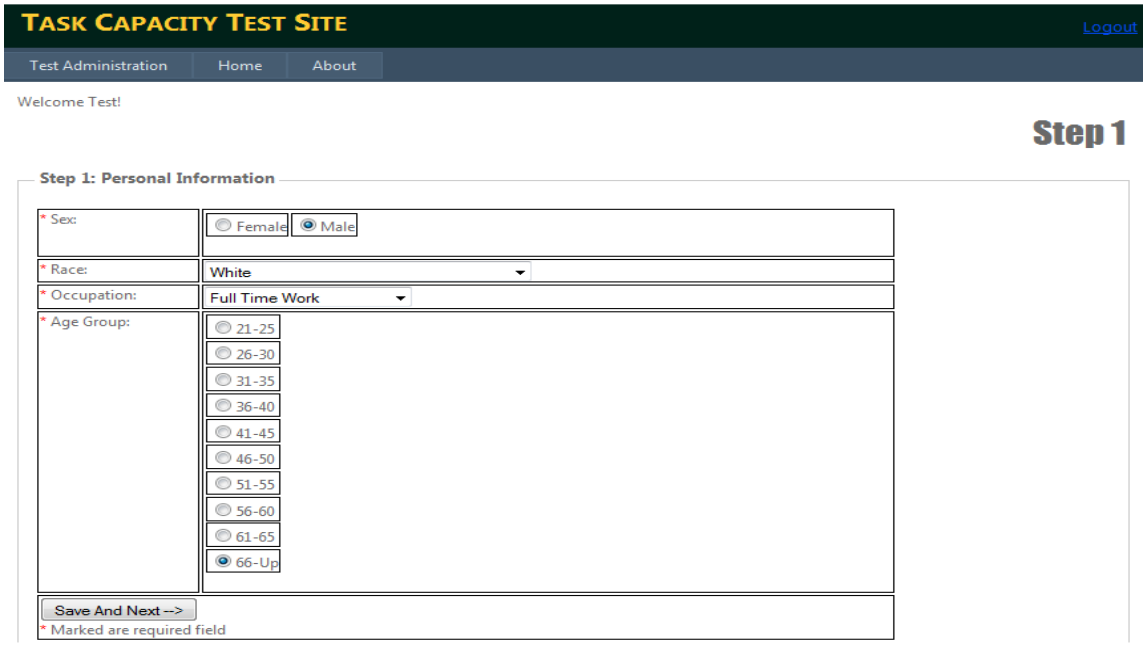


Figure C.1. Personal Information

Please press **Save and Next** button to read the **Instruction**.

Read the Tutorial-How to use the site

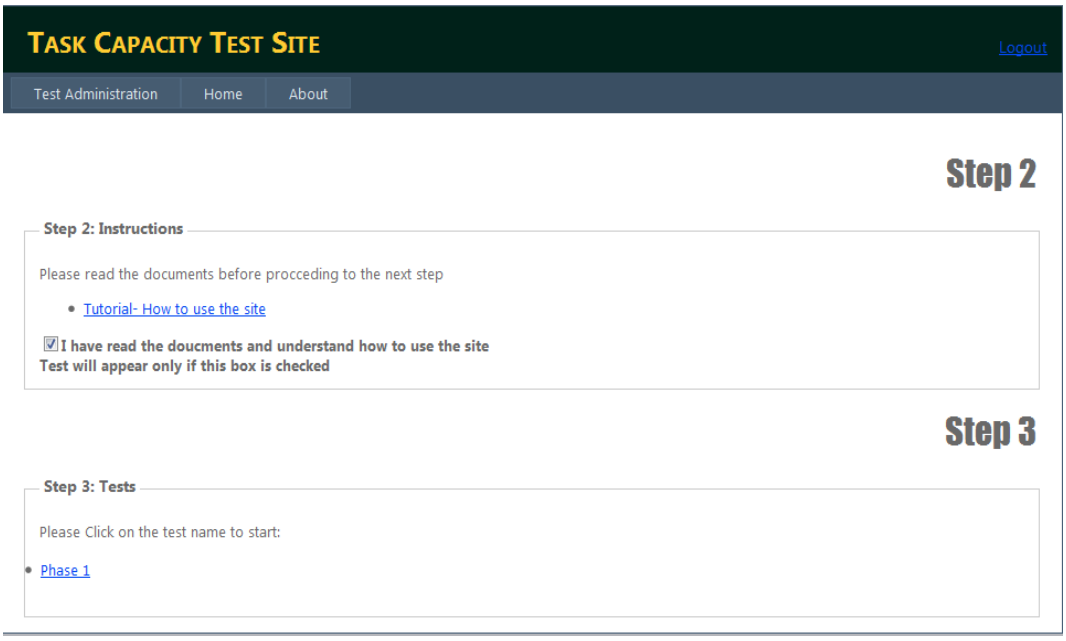


Figure C.2. Confirmation of Tutorial Reading

CHECK the box after reading the tutorial.

Phase I button will appear and click to go to the **TEST**

Your stress level determination question is asked here. You have to select response using desktop-mouse.

Stress Questions:

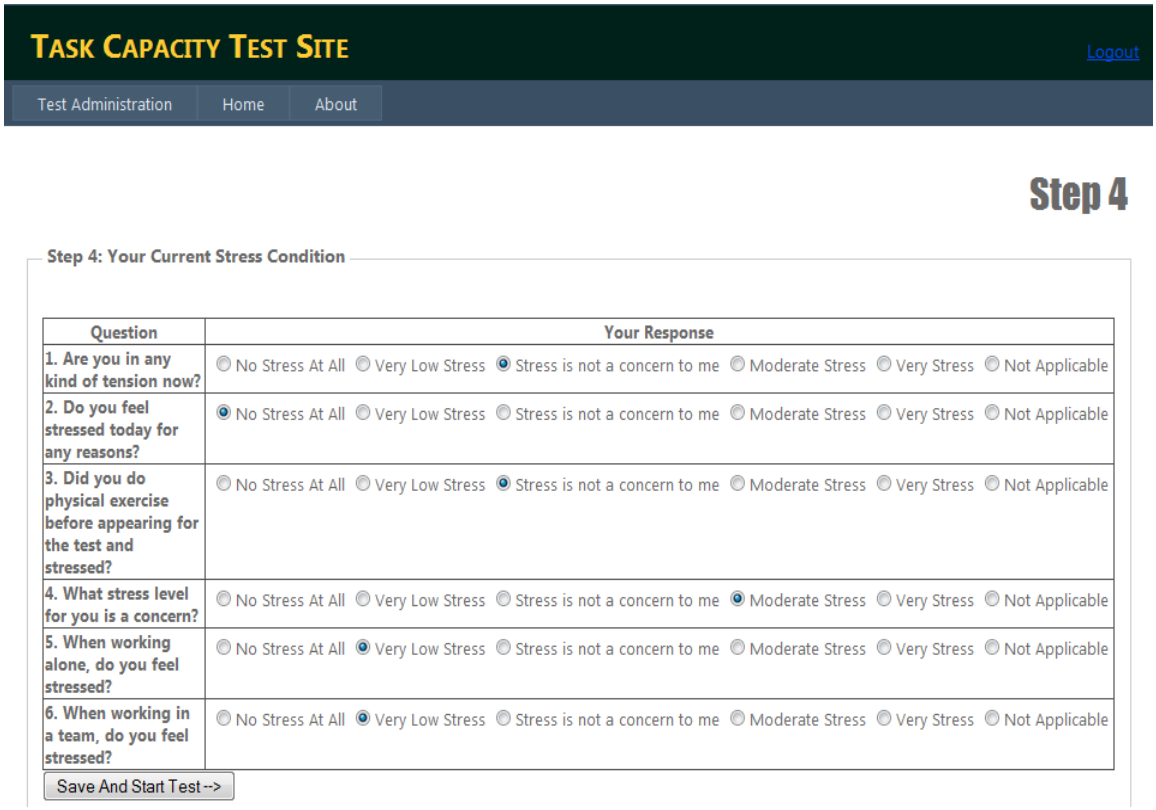
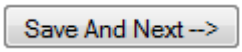


Figure C.3. Current Stress Condition

After the STRESS input the test will start by pressing 

Approximate time of the test is 20 minutes. Following section provides some examples.

Example 1:

Please read the question. It is a comparison Problem. It is a TIME INDEPENDENT question.

Check the given answers and compare with the **Given Answer**.

Select **YES** or **NO** button using the mouse.

Right after selecting YES/NO, pleases select **CONFIDENCE LEVEL** that describes how confident you are on the selected answer.

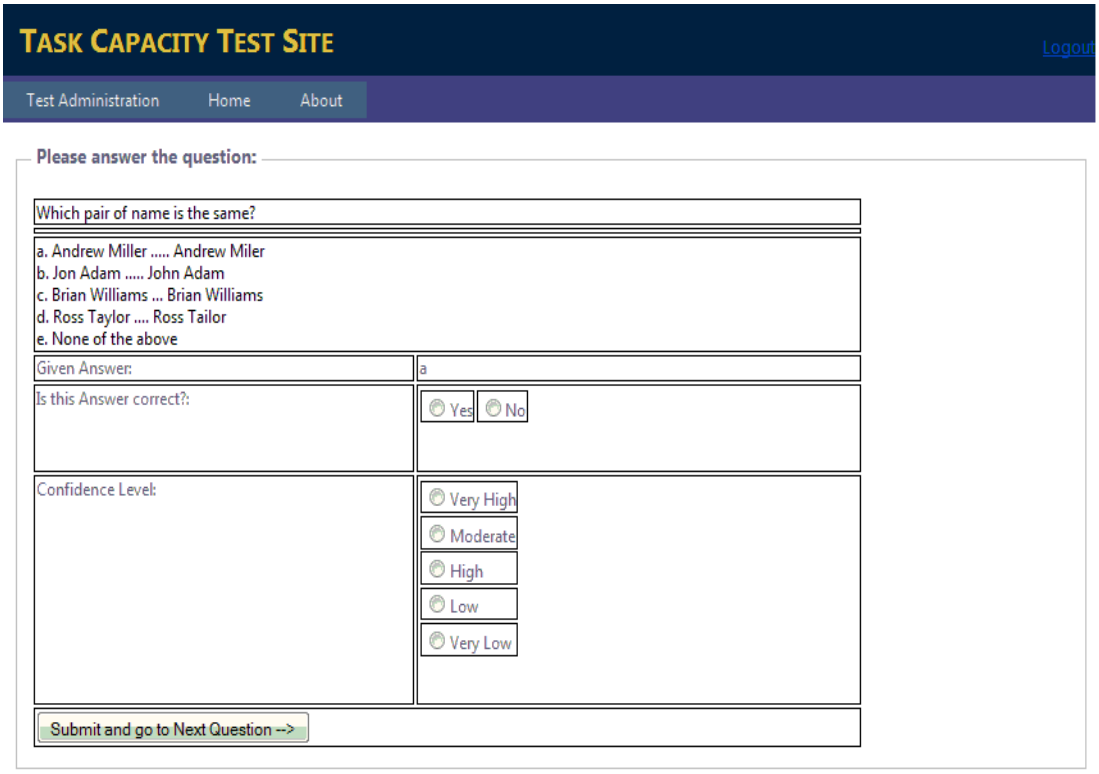


Figure C.4. Sample Question One

Please press **Submit and go to Next Question** button once you are done with the answer and confidence level selection.

Example 2:

Please read the question. It is a computational Problem. It is a TIME INDEPENDENT question.

Check the given answers and compare with the **Given Answer**.

Select **YES** or **NO** button using the mouse.

Right after selecting YES/NO, pleases select **CONFIDENCE LEVEL** that describes how confident you are on the selected answer.

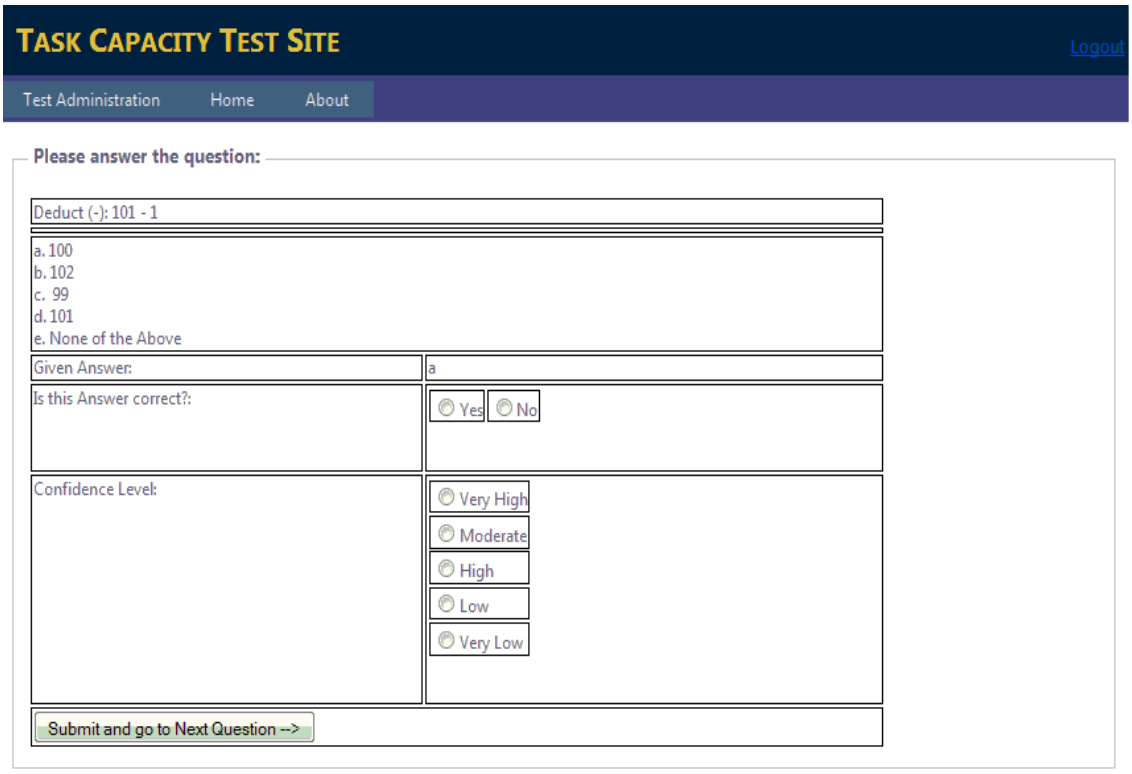


Figure C.5. Sample Question Two

Please press **Submit and go to Next Question** button once you are done with the answer and confidence level selection.

Example 3:

Please read the message while tracking the time button. After a predetermined time of few seconds the message will disappear and question will appear. It is a TIME DEPENDENT question.

Check the given answers and compare with the **Given Answer**.

Select **YES** or **NO** button using the mouse.

Right after selecting YES/NO, pleases select **CONFIDENCE LEVEL** that describes how confident you are on the selected answer.

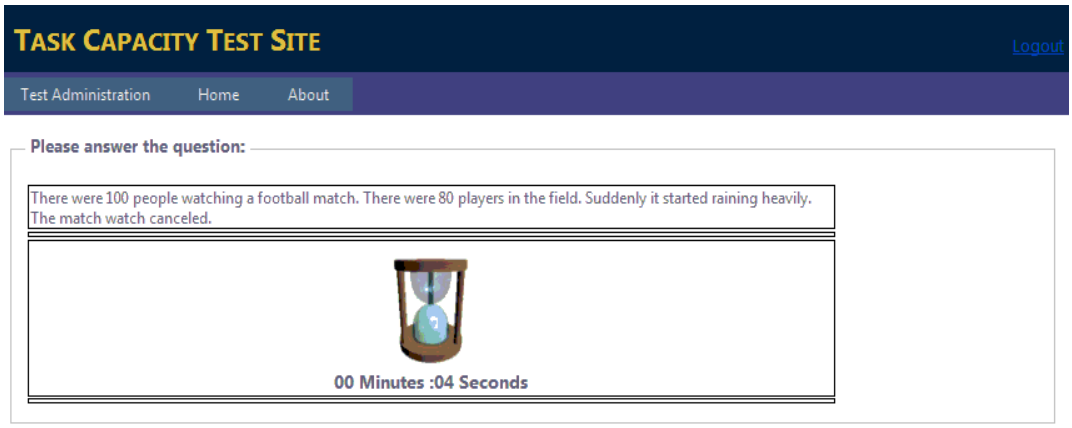


Figure C.6. Sample Question Three-Question is Displayed

After 5 seconds MESSAGE will disappear and QUESTION will appear.

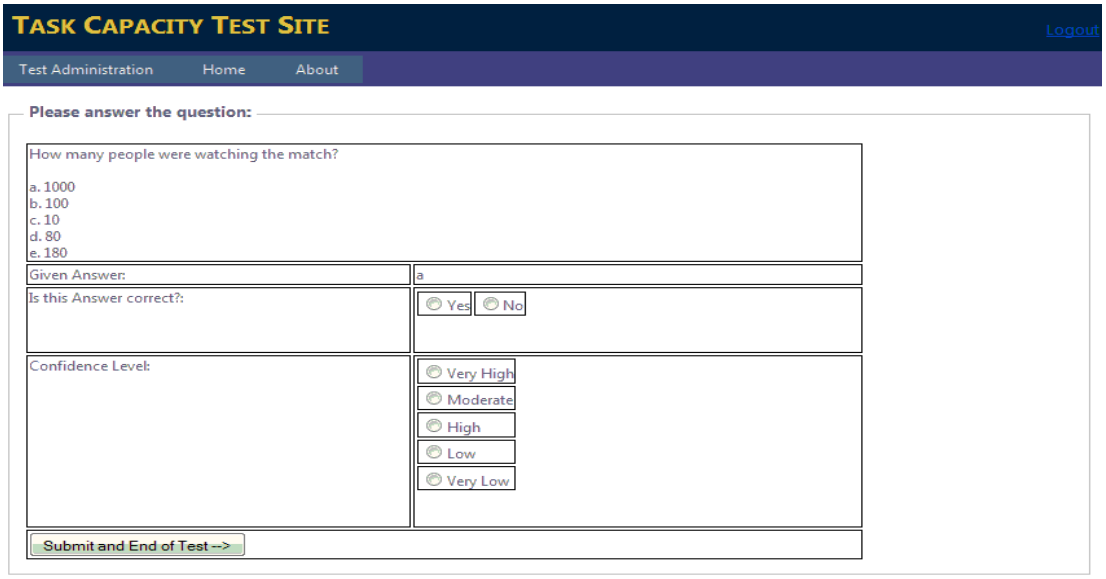


Figure C.7. Sample Question Three-Answer is Displayed

Please press **Submit and go to Next Question** button once you are done with the answer and confidence level selection. After successful completion of the test **STRESS level** measurement question will appear. Please select appropriate level that describes your stress level.

Stress Evaluation:

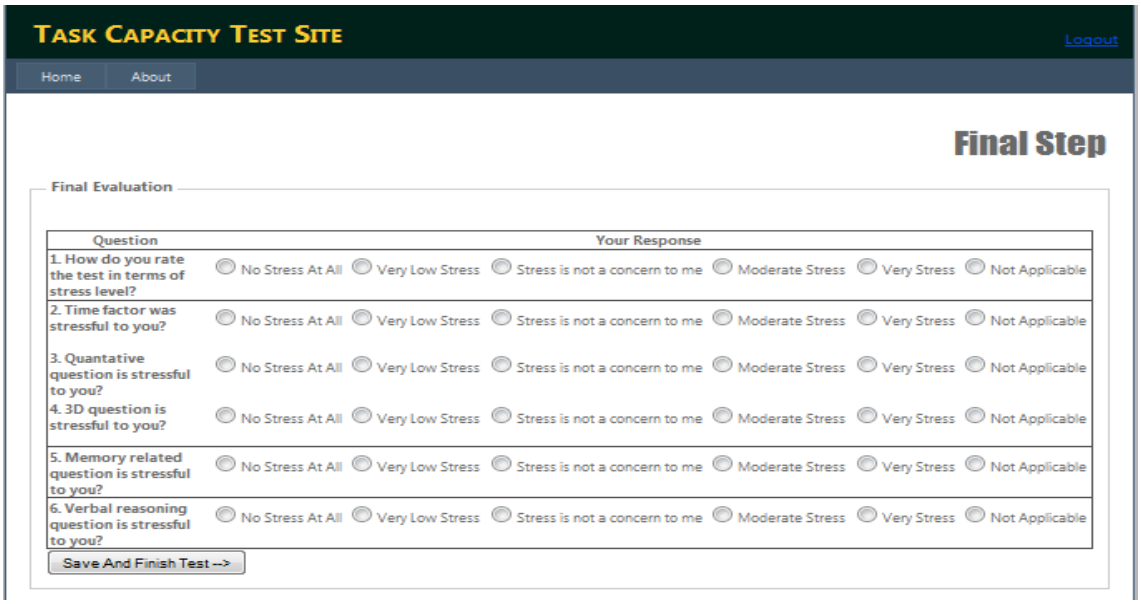


Figure C.8. Stress Evaluation-After Test Completion

Please press **Save and Finish Test** button to complete the test.

*TEST is complete, please press **logout** button on the right top corner.*

Appendix C.3. Stress Questionnaire

Table C.1. Stress Questionnaire at the Start of Test

Stress Question	User Response	Response Value
Are you in any kind of tension now?	Very Low Stress	
Do you feel stressed today for any reasons?	Moderate Stress	
Did you do physical exercise before appearing for the test and stressed?	No Stress At All	
What stress level for you is a concern?	Very Stress	
When working alone, do you feel stressed?	Very Low Stress	
When working in a team, do you feel stressed?	Very Stress	
	Total Stress Value	

Appendix C.4. Test Questionnaire

1. Which pair of name is the same?
2. Add (+): 76543 and 11111
3. Which picture displays flat piece bent, rolled or both?
4. Which two words have the same meaning? (10 Seconds)
5. Which two words have the opposite meaning? (5 seconds)
6. Which tool is identical in color and shape?
7. A man works 8 hours a day, 40 hours a week and 160 hour per month. He earns $ 1.40an hour. How much does he earn each quarter of a month? (15 Seconds)
8. Which figure in the second group is not exactly the same size and shape as each figure in the first group?
9. A random 7-digit number 5327691 is selected for the Minnesota Power Ball Lottery. What were the last 3 digits? (8 seconds to response)
10. Around 950 employees work at this five floor,375,065 square feet facility. About 189,250 patients were visited in the facility in FY2010. Variety of services such as Cardiology, Diabetic Education, Specialty Clinics (Endocrinology,Glucose Monitoring, Hepatitis C, Infectious Disease and General Surgery), Neurology, Pulmonary, Women's Health, and Primary Care are offered in this medical center. What is the approximate area of the facility? (15 seconds to response)
11. Multiplication: 3145 and 3 (10 Seconds)
12. There were 100 people watching a football match. There were 80 players in the field. Suddenly it started raining heavily. The match was canceled. (10 Seconds) How many people were watching the match?

13. Divide (/): 1033333 / 3
14. What the image represents?
15. A number is displayed: 9236581. What were the first three digits? (15 seconds to response)
16. Row wise the pattern is similar?
17. Is the pattern same?
18. How many birds, fishes and feathers was display respectively?
19. What shape is needed to be included in the image?
20. Total number of triangles in the pattern? (15 seconds to response)
21. Is to eye as eardrum is to-
22. 400 (-6) (-30) =
23. The four figures in the row to the left make a series. Find the single choice on the right
24. Which word is spelled wrong?
25. What is the coordinate of point A?
26. Which of the photo is not in sequence?
27. Which picture is taken under surveillance?
28. Find the next sixth and eighth number in the following sequence: 1, 4, 9, 16, 25, ...
29. Around 950 employees work at this five floor, 375,065 square feet facility. About 189,250 patients were visited in the facility in FY2010. Variety of services such as Cardiology, Diabetic Education, Specialty Clinics (Endocrinology, Glucose Monitoring, Hepatitis C, Infectious Disease and General Surgery), Neurology, Pulmonary, Women's Health, and Primary Care are offered in this medical center.

What is the total employee working in the facility? (10 seconds to response)

30. A pen costs $1.01. A whistle cost a dollar more than a marble and together they cost $1.10. How much did each cost?

Appendix C.5. Test Evaluation

Table C.2. Stress Questionnaire at the End of Test

Evaluation Question	User Response	Response Value
How do you rate the test in terms of stress level?	Moderate Stress	
Time factor was stressful to you?	Very Stress	
Quantitative question is stressful to you?	Moderate Stress	
3D question is stressful to you?	Very Stress	
Memory related question is stressful to you?	Very Stress	
Verbal reasoning question is stressful to you?	No Stress At All	
	Total Eval. Value	

Appendix C.6. Laboratory Report On Observation

Table C.3. Laboratory Subject Report on First Set

Date	ID #	Type of Test	Arrival	Departure	Participant Comment	Researcher Observation
08/29/2011	3001	Phase I	7:00 pm	7:30 pm	Enjoyed and felt challenging the test. Did not feel time pressure. Asked if others will enjoy the test, the subject thinks others will enjoy it because of the nature of the question pattern mixed with time dependent and time independent questions. Total time taken for the test was not too long and difficulty level of the question is acceptable.	As the subject is first to appear for the test in the lab, the researcher asked more questions on the test design after the subject completed the test. To give a quite environment to the subject all other computers were shut down.
09/01/2011	3002	Phase I	1:00 pm	1:30 pm	Did not get bored. Difficulty level set was acceptable. Found interesting and challenging. Did not feel time pressure or mental pressure too high or too low.	The researcher asked questions on the test and assessed the lab environment.
09/05/2011	3003	Phase I	1:30 pm	2:00 pm	Enjoyed the test. Initially had difficulty to follow the questions, but adopted quickly. No time pressure but challenging. Total number of questions was acceptable.	
09/05/2011	3004	Phase I	2:10 pm	2:40 pm	Liked the test setup and question type. Did not get bored. Number of questions was acceptable.	
09/05/2011	3005	Phase I	5:30 pm	6:00 pm	Time allocation was acceptable and did not feel time pressure.	
09/05/2011	3006	Phase I	6:15 pm	6:50 pm	Enjoyed the test. Number of questions was acceptable and difficulty level set was also acceptable.	
09/05/2011	3007	Phase I	8:00 pm	8:30 pm	Enjoyed the test, but felt difficulty level high. Did not felt time pressure.	
09/05/2011	3008	Phase I	8:45 pm	9:15pm	Difficulty level and number of questions was acceptable. Did not get bore.	

Table C.3 (Continued)

Date	ID #	Type of Test	Arrival	Departure	Participant Comment	Researcher Observation
09/06/2011	3009	Phase II	5:30 pm	6:15 pm	Subject was alright with the physical stress level from the biking. Did not complain on number of questions or difficulty level.	The subject came to give the test after work, so felt a little mental stress prior to the test, but enjoyed the test.
09/06/2011	3010	Phase II	9:30 pm	10:15 pm	Subject enthusiastically biked to reach the maximum end of low level stress. Did not get bored. The test length was ok.	
09/06/2011	3011	Phase II	10:30pm	11:15 pm	Higher end of low level stress scale was felt. Time length of the test was acceptable.	
09/07/2011	3012	Phase II	5:45 pm	6:30 pm	Test time duration was acceptable. No time pressure felt. Low level stress was not a big concern to the subject.	Subject thinks stress will not have any effect on the subject's test performance. According to the subject arithmetic task is difficult for others.
09/07/2011	3013	Phase II	6:30 pm	7:15 pm	Enjoyed the test, did not get bore, but found challenging.	
09/07/2011	3014	Phase II	7:45 pm	8:30 pm	Time allocation was acceptable, did not get bore.	The subject did not go to the higher resistance level of biking and was concerned on the resistance level experiencing.
09/07/2011	3015	Phase II	8:30 pm	9:15 pm	Happy with the test setup. Did not get bore and enjoyed.	Low level stress was not enough for the subject.
09/07/2011	3016	Phase II	9:15 pm	10:00 pm	Satisfied with the test setup and time allocation. Was concerned on how much stress can bear.	Though verbally was concerned on stress but biked according to protocol.
09/09/2011	3017	Phase I	10:00 am	10:30 am	Enjoyed. Time allocation was acceptable.	
09/09/2011	3018	Phase II	10:45 am	11:30 am	Physical stress level was acceptable. Time allocation was acceptable.	

Table C.3 (Continued)

Date	ID #	Type of Test	Arrival	Departure	Participant Comment	Researcher Observation
09/09/2011	3019	Phase I	3:00 pm	3:30 pm	Felt challenging. Time allocation was acceptable.	Stress level questions were concern in terms of understanding.
09/09/2011	3020	Phase II	5:30 pm	6:15 pm	Low level stress was not a concern. Did not feel time pressure, found interesting and challenging.	
09/09/2011	3021	Phase I	10:00 pm	10:30 pm	Felt challenging due to variety of questions. Liked the nature of sequence of questions. Total time spent was acceptable and enjoyed the variety.	
09/10/2011	3022	Phase I	5:30 pm	6:00 pm	Liked the setup of question sequence, felt no time pressure and not boring.	
09/11/2011	3023	Phase II	5:30 pm	6:15 pm	Low level stress was not a concern. Expects performance will improve with stress. Time allocation was alright and enjoyed the test.	According to the subject from previous experience, the subject's performance improves with physical stress.
09/11/2011	3024	Phase II	6:15 pm	7:00 pm	Low level stress is not a concern. Time allocation was acceptable, did not feel time pressure	Felt tired before arriving for the test.
09/14/2011	3025	Phase II	6:35 pm	7:15 pm	Had difficulty with the bike sitting, not convenient for sitting. Sit was small. Physical stress was not a concern. Had some difficulty to follow the test as the subject was not sure what type of questions to come next. Did not get the time to enjoy or get bored during the test.	
09/15/2011	3026	Phase II	8:00 pm	8:45 pm	Had difficulty with the paddle belt adjustment. Enjoyed biking. Enjoyed the test but felt time pressure. Liked the variety of questions in sequence. Felt the 30 questions as lengthy.	
09/15/2011	3027	Phase II	8:15 pm	9:00 pm	Enjoyed biking. Was willing to take more stress. Did enjoy the test. Liked the variety of questions. Liked the question sequence.	Did work in the field all day up to 5:00 pm.

Table C.3 (Continued)

Date	ID #	Type of Test	Arrival	Departure	Participant Comment	Researcher Observation
09/24/2011	3028	Phase II	10:10 pm	10:55 pm	Time allocation for the test was alright. Did not feel mental pressure because of previous experience in GRE type of examinations.	The subject had leg pain from the exercise done 4 hours before the test. Biked less than 10 minutes. Was concerned on peddling at high resistance, so stopped biking.
09/24/2011	3029	Phase II	9:00 pm	9:35 pm	Was enthusiastic in biking. Could take more resistance. Found interesting the test. Subject was looking for any tricky questions. Enjoyed the variation of question.	
10/01/2011	3030	Phase II	10:05 pm	10:45 pm	The subject never tried any mental task after physical exercise.	Biking is not a concern. Could take more stress. The subjects feel his performance increase after physical activity after one hour. Reported mental stress was above 10.
10/01/2011	3031	Phase II	10:45 pm	11:25 pm	The subject feels that since it is volunteered, more commitment to put better effort	Enjoyed the test, liked the variety in question setting as well the random nature of appearing the question.
10/01/2011	3032	Phase II	7:00 pm	7:40 pm	Time was a concern, otherwise enjoyed the test.	Physical stress was a concern, resulting not biking desired.
10/01/2011	3001	Phase II	8:45 pm	9:25 pm	Types of question was in mind, sequence not recalled, forgot most of the questions, felt easier this time.	Enjoyed biking.
10/08/2011	3002	Phase II	5:55 pm	6:30 pm	Load is not a concern. Can take more load.	
10/08/2011	3003	Phase II	8:50 pm	9:30 pm	Felt time dependent questions were allocated less time to complete; stress was a concern at the beginning of the test. Forgot everything from last time.	

Table C.3 (Continued)

Laboratory Subject Report on Second Set						
Date	**ID #**	**Type of Test**	**Arrival**	**Departure**	**Participant Comment**	**Researcher Observation**
10/05/2011	3004	Phase II	8:30 pm	9:15 pm	Subject thinks concentration was limited due to the physical stress, cannot think beyond a level.	No complain on biking. One answer the subject can recall. Felt easier this time.
10/08/2011	3005	Phase II	10:00 pm	10:35 pm	Felt stress has effected performance. Some questions were recalled, but not all.	
10/06/2011	3006	Phase II	7:00 pm	7:40 pm	Time dependent questions passed quickly this time than last time due to stress. Can recall the pattern, but not any questions. Biking was not a concern, could take more load.	It took less time to complete the test. Initially stress was a factor in answering the questions.
10/07/2011	3007	Phase II	8:00 pm	8:40 pm	Stress was a concern.	
10/15/2011	3008	Phase II	8:05 pm	9:40pm	Recognized pattern and what to remember.	
10/08/2011	3009	Phase II	8:00 pm	9:35 pm	Felt stress was a factor last time.	
10/09/2011	3010	Phase I	3:20 pm	3:40 pm	Felt stress free than last. Could recall some question type. Knew what to remember.	
10/07/2011	3011	Phase I	10:45pm	11:10 pm	Felt easier than first time, but could not recall the answer.	Subject was tired before appearing the test.
10/07/2011	3012	Phase I	5:35 pm	6:00 pm	Felt mentally stressed before the test.	
10/07/2011	3013	Phase I	6:30 pm	6:55 pm	Felt easier than last time.	
10/07/2011	3015	Phase I	6:35 pm	6:55 pm	There was no stress. Can recall pattern but not the question.	
10/17/2011	3016	Phase I	8:45 pm	9:10 pm	Felt easier this time, especially time dependent questions. And thinks stress was a factor last time.	
10/07/2011	3017	Phase II	8:00 am	8:40 am	Felt stress level low and performed well.	
10/07/2011	3018	Phase I	8:15 am	8:40 am	Felt did well, stress was not a concern.	
10/07/2011	3019	Phase II	3:00 pm	3:30 pm	Felt did well, stress was not a concern.	The subject was willing to take more load.
10/08/2011	3020	Phase I	5:25 pm	5:45 pm	Felt relaxed. No time pressure. Expected better performance this time.	
10/11/2011	3021	Phase II	10:00 pm	10:30 pm	Subject was willing to take more loads. Stress is not a concern.	Subject was stressed after biking.

Table C.3 (Continued)

Date	ID #	Type of Test	Arrival	Departure	Participant Comment	Researcher Observation
10/07/2011	3022	Phase II	5:30 pm	6:00 pm	Stress was a concern.	
10/18/2011	3023	Phase I	7:30 pm	7:50 pm	Could not recall any thing because of time difference.	
10/08/2011	3024	Phase I	10:05 pm	10:25 pm	Stress has an effect on performance. Could recall pattern.	
10/10/2011	3025	Phase I	9:05 pm	9:25 pm	Felt easier this time. Could follow the steps better. Thought did better this time because of relax condition.	
10/19/2011	3026	Phase I	8:00 pm	8:45 pm	The test was alright.	
10/07/2011	3027	Phase I	9:00 pm	9:20 pm	It was less mentally challenged this time.	
10/17/2011	3029	Phase I	9:00 pm	9:20 pm	Was in a good mood to participate in the test. Could recall pattern.	Was calm and happy before the test

Appendix C.7. Content Validity Analysis

Table C.4. Questionnaire Evaluation

Question #	Task Type	Yes	No	IQ`[1]	PSQ[2]	SA[3]	Content Validity*
Question # 1	Compute			X			
Question # 2	Compare			X			
Question # 3	Analyze				X		
Question # 4	Compare and Categorize			X	X		
Question # 5	Compare and Categorize			X	X		
Question # 6	Identify and Categorize			X	X		
Question # 7	Compute and Short-memory			X			
Question # 8	Identify, Analyze and Compare			X	X		
Question # 9	Store and Short-memory			X		X	
Question # 10	Category, Store and Short-memory			X	X	X	
Question # 11	Compute			X			
Question # 12	Category, Store and Short-memory			X	X	X	
Question # 13	Compute			X			
Question # 14	Identify			X			
Question # 15	Store and Short-memory			X		X	
Question # 16	Compare, Analyze and Plan			X	X		
Question # 17	Compare and Analyze			X	X		
Question # 18	Identify, Count and Short-memory			X	X		
Question # 19	Search and identify			X	X		
Question # 20	Search, Identify, Count and Short-memory			X	X		
Question # 21	Identify, Interpret and Filter			X	X		
Question # 22	Compute			X			
Question # 23	Identify, Short-memory, Plan and Analyze			X	X		
Question # 24	Identify			X			
Question # 25	Compute and Analyze			X	X		
Question # 26	Analyze and Plan			X	X		
Question # 27	Compare and Analyze			X	X		
Question # 28	Identify, Short-memory, Plan and Compute			X	X		
Question # 29	Identify			X			
Question # 30	Identify, Compute, Interpret and Short-memory			X	X		

Analysis of Tasks (IQ`[1] – Knowledge and Memory, PSQ[2] – Problem Solving SA[3] – Situational Awareness)

Appendix C.8. Individual Content Validity Analysis

Table C.5. Task Evaluation by Test Subjects

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	1	8	40
2	1	7	20
3	1	8	60
4	1	7	15
5	1	7	10
6	1	6	10
7	1	8	60
8	1	6	10
9	1	6	10
10	1	7	40
11	1	7	35
12	1	7	40
13	1	8	50
14	1	8	60
15	1	6	40
16	1	5	10
17	1	5	15
18	1	8	60
19	1	6	30
20	1	5	20
21	1	5	10
22	1	8	40
23	1	6	20
24	1	5	10
25	1	4	10
26	1	5	10
27	1	6	30
28	1	5	10
29	1	5	20
30	1	7	20

Table C.5 (Continued)

question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	2	7	70
2	2	7.5	80
3	2	5	40
4	2	7	80
5	2	7	80
6	2	8	80
7	2	8	80
8	2	6	60
9	2	5	50
10	2	4	40
11	2	9	90
12	2	4	40
13	2	9	90
14	2	8	80
15	2	5	50
16	2	7	70
17	2	7	70
18	2	7	70
19	2	7	75
20	2	7	75
21	2	8	80
22	2	7	70
23	2	7	70
24	2	8	80
25	2	7	75
26	2	6	60
27	2	4	40
28	2	4	40
29	2	7	70
30	2	5	50

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	3	9	50
2	3	3	20
3	3	5	50
4	3	6	50
5	3	6	50
6	3	4	45
7	3	7	60
8	3	4	30
9	3	6	50
10	3	6	30
11	3	6	25
12	3	4	30
13	3	5	25
14	3	7	65
15	3	5	35
16	3	3	20
17	3	5	25
18	3	4	30
19	3	3	20
20	3	4	30
21	3	3	25
22	3	5	50
23	3	2	20
24	3	2	30
25	3	4	40
26	3	6	50
27	3	5	30
28	3	4	30
29	3	4	35
30	3	5	40

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	4	7	10
2	4	8.5	80
3	4	3.5	50
4	4	8.5	80
5	4	8.5	80
6	4	8.5	80
7	4	8.5	80
8	4	8.5	80
9	4	8.5	80
10	4	7.5	75
11	4	9	100
12	4	7.5	75
13	4	9	100
14	4	9	100
15	4	9	100
16	4	6	35
17	4	3.5	35
18	4	4	20
19	4	4	20
20	4	6	55
21	4	4	30
22	4	8.5	95
23	4	6	60
24	4	9	95
25	4	8	85
26	4	5	55
27	4	3.5	10
28	4	9	95
29	4	4	35
30	4	6	55

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	5	9	90
2	5	9	90
3	5	9	90
4	5	8.5	80
5	5	8.5	80
6	5	6.5	60
7	5	6.5	40
8	5	7	40
9	5	6.5	20
10	5	5.75	20
11	5	9	90
12	5	6	20
13	5	9	90
14	5	8.5	90
15	5	6.75	20
16	5	7	50
17	5	8.25	80
18	5	6	10
19	5	7.5	50
20	5	5	30
21	5	5.75	40
22	5	9	90
23	5	5.75	35
24	5	8.25	90
25	5	9	90
26	5	6.75	60
27	5	9	90
28	5	5.25	30
29	5	7.5	90
30	5	5.75	30

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	6	6.5	60
2	6	4	30
3	6	8	80
4	6	5.5	60
5	6	6	70
6	6	5	40
7	6	6	80
8	6	3	40
9	6	7	80
10	6	5	40
11	6	6	70
12	6	5	40
13	6	6.5	60
14	6	7	65
15	6	5	50
16	6	4	50
17	6	3	40
18	6	7	80
19	6	6	70
20	6	6	60
21	6	4	40
22	6	6	70
23	6	6	60
24	6	8	80
25	6	7	60
26	6	6	50
27	6	7	60
28	6	6	40
29	6	7	80
30	6	6	70

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	7	4	40
2	7	5	15
3	7	6	10
4	7	7	25
5	7	7	30
6	7	8	30
7	7	8	40
8	7	6	10
9	7	6	20
10	7	7	10
11	7	6	30
12	7	5	20
13	7	6	30
14	7	6	70
15	7	6	25
16	7	7	30
17	7	7	40
18	7	5	30
19	7	4	50
20	7	5	40
21	7	6	35
22	7	7	60
23	7	5	20
24	7	6	50
25	7	7	40
26	7	6	40
27	7	7	50
28	7	6	45
29	7	7	45
30	7	6	50

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	8	9	100
2	8	8	70
3	8	9	100
4	8	7	70
5	8	7	70
6	8	8	80
7	8	7	60
8	8	8	70
9	8	8	80
10	8	6	60
11	8	9	100
12	8	6	60
13	8	8	70
14	8	9	100
15	8	8	65
16	8	7	65
17	8	7	67
18	8	5	56
19	8	7	72
20	8	6	52
21	8	5	45
22	8	9	100
23	8	7	74
24	8	9	100
25	8	8	92
26	8	8	78
27	8	8	75
28	8	6	52
29	8	8	89
30	8	7	68

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	9	9	100
2	9	8	90
3	9	9	100
4	9	6	70
5	9	6	70
6	9	8	90
7	9	8	80
8	9	7	50
9	9	8	80
10	9	6	50
11	9	9	100
12	9	8	90
13	9	8	80
14	9	9	100
15	9	9	90
16	9	7	70
17	9	6	50
18	9	8	75
19	9	8	70
20	9	8	80
21	9	7	80
22	9	7.5	50
23	9	9	100
24	9	8	70
25	9	8	70
26	9	8.5	60
27	9	7	80
28	9	9	80
29	9	9	100
30	9	9	80

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	10	7	60
2	10	7	80
3	10	5	50
4	10	8	70
5	10	7	60
6	10	5	60
7	10	4	50
8	10	7	60
9	10	3	40
10	10	4	50
11	10	6	70
12	10	5	60
13	10	7	70
14	10	5	40
15	10	5	30
16	10	6	50
17	10	6	50
18	10	5	40
19	10	5	50
20	10	3	30
21	10	4	50
22	10	6	30
23	10	3	30
24	10	6	70
25	10	7	80
26	10	6	70
27	10	7	60
28	10	7	70
29	10	3	40
30	10	4	40

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	11	5	60
2	11	3	10
3	11	3	10
4	11	3	10
5	11	3	10
6	11	4	30
7	11	7	60
8	11	8	90
9	11	8	80
10	11	6	50
11	11	3	10
12	11	5	70
13	11	3	20
14	11	4	60
15	11	5	60
16	11	7	80
17	11	5	50
18	11	5	50
19	11	5	50
20	11	6	70
21	11	7	80
22	11	5	20
23	11	3	20
24	11	6	70
25	11	8	70
26	11	3	10
27	11	3	20
28	11	6	70
29	11	3	20
30	11	7	60

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	12	7	20
2	12	3	10
3	12	7	30
4	12	9	60
5	12	9	60
6	12	9	60
7	12	3	20
8	12	9	70
9	12	9	10
10	12	4	30
11	12	9	50
12	12	4	30
13	12	9	10
14	12	9	50
15	12	9	50
16	12	9	10
17	12	9	50
18	12	10	10
19	12	9	10
20	12	9	10
21	12	10	50
22	12	9	40
23	12	9	50
24	12	10	50
25	12	7	50
26	12	9	40
27	12	10	60
28	12	10	50
29	12	9	10
30	12	9	10

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	13	7	70
2	13	6	60
3	13	6	60
4	13	7	70
5	13	7	70
6	13	6	60
7	13	6	60
8	13	7	70
9	13	5	50
10	13	5	50
11	13	8	80
12	13	7	70
13	13	8	70
14	13	9	90
15	13	7	70
16	13	7	70
17	13	7	70
18	13	7	70
19	13	8	70
20	13	7	70
21	13	9	90
22	13	8	80
23	13	6	60
24	13	7	70
25	13	7	70
26	13	8	80
27	13	8	80
28	13	6	60
29	13	7	70
30	13	7	70

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	14	9	85
2	14	9	85
3	14	8	70
4	14	8	85
5	14	8	80
6	14	8	80
7	14	8.5	85
8	14	6	60
9	14	5	50
10	14	5	60
11	14	9	90
12	14	5	60
13	14	9	90
14	14	7	70
15	14	7	75
16	14	6.5	60
17	14	6.5	70
18	14	6.5	70
19	14	8	80
20	14	6	65
21	14	7	75
22	14	9	90
23	14	6	55
24	14	7	50
25	14	8.5	60
26	14	5	60
27	14	7.5	60
28	14	7	65
29	14	7	80
30	14	7	80

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	15	8	80
2	15	7	50
3	15	6	70
4	15	6	50
5	15	6	50
6	15	8	70
7	15	5	30
8	15	6	50
9	15	5	20
10	15	5	10
11	15	8	80
12	15	5	10
13	15	8	80
14	15	7	20
15	15	5	20
16	15	5	20
17	15	5	20
18	15	5	20
19	15	5	20
20	15	5	40
21	15	8	90
22	15	8	80
23	15	8	30
24	15	8	70
25	15	8	20
26	15	5	80
27	15	8	50
28	15	5	30
29	15	8	90
30	15	8	80

Table C.5 (Continued)

Question #	Subject #	How important the task is in daily life	How much the task is used in daily life
1	16	8	90
2	16	3	10
3	16	4	40
4	16	6	70
5	16	4	40
6	16	5	60
7	16	5	50
8	16	4	40
9	16	6	70
10	16	5	50
11	16	7	80
12	16	5	40
13	16	8	80
14	16	9	80
15	16	5	20
16	16	3	10
17	16	3	10
18	16	4	10
19	16	4	10
20	16	5	40
21	16	4	20
22	16	7	80
23	16	3	10
24	16	7	70
25	16	5	40
26	16	4	20
27	16	6	70
28	16	3	10
29	16	6	70
30	16	8	60

Appendix C.9. Questionnaire Difficulty Level Evaluation

Table C.6. Questionnaire Difficulty Level

Serial #	Subject ID	Question # 1	Question # 2	Question # 3	Question # 4	Question # 5	Question # 6	Question # 7
1	3001	1	1	0	0	1	1	0
2	3002	1	1	0	1	1	1	1
3	3003	1	1	0	1	1	0	1
4	3004	1	1	0	1	1	0	0
5	3005	1	1	1	0	1	1	1
6	3006	1	1	1	1	1	1	1
7	3007	1	1	0	1	1	1	0
8	3008	1	1	1	1	1	1	0
9	3009	1	1	0	1	1	1	1
10	3010	1	1	0	1	1	1	1
11	3011	0	1	1	0	1	0	1
12	3012	1	1	0	1	1	1	1
13	3013	1	1	1	1	1	0	0
14	3014	1	1	1	1	1	1	1
15	3015	1	1	0	1	1	0	0
16	3016	1	1	0	1	1	0	1
17	3017	1	1	1	1	1	1	1
18	3018	1	1	0	1	1	1	1
19	3019	1	1	1	1	1	0	1
20	3020	1	1	0	1	1	1	1
21	3021	1	1	0	1	1	0	1
22	3022	1	1	1	1	1	1	1
23	3023	1	1	0	1	1	0	1
24	3024	1	1	1	1	0	1	0
25	3025	1	1	0	0	1	0	1
26	3026	1	1	1	1	1	1	1
27	3027	1	1	0	1	1	1	1
28	3028	1	1	1	1	1	1	1
29	3029	1	1	0	1	1	1	1
30	3030	1	1	0	1	1	1	1
31	3031	1	1	0	1	0	0	1
32	3032	1	1	0	1	1	1	1
33	201	1	1	0	1	1	1	1
34	202	1	1	0	1	1	1	1
35	203	1	1	0	1	1	1	1

Table C.6 (Continued)

Serial #	Subject ID	Question # 1	Question # 2	Question # 3	Question # 4	Question # 5	Question # 6	Question # 7
36	208	1	1	1	1	1	1	1
37	210	0	1	0	1	1	1	1
38	211	1	1	1	1	1	1	1
39	216	1	1	0	0	1	1	1
40	217	1	1	0	1	1	1	1
41	218	1	1	0	1	1	1	1
42	219	1	1	1	1	1	1	0
43	220	1	1	0	1	1	1	0
44	221	1	1	0	1	1	1	1
45	222	1	1	1	1	1	0	1
46	223	1	1	0	1	1	1	1
47	226	1	1	1	1	1	1	1
48	227	1	1	0	0	1	1	1
50	4001	0	1	0	1	1	1	1
51	4003	1	1	1	1	1	1	1
52	4004	1	1	0	1	1	1	1
53	4005	0	1	1	1	1	1	1
54	4006	1	1	0	1	1	0	0
55	4007	1	1	0	1	1	0	1
56	4008	0	1	1	1	0	1	0
57	4009	1	1	0	0	1	1	1
58	4010	1	1	1	1	1	1	1
59	4011	1	1	0	1	1	1	1
60	4012	1	1	0	1	1	0	1
61	4013	1	1	0	1	1	1	1
62	4014	1	1	0	1	1	0	1
63	4015	1	1	1	1	0	1	1

Table C.6 (Continued)

Serial #	Subject ID	Question # 8	Question # 9	Question # 10	Question # 11	Question # 12	Question # 13	Question # 14
1	3001	1	0	0	1	0	1	1
2	3002	1	1	1	1	1	1	0
3	3003	1	1	0	1	0	1	1
4	3004	1	1	1	1	1	1	1
5	3005	1	1	0	1	1	0	1
6	3006	1	1	1	1	1	1	1
7	3007	1	0	1	0	1	0	0
8	3008	1	1	0	1	1	1	1
9	3009	0	0	0	1	1	1	1
10	3010	0	0	1	1	1	1	1
11	3011	1	1	0	1	1	0	1
12	3012	1	0	1	1	0	1	1
13	3013	1	1	0	1	1	1	1
14	3014	1	0	1	1	1	1	1
15	3015	1	1	0	1	0	1	1
16	3016	1	0	1	1	1	0	1
17	3017	1	1	0	0	1	1	1
18	3018	1	1	1	1	1	1	0
19	3019	1	1	1	1	1	1	1
20	3020	1	1	1	1	0	0	1
21	3021	1	0	1	1	1	0	1
22	3022	1	1	1	1	1	1	1
23	3023	1	0	1	1	1	0	1
24	3024	1	1	0	1	1	1	1
25	3025	1	0	0	1	1	0	1
26	3026	1	1	1	1	1	0	1
27	3027	1	1	1	1	1	0	1
28	3028	1	0	1	1	1	1	1
29	3029	1	1	1	1	1	1	1
30	3030	1	1	1	1	1	0	1
31	3031	0	0	1	0	0	0	1
32	3032	1	1	1	1	0	1	1
33	201	1	1	1	1	1	0	1
34	202	0	0	1	1	1	1	1
35	203	1	1	0	1	1	1	1
36	208	1	1	1	1	0	1	1

Table C.6 (Continued)

Serial #	Subject ID	Question # 8	Question # 9	Question # 10	Question # 11	Question # 12	Question # 13	Question # 14
37	210	1	0	1	0	1	1	1
38	211	1	0	1	1	1	1	1
39	216	1	0	1	1	1	1	1
40	217	1	0	1	1	1	1	1
41	218	1	1	1	1	1	1	1
42	219	1	1	1	1	1	1	1
43	220	1	0	1	1	1	1	1
44	221	1	1	1	1	0	1	1
45	222	0	0	1	1	1	1	1
46	223	1	0	1	1	1	1	1
47	226	1	0	0	1	0	1	1
48	227	1	1	1	1	1	1	1
50	4001	0	1	0	0	1	0	
51	4003	1	1	1	1	1	1	1
52	4004	1	1	1	0	1	1	0
53	4005	0	0	1	1	1	1	0
54	4006	1	0	0	1	0	0	1
55	4007	1	1	0	1	1	1	1
56	4008	1	1	0	1	1	1	1
57	4009	0	0	1	1	1	1	0
58	4010	1	1	1	0	1	0	1
59	4011	1	1	1	1	1	0	1
60	4012	1	0	0	0	1	1	1
61	4013	1	0	1	1	1	1	1
62	4014	1	1	0	1	1	1	1
63	4015	1						

Table C.6 (Continued)

Serial #	Subject ID	Question # 15	Question # 16	Question # 17	Question # 18	Question # 19	Question # 20	Question # 21
1	3001	1	1	0	1	1	0	0
2	3002	1	0	1	1	1	1	0
3	3003	1	1	1	1	1	1	1
4	3004	1	1	0	0	1	1	0
5	3005	1	1	0	1	1	0	1
6	3006	1	1	1	0	1	0	0
7	3007	1	0	1	1	1	0	0
8	3008	1	1	0	0	1	1	0
9	3009	1	1	1	0	1	1	0
10	3010	1	1	0	0	1	0	0
11	3011	1	0	1	0	1	0	0
12	3012	1	1	0	1	1	0	0
13	3013	1	1	1	1	1	0	0
14	3014	1	1	0	1	1	0	0
15	3015	1	1	1	1	1	0	0
16	3016	1	0	1	0	1	1	0
17	3017	1	1	0	1	1	1	0
18	3018	1	0	1	1	1	1	0
19	3019	1	1	1	1	1	0	0
20	3020	1	1	1	0	1	0	0
21	3021	1	1	1	1	1	1	0
22	3022	1	0	0	1	1	0	1
23	3023	1	0	1	0	1	1	0
24	3024	1	0	1	0	1	0	1
25	3025	1	1	1	1	0	1	0
26	3026	1	0	1	1	1	0	1
27	3027	1	1	0	1	1	1	0
28	3028	1	0	1	1	1	1	1
29	3029	1	0	0	1	1	1	0
30	3030	1	0	1	0	1	0	1
31	3031	0	0	1	1	1	0	0
32	3032	1	1	1	1	1	1	0
33	201	0	1	1	0	1	1	0
34	202	1	1	0	1	0	1	1
35	203	1	0	1	0	1	1	0
36	208	1	0	1	1	1	1	0
37	210	1	1	0	1	1	1	1
38	211	1	1	1	1	1	1	1

Table C.6 (Continued)

Serial #	Subject ID	Question # 15	Question # 16	Question # 17	Question # 18	Question # 19	Question # 20	Question # 21
39	216	1	1	0	1	1	1	0
40	217	1	1	0	1	1	1	1
41	218	1	0	0	0	1	1	1
42	219	1	1	1	0	1	0	1
43	220	1	1	1	0	0	1	1
44	221	1	0	1	1	1	1	0
45	222	1	0	1	0	0	1	0
46	223	1	0	1	0	1	1	0
47	226	1	1	0	1	1	1	1
48	227	1	0	0	0	1	1	1
50	4001							
51	4003	1						
52	4004	1	1	0	1	1	0	
53	4005	1	0	0	0	1	1	
54	4006							
55	4007	1	0	1	1	1		
56	4008	1	1	1				
57	4009	1	0	1	1			
58	4010	1	0	1	1	1	0	0
59	4011	1	1	1	1	1	1	0
60	4012							
61	4013	1	1	1	1	1	1	0
62	4014	0						
63	4015							

Table C.6 (Continued)

Serial #	Subject ID	Question # 22	Question # 23	Question # 24	Question # 25	Question # 26	Question # 27	Question # 28
1	3001	1	0	1	1	1	1	1
2	3002	1	1	1	1	1	1	1
3	3003	1	1	1	1	1	1	0
4	3004	1	1	1	1	0	1	0
5	3005	0	1	1	1	1	1	1
6	3006	1	1	0	1	0	0	1
7	3007	0	1	1	1	1	0	0
8	3008	1	1	1	1	1	1	0
9	3009	1	1	1	1	0	0	1
10	3010	1	1	0	1	0	1	1
11	3011	1	1	1	1	0	0	1
12	3012	1	0	0	1	0	1	0
13	3013	1	1	1	1	0	1	1
14	3014	1	1	1	1	1	1	1
15	3015	1	0	1	1	1	0	1
16	3016	1	1	1	1	0	1	1
17	3017	1	1	1	1	0	1	1
18	3018	1	1	1	1	1	0	0
19	3019	0	0	1	1	1	0	1
20	3020	1	1	1	1	0	0	0
21	3021	1	1	0	1	1	0	1
22	3022	1	1	1	1	1	1	0
23	3023	1	1	1	1	0	1	1
24	3024	1	1	1	1	0	0	1
25	3025	0	1	1	1	0	1	0
26	3026	0	1	0	1	0	1	0
27	3027	1	0	0	1	0	1	0
28	3028	1	1	1	1	0	0	1
29	3029	1	1	1	1	0	0	0
30	3030	1	1	1	1	0	1	0
31	3031	1	1	1	1	0	1	1
32	3032	1	0	0	1	1	0	1
33	201	1	1	0	1	0	1	1
34	202	1	1	1	1	1	1	0
35	203	1	1	1	1	1	0	0
36	208	1	1	1	1	1	1	0

Table C.6 (Continued)

Serial #	Subject ID	Question # 22	Question # 23	Question # 24	Question # 25	Question # 26	Question # 27	Question # 28
37	210	0	1	1	0	0	1	0
38	211	0	1	1	1	1	1	1
39	216	1	1	1	1	1	1	0
40	217	1	0	1	1	1	1	1
41	218	0	1	1	1	0	1	1
42	219	1	1	0	1	1	0	1
43	220	1	1	1	1	1	1	0
44	221	0	1	1	1	1	1	0
45	222	0	1	0	0	0	1	0
46	223	1	1	1	1	1	0	1
47	226	1	1	0	1	0	1	1
48	227	1	1	1	1	1	0	0

Table C.6 (Continued)

Serial #	Subject ID	Question # 29	Question # 30
1	3001	0	1
2	3002	1	1
3	3003	1	1
4	3004	1	1
5	3005	1	1
6	3006	1	1
7	3007	1	1
8	3008	0	1
9	3009	0	1
10	3010	1	1
11	3011	1	1
12	3012	1	1
13	3013	0	1
14	3014	0	1
15	3015	0	0
16	3016	1	1
17	3017	1	1
18	3018	1	1
19	3019	0	1
20	3020	1	1
21	3021	1	1
22	3022	1	1
23	3023	1	1
24	3024	1	1
25	3025	1	1
26	3026	1	1
27	3027	1	1
28	3028	1	1
29	3029	1	1
30	3030	1	1
31	3031	1	1
32	3032	1	1
33	201	0	0
34	202	1	0
35	203	1	1
36	208	1	1

Table C.6 (Continued)

Serial #	Subject ID	Question # 29	Question # 30
37	210	1	1
38	211	1	0
39	216	1	1
40	217	1	0
41	218	0	1
42	219	1	1
43	220	1	0
44	221	1	1
45	222	1	1
46	223	1	1
47	226	1	1
48	227	0	1

Appendix C.10. Results For Phase I And Phase II First

Table C.7. Task Capacity Accuracy (Phase I and Phase II First)

Phase I

Serial #	Subject ID	Laboratory (Phase I)	Task Capacity %
		Phase I	
1	3001	X	80
2	3002	X	80
3	3003	X	85
4	3004	X	65
5	3005	X	85
6	3006	X	75
7	3007	X	75
8	3008	X	80
9	3017	X	85
10	3019	X	75
11	3021	X	70
12	3022	X	85
Phase II			
Serial #	Subject ID	Laboratory (Phase II)	Task Capacity %
1	3009	X	70
2	3010	X	65
3	3011	X	60
4	3012	X	65
5	3013	X	70
6	3015	X	70
7	3016	X	65
8	3018	X	70
9	3020	X	65
10	3024	X	80
11	3025	X	60
12	3026	X	70
13	3027	X	60
14	3029	X	65
15	3023	X	65

Table C.8. SA Accuracy (Phase I and Phase II First)

Phase I

Serial #	Subject ID	Laboratory (Phase I)		Situation Awareness %
		Phase I	Phase II	
1	3001	X		30
2	3002	X		100
3	3003	X		80
4	3004	X		90
5	3005	X		70
6	3006	X		90
7	3007	X		70
8	3008	X		70
9	3017	X		80
10	3019	X		80
11	3021	X		90
12	3022	X		90
Phase II				
Serial #	Subject ID	Laboratory (Phase II)		Situation Awareness %
1	3009		X	70
2	3010		X	80
3	3011		X	60
4	3012		X	70
5	3013		X	50
6	3015		X	50
7	3016		X	90
8	3018		X	100
9	3020		X	80
10	3024		X	60
11	3025		X	70
12	3026		X	90
13	3027		X	100
14	3029		X	100
15	3023		X	90

Appendix C.11. Results For Phase II And Phase I Second

Table C.9. Task Capacity (Phase I and Phase II Second)

Phase II

Serial #	Subject ID	Laboratory (Phase II)	Task Capacity %
		Phase II	
1	3001	X	60
2	3002	X	75
3	3003	X	70
4	3004	X	70
5	3005	X	75
6	3006	X	85
1	3007	X	60
7	3008	X	75
8	3017	X	85
9	3019	X	65
10	3021	X	75
11	3022	X	80
Phase I			
Serial #	Subject ID	Laboratory (Phase I)	Task Capacity %
2	3009	X	85
3	3010	X	75
4	3011	X	60
5	3012	X	70
6	3013	X	85
7	3015	X	75
8	3016	X	80
9	3018	X	70
10	3020	X	60
11	3024	X	75
12	3025	X	70
13	3029	X	80
14	3023	X	80
15	3026	X	85
16	3027	X	70

Table C.10. SA Accuracy (Phase I and Phase II Second)

Phase II

Serial #	Subject ID	Laboratory (Phase II)	Situational Awareness %
		Phase II	
1	3001	X	80
2	3002	X	90
3	3003	X	80
4	3004	X	90
5	3005	X	80
6	3006	X	80
1	3007	x	60
7	3008	X	80
8	3017	X	80
9	3019	X	80
10	3021	X	70
11	3022	X	90
Phase I			
Serial #	Subject ID	Laboratory (Phase I)	Situational Awareness %
2	3009	X	70
3	3010	X	90
4	3011	X	70
5	3012	X	60
6	3013	X	60
7	3015	X	80
8	3016	X	100
9	3018	X	80
10	3020	X	90
11	3023	X	70
12	3024	X	90
13	3025	X	70
14	3026	X	90
15	3027	X	80
16	3029	X	100