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EVALUATION OF THE EFFECTS OF THERMAL STRESS ON INCREASING OCCURRENCE OF HUMAN ERRORS USING SUBJECTIVE TESTS

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ABSTRACT

Introduction: There are several harmful factors at work that can cause acute and chronic effects on workers. The thermal stress is one of the most detrimental factors in outdoor and indoor work environments. In addition, the incidence of occupational diseases it is considered as a driving factor in the occurrence of human errors and can increase the rate of accidents.

Material and methods: In this study effects of temperature ranges (WBGT index at 29, 32 & 35°C) on performance of subjective tests: steadiness test and two-arm coordination test by a group of men were evaluated.

Findings: The statistical tests did not show any significant effect between the high temperature and occurrence of human errors in steadiness test and two-arm coordination test. (P Value=0.132, 0.051, respectively).

Conclusion: However, there was a close relationship between errors and high temperature, therefore, further studies are required.

Keywords: Heat stress, human errors, subjective tests

INTRODUCTION

Individuals in in various conditions are exposed to climatic conditions; inter alia, employees in the open or hot air with low hygiene standards. However, nowadays the physiological limitations for tolerating the hot climatic conditions have deviated the attention of researchers to the effectuality of conditions on human behavior. The relation between thermal stresses and the increase of the number of accidents in the job area during the current fifty years and the similar relations with the unsafe job behaviors nowadays has obviously been proved. (Ramzi et al., 1983). Confrontation of industry workers in the hot job areas is a constant obstacle to improve the productivity of work and the occurrence of problems which are influential in their health. To confront this problem lots of attempts have been made toward determining the harmful effects of job area on the amount of satisfaction, rate of accidents, diseases, and the productivity of workers in various industries. (Hancock, 1998) Documents of the epidemiologic studies concerning the relation between thermal stress and the outbreak of disease and death as direct effects of heat exist. Most of the existing studies have concentrated on the outbreak of heat-related diseases and mortality and few studies have been carried out on the hygienic effects of heat are on the go. Lots of data have just registered the results and haven't turned much into classifying the causes of events. For instance, according to the report by the workers' union of Italy in the year 2003 from among 977803 of job accidents 881676 accidents have occurred in the industries and the services sector and from among these 1263 accidents have led to death. However, this statistics hasn't determined the root of accidents which are relevant to thermal stresses. (Morabito, 2006).

Heat depending on the severity and the environmental features has various aftereffects on human and their various performances while an average heat stress leads to the reduction of these stimulations and arousal in human and higher levels of stress lead to the intensification of stimulations and the smart attempts can neutralize these effects. In most of studies temperature rise has been considered as a stimulant to smart activities. (Wyon et al., 1979) Thermal stresses can also bring about various aftereffects. For instance, an increase in the deep body temperature up to 40 degrees centigrade can bring about heat diseases such as heat shock, cramp, and heat

stroke. In the mentioned studies some of the symptoms of the heat-induced diseases are mentioned as decline in sobriety, decline in perception and in general a decline in the central nervous system. In addition to the acute aftereffects, excessive temperature can cause metabolistic changes and changes in the cerebral function. The relation between nervous system and the thermal data processing system is not still so clear; however, it seems that the injuries which the nervous system tissue has been inflicted with are intensely in relation with heat and the time of encountering. An increase in the permeability of the hematic-cerebral obstacle leads to the occurrence of inflammation which the dysfunction of the hematic-cerebral obstacle is a proper justification for the absence of soberness in individuals. (Xuan et al., 2006) It is clear that in case of occurrence of thermal stresses some of the cognitive processes of mind will be injured and the extent of injury is harshly relevant to the stress-inducing factor. In this area most of the studies have assessed the psychomotor functions and/or cognitive-motor functions. Based on this, any damage to these patterns and the psychomotor capabilities (specifically delicate actions) will be clearly proven but in the processes which are more cognitively-required this issue will be more sophisticated. According to the biological and nervous functions thermal stresses which regulate the body temperature disrupt. On the other hand, any disorder which appears due to temperature rise can disrupt the process of data exchange and the relevant functions. Lots of studies have introduced the thermally-induced tension factors as factors which reduce the function of memory, motor movement or perceptive movements, problem-solving, and learning in various conditions. (Mark, 2004) Also, a study was carried out by Gopinathan et al. in the year 1987 about the changes in mental function under several levels of thermal stress which is due to dehydration in eleven persons who have been acclimatized to the tropical climate. In this study psychological functions, calculation ability, short-term memory, and the visuomotor tracking were evaluated. The results indicated that a meaningful deviation exists in the psychological functions of these individuals at the %2 water levels and more. Also, in the year 1985 Sharma et al. studied the influence of dehydration at various levels (i.e.1, 2 , and 3 percent of body weight loss) on the various complexities of the cerebral functions in eight individuals who have been acclimatized to the heat of the tropical India. These individuals were also studied after an

exercise in heat under the two conditions of hot and dry and hot and humid by means of WBGT index at 34 degrees Centigrade. In this situation no meaningful change was observed in their mental function. On the other hand, in the first two and three levels of dehydration a negligible reduction was observed in functions which weren't meaningful. Psychologists achieved contradictory findings in relation to human function under high temperatures while lots of researchers reported the high temperature as an influential factor in the primary stimulation for the perceptive and cognitive function and some others considered the reduction of brain function due to thermal intervention to be fairly moderate. (Shayle, 2006) From among behavioral changes which are observable in the function of employees is the occurrence of human errors. Human errors can be defined as wrong decisions, improper function or dysfunction in the required time to do an action. (Anita, 1995) The intended thermal index in this study is the WBGT index since this index is appropriate for the fast evaluation of weather conditions in an environment. Some of the privileges of this index are its fast and facile reaction or response to sun (phototropism) and wind. Besides this, the obtained quantities out of this index are easily interpretable by the user and the identification of this index is very fast.

As it was mentioned, confronting heat is an inevitable factor in most of the job areas and an increase in global warming workers will be exposed to the negative after effects of this phenomenon as an extra factor and aside from the direct influences of this factor and the appearance of occupational diseases this factor is considered as a stimulant factor in the occurrence of human errors and as a result the occurrence of accidents. Considering the criticality and significance of the occurrence of human errors scrutinizing them and finding ways to control them are the necessities of the research. Thus, in this study the probable after effects of thermal in the occurrence of human errors have been considered and an attempt has been made to realize the relation in this area. In this study the intended samples were being evaluated in three thermal conditions by means of the temperature index of WBGT (temperate, hot and very hot) which is similar to the real job area conditions. In order to evaluate the effects of heat on the human performance a series of Battery tests (i.e. Two-arm coordinate test and the steadfastness test) were used that each one of these tests evaluate a kind of performance in an individual and to sum up they present a

relatively proper conclusion of the environmental effects on the function of human and the appearance of human error under various thermal conditions.

MATERIALS AND METHODS

The present study is an empirical and sectional study which was carried out in the year 2011-12 in the laboratory of physical factors in the School of Hygiene of Tehran Medical University. Before the entrance of individuals in this study purposes of the study were stated for the participants and finally the volunteers decided to cooperate in the study. Considering this issue that the utilized tests in the present study are under the influence of personal factors before starting the tests the auditory and visionary health of participants and also the proper sleeping condition for the participants were studied by means of the General Health Questionnaire.

In order to determine the influence of heat on the function of participants the extent of WBGT index was determined in the place of executing the test based on the standard number 7243 of the International Standard Organization (ISO) for the un-acclimatized at the three rate of 35, 32, and 29 degrees Centigrade until besides determining the effects of heat the procedure of occurrence of errors be determined by temperature rise.

In this investigation two types of tests were used. Before starting the main tests the participants filled the form of demographic data, health status questionnaire for the auditory and visual condition and the minimal rate of eight hours of sleep per day before the test and also the smoking condition. Then the participants were trained for the way of doing the tests and after the complete training the respondents started to take the tests.

In order to determine the occupational skill the occupational skill assessment test battery was used. This test is generally being used for assessing the improvement of rehabilitation and the ability to return to job for individuals who are involved in doing their jobs. To scrutinize and determine the personal errors the steadfastness test and the two-arm coordination test were used.

In the steadfastness test a projector-equipped apparatus was used and this test is basically used for testing the resistance power of the respondent. In this method the participant is asked to hold a gramophone pen in holes with various diameters without touching the edges of holes. In an ideal condition the participant puts the pen into the holes without touching the body which the holes shrink one after another and in case of lack of touch the monitor doesn't reveal any contact. However,

usually in the tests due to the hand tremors the pen hits the body and the apparatus besides registering the number of errors shows the time of connection of pen to the body based on one hundredth of second. Considering the digits and the times it will be possible to some extent to determine disconcentration and the control of the person over the pen. In diagram number one the picture of required equipment in this test is illustrated.

In the two-arm coordination test in order to measure the ability to move or movability both hands are working in a harmonious manner. This test is usually being used as a tool for measuring the practical, driving, and controlling skills of participants. This test includes a stellar pattern which the participant should design it with an aid of the gramophone pen and by measuring the time and the existing errors. With an aid of a sensitive pen which is held by two hands the participant should cross the stellar path in the least possible time without getting out of the path and ideally no error should be registered. However, this test like the previous test is equipped with a monitor and the processor of the apparatus registers the time of exit from the path. Diagram number two illustrates the equipment of this test.

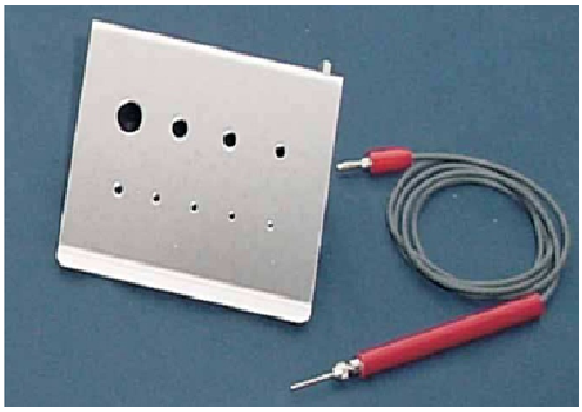

Diagram No.1-steadfastness test equipment

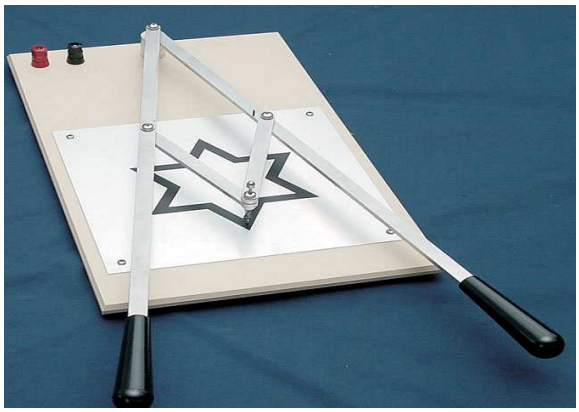

Diagram No.2-equipment for the two-hand coordination test.

The response to the error for the both two-hand coordination test and the steadfastness test will be determined by means of number of errors which are made by the respondent during the test. Data of these two tests are the time of response and the number of errors which are made by the respondent during the test.

Table No.1: registered variables in each of the tests separately.

Test title	Response	
Steadfastness test	Response time	Number of errors
Two-hand coordination test	Response time	Number of errors

In order to simulate the climatic conditions to achieve the definite quantities of thermal index in vitro (WBGT=17°c, WBGT=29°c, WGBT=39°c) and in order to change the index of WBGT in the closed space it is necessary to increase the radiative temp rate and also the space temp besides the natural temperature. This issue is possible by means of a fiber heater by putting a container of water with a definite volume. The heater is able to change the temperature of the buoyant and the space temperature and the water container which is on the heater changes the rate of humidity. The condition for the amount of WBGT was measured, registered, and controlled by WBGT-meter during the test. The consumed time for doing the test was registered by a chronometer. The speed of response was one of the dependent variables which were measured in this test. To start the test a signal was emitted for the respondents and simultaneous to the start of the test by respondent the chronometer was put in the start position and exactly after the end of the work it was stopped and the consumed time for doing the job was measured.

FINDINGS

The tests were taken by ten men and the mean and the standard deviation of the age of the respondents was 24.5+/-3. The results were analyzed by the statistical SPSS-17 software and for the whole statistical tests the level of significance was considered as 0.05.

In the steadfastness test the respondent should pass a pen through holes and should do their best to prevent the contact of the pen with the body of the holes and finally the number of contacts and the time of connection of pen to the body of the holes will be measured by the apparatus and the tester registers the data. As it was mentioned, the tests were given in the WBGT thermal ranges of 17, 29, and 32 degrees Centigrade the effects of heat on the occurrence of human error get clear. Before doing any statistical test normality of the test data was tested and after doing the test one-way ANOVA was done. To sum up, the error time for individuals in various temperatures was determined. The results indicated that there is no meaningful relationship between the error times in various thermal conditions. (i.e.17, 29, and 32 degrees Centigrade) (P-Value=0.132) The same test statistical was performed for determining the number of errors in various thermal conditions and it became clear that there is no meaningful relation between the numbers of contacts of the pen with the wall of the holes. (P-value=0.051) However, this level is so close to the level of significance. Table number 2

illustrates the description of the data of the two tests. Figure number one illustrates the mean of error time and the Figure number 2 illustrates the number of errors in the triple thermal conditions for the steadfastness test. In the second test or the two-hand coordination test the respondent should direct a sensitive pen by two hands through a star-shaped path and in case of exit of the pen the path the apparatus started to measure the error time and as it returns to the path the time stopped. This test registered the required time for doing the test besides the error time for each respondent. All the respondents succeeded in taking the test without doing any error and the error time for all the respondents was zero. Besides this, the obtained results out of the statistical analyses between the time of taking the test and the various thermal conditions didn't determine any meaningful relation. (P-value=0.289, p.v>0.05) Figure 3 indicates the average time for doing the two-hand coordination test in various thermal conditions.

Table 2: Data of the taken test in this study

Type of test	Steadfastness test	Two-hand coordination test
Error time mean(second)	6.10	-
Error time standard deviation	4.89	-
Average number of occurred errors	65.66	0.00
Standard deviation for the Number of errors	38.87	-
Average time of giving the exam (second)	-	36.83
Standard deviation for giving the exam(second)	-	7.76
Number of samples	30	30

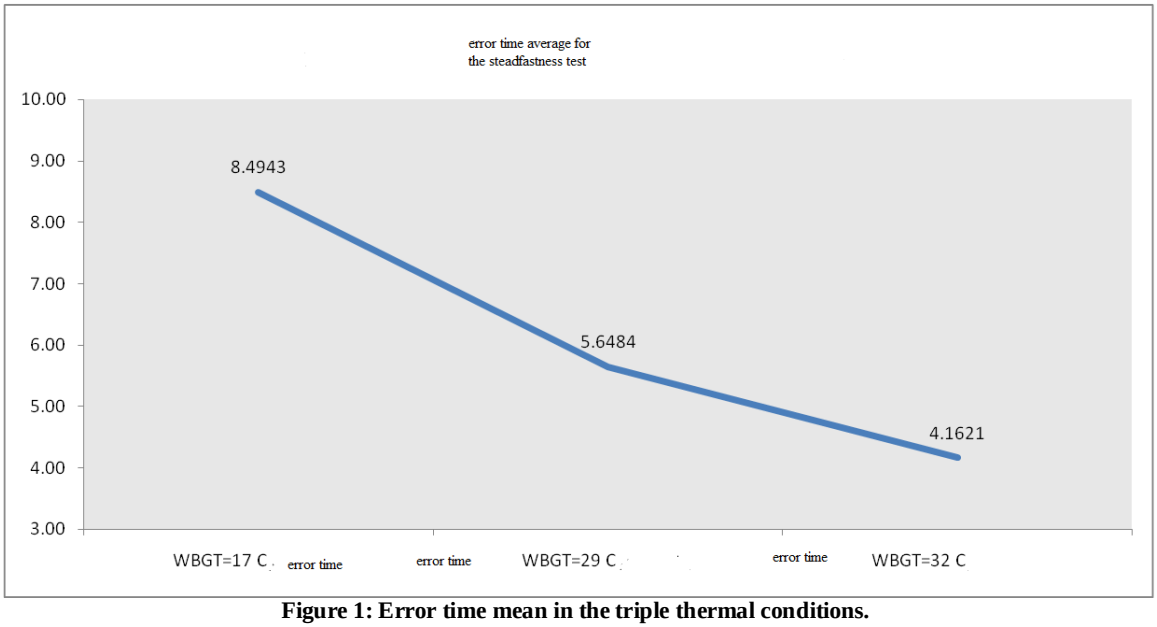

Figure 1: Error time mean in the triple thermal conditions.

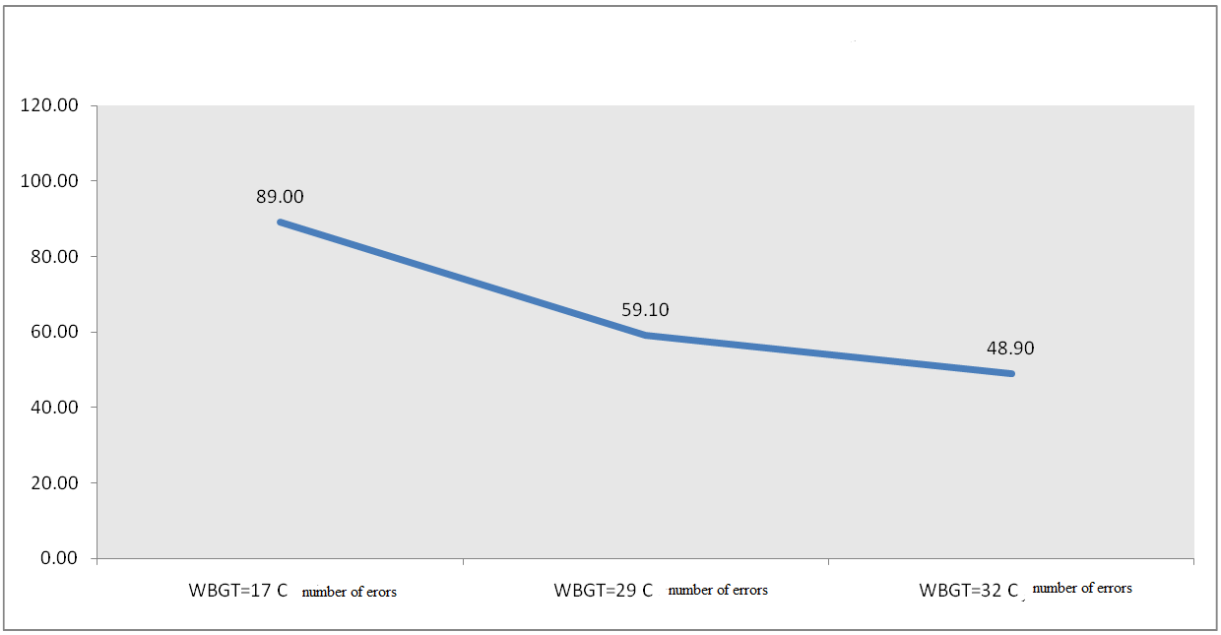

Figure 2: Error time mean in the triple thermal conditions.

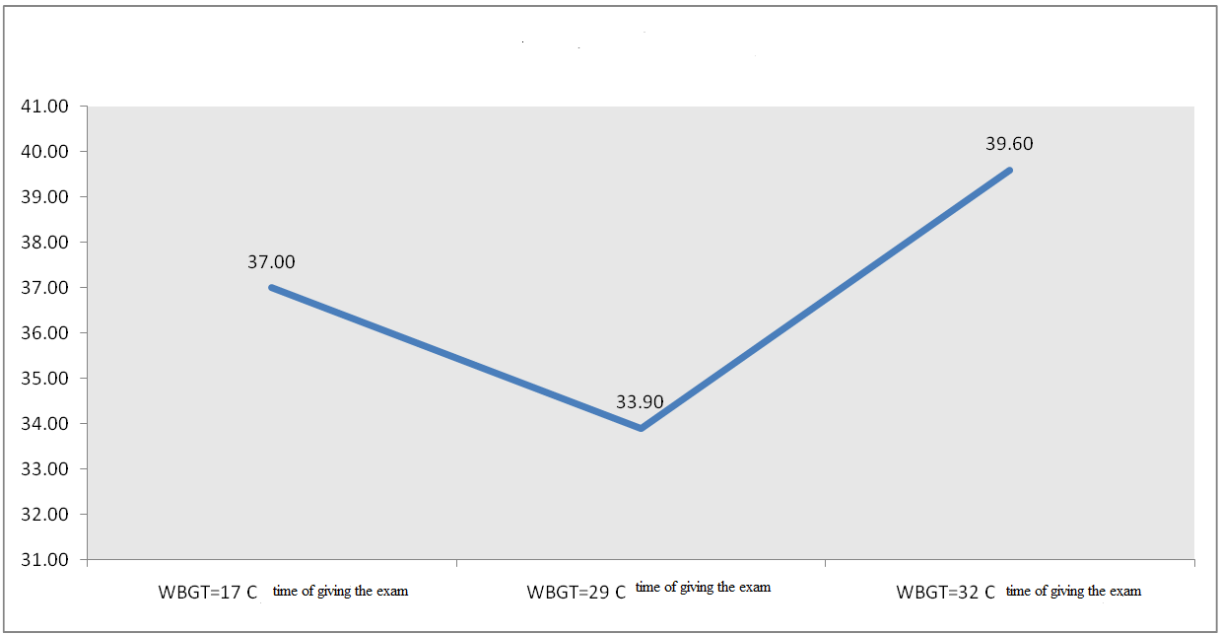

Figure 3: Average time of doing the two-arm coordination test in the triple thermal conditions.

DISCUSSION AND RESULT

The results of statistical analyses in the steadiness test determined that there is a meaningful relation between the time in which the participant hits the pin of the apparatus to the body and the variations in WBGT. In fact these results indicate that parallel to an increase in the heat of the space it can't be said that the number of errors has increased. This factor should be illustrated less in conditions in which the participant feels less easy. However, no meaningful

relation was found among the participants of the study. But the quantity of p-value has been so close to the level of significance. In addition to this the two-hand coordination test was unable to prove a meaningful relation between an increase in the number of errors and the required time for taking the test in various thermal conditions.

According to multiple studies in the area of the influences of heat in the simple mental functions it became clear that thermal stresses reduce the quantity of functions of mental activities. (Narenji et al.1979). For instance, in a study by Poplar and Warner which was being carried out on BA level students to measure their learning temperature was regulated as an environmental factor in a definite range of 16 to 33.3 degrees Centigrade with a relative humidity of %45. The results of this study indicated that university students work faster in higher temperatures; however, their number of errors was high as well. (Poplar, 1968) Also, in a study by Omidvari et al. in the year 2000 on the workers in the hot sections of the cow hide and shoe industry it became clear that an increase in the noise and heat causes the degree of fallibility of individuals and the reduction of their efficiency. Also, in scrutinizing the simultaneous effect of sound and heat it became clear that these two factors have no cumulative effect on one another and cause an increase in the occupational faults or errors in the individulas. (Omidvari, 2000)

According to some studies an increase in the deep body temperature even within the middle ranges of a harmful factor is for harming the cognitive function. (Simon et al., 2008) Perspiration and hot spaces leads to a disorder or discomfort in the individual and finally leads to a change in behavior and distraction. Since the whole occupational functions are in need of using part of the cognitive section of the brain for the function and security of the worker some studies have been done which in some of them the effect of harmful thermal stresses have been recognized. (Macworth, 1952) However, in some studies the results indicated that the thermal stresses lead to an increase in the concentration and action of the workers. (Wing, 1965) and according to these studies two significant points were achieved. First, thermal stresses by considering the kind of cognitive functions can be prohibitive or stimulant. (Wilkinson, 1974; Pelton, 1976; Girder, 1973; Ramzi, 1978; Hancock, 1982; Pilcher, 2002) and secondly the relation between thermal stresses and their effects should be measured against the deep body temperature not against the surface skin

temperature. (Ramzi et al., 1983; Simon et al., 2008) Moreover, some other studies have recommended the establishment of a short period (i.e. almost ten days) for the sake of acclimatization of the individuals with the space for the improvement of variations in the deep body temperature and hold that the acclimatized individual will experience these variations just negligibly and the negative effects of it on the cognitive function of body will be lesser than that. (Glori, 1983; Amos et al., 2000;Rod Kowis et al., 2007).

Lots of studies in the area of the effects of water loss or dehydration of the body due to heat on the cognitive functions of the individual have been done. The results of these studies indicate that the dehydration of the body more than %2 leads to the reduction of visual tracking and the short-term memory and the attention deficit. (Grand jin, 2007; Lieberman, 2007) However, lots of studies should be done until the contrasts and the deviating factors such as the quantity of consumed caffeine and the various ways of body dehydration will be scrutinized correctly. (Jee, 2010) It seems that due to the minuteness of the sample volume in this study the results weren't properly analyzable statistically. Considering these studies it seems that heat is more a decreasing factor towards the mental functions than a stimulant factor. However, more and more studies should be done to judge this story. In addition to the influence of space factors on the brain function the factor of skill can be introduced as an influential factor in the occurrence of human errors. By having an overview of the results of the diagrams number one and two it seems that parallel to an increase in temperature the number of errors increases and the time or duration of error reduces. While the researcher considers the reverse case.By returning to the conditions of doing the test we realize that lesser temperature in the first level was regulated and the participants in the test had less experience and practical skills in taking the test. By an increase in the repetition times and the alteration of the conditions more skill will be achieved and due to this the number and the time of error reduce. This happens while in the study by Mcworth the same point was mentioned. He holds that the thermal variations (within a temperate not severe range) harshly influences the function and introduces the skill as a significant factor in the reduction of the quantity of errors which are done by an operator. (Mcworth, 1961) However, in the study by Bloom it became clear that most of the human errors are due to the bad performance of the operator and the reason

for most of them is technology, space factors, and the organizational factors and this has nothing to do with the abilities of the person and the human errors are considerably preventable and one of the best prevention ways is a design which is human-oriented. (Anita, 1995)

Shappell in a study to analyze the human errors in the pilots came to this conclusion that the air accidents are totally due to accidents which culminate after an unsafe action by the operator. Also, the results of the studies by Shappell indicated that the physical conditions of the space such as heat, vibration, and illumination influence the function of the individual. Also, high temp of the space is solely capable of reducing the body water and as a result leads to the reduction of the sober level and due to that leads to the reduction of decision-making speed and even an inability to control the airplane. In this study Shappell has considered the influential factors in the appearance of human errors which lead to the occurrence of air accidents. (Shappell, 2006)

CONCLUSION

In general heat stresses are considered as harmful factors in the realm of physical and mental activities. Considering some of the studies a high space temperature can be a stimulant factor for the mental activities and this issue can be correct until the temperature of the space doesn't lead to a disorder in the individual and as a result leads to a change in their behavior. This time the individual tries to do his/her job faster and in this manner the number of their errors will rise. In addition to this, the space temperature will have no outstanding effect on the mental function until it doesn't increase the deep body temperature and as the procedure of deep body temperature rise commences human brain will be afflicted with disorder and the function loss. Considering the obtained results the present study wasn't able to prove that the thermal stresses can lead to the increase in the number of errors and the analysis of brain activities. However, there was a close relation between the occurrence of the error and a high space temperature. In order to get sure about how the thermal influences are on the mental function another study should be done in a more controlled situation with tangible thermal variations and also a more volume for the test sample should be designed and its results should be analyzed.

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