2016

Evaluation of Computer Workstation Standards

Midhun Vasan
Iowa State University

Evaluation of computer workstation standards

by

Midhun Vasan

A thesis submitted to the graduate faculty
in partial fulfilment of the requirements for the degree of
MASTER OF SCIENCE

Major: Industrial Engineering

Program of Study Committee:
Richard T Stone, Major Professor
Michael Dorneich
Stephen Vardeman

Iowa State University

Ames, Iowa

2016

DEDICATION

I dedicate this to my father, Mr. M. Gokula Vasan, who taught me the value of earning your place in life. The day I become half the man you are, I will consider myself the luckiest person alive. Proud to be your son.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

First and foremost, I thank my parents, my father Mr. M. Gokula Vasan and my mother Mrs. Vasantha Vasan and would like to tell them how grateful I am for providing me with the opportunity to pursue my Master's degree. Always encouraging me to learn as much as I can from all the resources available to me. I would like to thank my partner, Akshita Pillai for mentally supporting me through all the troubled times and being there for me when I needed someone to calm me down.

I would thank my advisor Dr. Richard Stone, who has always encouraged me through both my coursework and my thesis. He has always put a spin on anything that went wrong or any moment of trouble and made it seem like an opportunity to learn and make the best out of the bad situation. It is always great to have someone appreciating you even when you feel you have not done enough work. It was a great experience working with him.

I would like to thank my committee members, Dr. Michael Dorneich and Dr. Stephen Vardeman for all their inputs and help with my thesis. Dr. Dorneich's door has always been open for pop-in quick questions, which were never turned down. His detail oriented nature and organized work structure which I got to know through IE 572, has helped me understand the need for a crisp and clear plan when it comes to getting work done. Dr. Vardeman's input on my data analysis helped me a long way in the tedious task of presenting my data.

ABSTRACT

This thesis aims at studying and evaluating the relevancy of the latest existing standards that have been established for setting up a computer workstation. The standards referred to in this study is the ANSI/HFES 100 (2007). Over the past two decades, standards have been updated to get along with new technology. However, by human nature, we does not always use these standards in the best way. Also, even if someone does set up their workstation in a way that are in accordance with standards, chances are that the user did not even know they were setting it in those 'standard recognized' way. It is more through their natural instinct and comfort that they do end up setting the workstation in that way. During computer tasks, people tend to shift their posture well outside of 'standard advised' posture ranges. If that is the case, then why enforce standards at all? That is exactly the intention of this thesis. By having two groups (one workstation set up according to standards and the other is set up by the user according to their comfort) the experimenter is able to compare and show that the postural behavior between the two groups are not significantly different and hence, the data gathered fails to show that standards could make any difference in the way a user sets up his/her workstation and also it does not affect the postural behavior or shifts in posture during the two-hour task. The study also tries to find out the effect of a two-hour computer task on stereoacuity and pupil diameter changes in participants. From the results and conclusion arrived in this study, companies can decide whether or not to spend valuable money and time in hiring an ergonomic expert in setting up workstations. Maybe the best thing they could do is provide the ergonomic office furniture and trust the judgement of the users to put it to best use.

CHAPTER I

INTRODUCTION

International Standards Organization (ISO) defines a standard as *"a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose"* as per mentioned in the ISO website ("ISO Standards - ISO", 2016). Standards serve the purpose of ensuring that a system is used or followed across a large population in the same way. It acts as a method for sharing specific details or knowledge across the population without requiring one to be an expert in the topic. Throughout history, standards helped contribute to society in terms of health, safety, infrastructure design and many related fields. With the advancement of time and emerging technologies of the present world, application of standards has reached broader areas such as management techniques in running a good business, measurement of environmental health (Brown, Pyke and Steenhof, 2010).

A major part of this study is regarding the relevancy of one such standard established for setting up computer workstation. Normal human behavior does not always go with healthy behavior. Humans tend to take bad postures to get work done. Take for example that most people bend over their hips to pick up a box or any object from the ground rather than squatting down just because squatting consumes more energy. Do people actually think about these facts? Ever slouched while you are sitting on a chair? It takes less effort than having to make yourself sit upright. Human nature kicks in and people go about their lives. You could argue the point that maybe it is because people are not given enough awareness about good ergonomic habits. When is the last time you ever actually checked if the distance at which you are seated from the monitor while using a computer is within the advised standards? Ever thought whether the posture which you “feel” comfortable in while sitting there is actually safe or ergonomic? Have you ever sat at the edge of your seat or leaned in forwards towards the monitor after reclining on the backrest for a while? Ever slouched while typing out some assignment or email? When you think about it, you know that you have taken up bad postures while sitting at a computer workstation. You were too busy with the work at hand that you forgot to think about the efficiency of your posture or the effect it has on your performance. If you stop to think about the long term negative repercussions of the posture assumed every time you change your posture, then you get distracted from the work at hand and may lead to reduced work performance.

With the evolution of technology from the CRT screens taking up the whole area of the workspace to the latest LCD/LED monitors and also with the many lawsuits faced by companies from the employees due to many cases of Musculoskeletal Disorders (MSDs) there is increasing research in finding a suitable way to arrange your workstation. Standards have evolved over the past two decades. This study aims at evaluating a particular set of standards (ANSI/HFES 100-2007) that have been established to guide in setting up a computer workstation. Through the study, the experimenter tries to see if these standards do make a difference when compared to people who just set up their workstation according to their free will or in a way that comforts them. Within this set up the experimenter introduces two different chairs with different backrest features to understand the effect of chairs on postural behavior.

The study also aims to find out the effect of short term computer tasks on pupil dilation and stereoacuity of computer users. These will be stated in the hypotheses section.

Hypotheses

1. The postural behavior variables measured among the participants are not different for the two different arrangements of workstation (Standard and Non-Standard).
2. The postural behavior variables measured among participants are not different for the two different type of chairs used.
3. Stereoacuity or ability to identify disparity measured are not different for two different arrangements of workstation (Standard and Non-Standard).
4. Pupil diameter measured are not different for the two different types of chairs used.

CHAPTER 2

LITERATURE REVIEW

Computer Use

Computers have become an integrated part of our everyday lives. From personal to professional levels, it is being used on a major scale. In 2003, approximately 190 million personal computers have been reported to be used according to a study (Gerr, F., Marcus & Monteilh, 2004). Computer use has spread across wide range of age groups. School children and adolescents were found to be more frequent users of computers than adults in 2001 (DeBell and Chapman 2006). Since computers help in accessing information faster and easier, it may also be considered to represent, in a way, the users' standard of living (National Research Council 1999). A study conducted by National Center for Education Statistics in 2005 concluded that 67% of kids going to nursery school used computers and 23% of them using internet (DeBel, M. 2005). It would be safe to assume that the extent to which humans would rely on computers in the coming years for the simplest of day to day activities and the number of users will keep increasing.

Musculoskeletal Disorders

Musculoskeletal disorders have been described as conditions or injuries which involve the nerves, tendons, muscles and other support-providing-structures of our body (Bernard 1997). Previous studies have used terminologies which included cumulative trauma disorders and/or repetitive strain injuries to describe Work-related Musculoskeletal Disorders (WMSDs). Putz-Anderson (1988) described cumulative trauma disorders as discomfort and/or problems that develop due to cumulative, repeated exposure to stressors which affect specific body parts and eventually leads to trauma or damage of tissue and joints. In many industrial countries, among computer users and the general population, musculoskeletal discomfort involving neck, shoulder and arms are common according to two studies (Gerr, F., Marcus & Monteilh, 2004).

A study conducted in 1992 by the National Institute of Occupational Health in Sweden showed increased case of eye and wrist issues/discomforts among Visual Display Terminal (VDT) users (Bergqvist et al., 1992). A correlation between computer use and musculoskeletal issues was concluded by another study, although it could not prove any correlation between computer use and upper limb musculoskeletal issues (Waersted et al., 2010). These contradictions may be explained by the difference in methodology or other compounding factors that could have affected the studies. Previous studies on students using computers have shown computer-use related musculoskeletal symptoms (MSS) prevalence rates of 52.8% (Dockrell et al.,2015), 53.4%(Katz et al.,2000), 54.0% (Jenkins et al., 2007), 67% (Hupert et al., 2004) and 80.6% (Hamilton et al., 2005). It is interesting to note that discomfort and complaints arising out of computer use can still prevail even under properly adjusted workstations (Arndt, 1983). This may be due to psychological factors which will be explained at a later part of this section.

While working at a VDT workstation, users do not always take a posture that is best for their health. Most of the time they do not even notice this as they keep switching between their postures. Some studies done before have concluded that awkward or wrong postures at a computer workstation could raise your chances of developing MSDs (Ortiz-Hernandez et al., 2003; Carter & Banister; 1994; Bergqvist et al.,1995; Yu & Wong,1996). Ortiz-Hernandez et al. (2003), concluded that long term seating with a slouched spine, leads to increased stress on the discs of the vertebrae and in turn causes muscle pain. A similar conclusion was arrived at by Ariens et al.

(2002) with regard to forward extension of the neck and working in that position for prolonged period of time. A longitudinal study on work-related physical and psychosocial characteristics of complaints of neck, shoulder, forearm and hand pain conducted by Eltayeb, Staal, Hassan and de Bie (2009) on computer users observed four main predictors for shoulder and neck pain, one of them being irregular head and body posture, rest of the three predictors being hours of work per day, difficulty level of the task and previous history of complaints. It also observed two predictors for forearm and hand pain as demand from job and previous history of complaints. Several other studies also confirmed that previous history of complaints to be a strong predictor for indication of pain/discomfort/complaints (Bongers et al., 2006; Smedley et. al., 2003). The study by Eltayeb, Staal, Hassan and de Bie (2009) suggests that while implementing or planning out a strategy which works at reducing incidents of neck, shoulder and forearm complaints/discomforts, both the ergonomic and psychological aspects and their relation with each other should be considered.

Several studies have been conducted to study the effect of monitor height on neck flexion and discomfort which in turn leads to Work-related MSDs in the long run. Level of tension felt on the neck was found to be proportionate to the flexion or deviation of the neck or head position according to two studies (Hamilton, 1996; Villanueva et al., 1997). Lowering the monitor and thus changing the viewing angle from 15º to 40º was found to increase muscle activity in the cervical erector spinae muscle (Turville et al., 1998). Another study (Sommerich et al., 2001) arrived at a similar conclusion when it was found that for a viewing angle of 35º below the horizontal there was an increase in muscle activity for different muscles with the most influence on the cervical erector spinae muscles. Raising the screen was also observed to increase the muscle activity for an 89-minute VDT study, where the baseline height was fixed at a point where the top of the screen was at exact level of the participant’s eyes and then increased to the highest at 15 cm above the baseline (Seghers, Jochem & Spaepen, 2003). It was also found in the same study that when the screen was lowered to a height of a laptop, to simulate how users would gaze down to a laptop screen, the highest level of neck extensor muscle (Splenius capitus) activity was observed due to the extreme flexion in the neck. From that study it may be concluded that laptop users face more discomforts and/or pain to their body as compared to desktop monitor users from the obvious height at which laptops are usually mounted. With the portability and convenience of using laptops the risk of MSDs is on the rise.

Not a lot of literature exists which shows relation between VDT use and muscle activity of the shoulder. In the study mentioned previously (Seghers, Jochem & Spaepen, 2003), low activity levels were measured for deltoid muscles which has been explained to be due to the arm rests of the chair and the height of the table used in the study which provided proper support for the forearms. Similar observations were made by Aaras et al., (1997), where significantly lower trapezius muscle activity was observed when support for forearms were provided. Hence the design of office chairs plays some role in discomforts and pain developments of the users. Using different methods, office chairs and seated positions have been studied by previous studies (Andersson & Ortengren, 1974; Baumgartner et al., 2012; Bendix et al., 1985). A study was conducted on chair designs and its redesign to analyze, among other effects, the effect of redesign on the seat pan's peak pressure (Groenesteijn et al., 2009). The redesign introduced a denser seat pan and the shape was made more basin-like. No significant difference was observed between the two chair designs as far as the peak pressure was concerned. Another study (Carcone & Keir, 2007) reported that by adding a supplementary backrest to a chair, there was a reduction of 35% and 20% in peak and average pressure respectively exerted on the back in the upright posture. A study was conducted on 24 participants using 12 different office chairs differing in design with each other to understand the effect of chair design on posture of the participants and the pressure distribution on the seat pan (Vos et. al., 2006). The study concluded that the chair design had more effect on the pressure distribution and followed by the posture. The study also found that the pressure distribution values were higher for males than females. This may be explained using the difference in the physique between males and females.

Psychological factors have also been reported to have some associations with body discomfort or pain. A cross-sectional study of 3475 computer users, conducted to study the association between stress and neck and shoulder discomfort/pain symptoms concluded that odds for symptoms involving neck was doubled for users with high job demands while no association was observed for shoulder discomfort/pain (Jensen, et al., 2002). Another study in Sweden involving 420 medical secretaries observed that poor psychological environment was associated with neck and shoulder symptoms compared to those who have more favorable psychological work environments (Linton & Kamwendo, 1989). 973 computer users working on a deadline in a metropolitan newspaper in the United States were observed for association with neck and hand musculoskeletal discomforts. It was observed that participants with shoulder musculoskeletal discomfort/pain were more likely to report high job pressure and those with neck musculoskeletal discomfort/pain reported less job variance (Bernard et al., 1994). A study on 533 telecommunications workers working a computer workstation showed that workers exhibiting neck or shoulder discomfort/pain reported high work pressure and routine work which lacked in decision making opportunities. Those with arm or hand discomforts reported their work to involve high information processing needs (Hales et al., 1994). Not all studies on psychological factors have consistent results. A study involving 218 newspaper workers who were computer users showed no association between job demand or control and musculoskeletal discomforts/pain (Ortiz-Hernandez et al.,2003).

Visual Fatigue

Another issue, the increasing computer usage has brought about is visual fatigue. Eye strain was described as “vague discomfort which may be localized in the head or eyes”, by Tyrrell and Leibowitz (1990) and put it under a category of visual fatigue. Tyrrell and Leibowitz also described visual fatigue to be a subjective visual distress/symptom. Leavitt (1995) reported 75% of VDT users to be exhibiting eye strain symptom while Pickett and Lees (1991) reported this to be high as 85%. A study conducted on visual display terminal (VDT) users in Poland revealed that the greatest discomfort reported by the users was visual fatigue followed by mental load and musculoskeletal pain. The number of women reporting these discomforts were found to be higher than that of men (Kamieńska-Zyła, 1993). On another study conducted on VDT tasks involving data entry by office workers concluded that increased keyboard work resulted in increased reports of eye strain (Bergqvist, 1995). This may be because of increased entry work which causes an increases attention to keyboard. Another conclusion that would come very easy to one’s mind would be that increased data entry means more attention to VDT screens which could also cause eye strain. However, another study on eye discomforts and VDT tasks showed weak correlation between increased attention to VDT screens and the risk of eye discomforts (Berqvist and Knave, 1994).

Viewing angle has been considered to have some effect on the visual strain or fatigue among computer users. Human eyes’ resting point is considered to be between 0º to 15º downward gaze from the horizontal assuming that the head having deviation from the length of spine or more clearly assuming that the head is in an upright position. The optimum viewing angle is recommended to be 0 degrees but since a computer screen cannot be looked at with just one viewing angle, the above mentioned range can be explained. A study (Sotoyama et al., 1997) on visual comfort with regard to viewing angle and its effect on tearing of the eyes reported that there was an increase in amount of tearing of the eyes for viewing angles of 0º to 30º below the horizontal. This was explained by the fact that ocular surface increases with increases in the viewing angle which in turn causes the tears to evaporate and lead to dry eyes. Another factor that effects eye comfort is the height at which the monitor screen is placed. According to a study by Villanueva et al. (1996), there is an evident correlation between the angle to which humans adjusts their neck to accommodate a comfortable viewing angle. This is dependent on the height of the monitor placement. The higher a monitor is placed the more you tend to tilt your head back to view the monitor and increase the neck angle which in turn leads to increase in discomfort of the neck. The same conclusion was reported by more than one study (Saito & SOTOYAMA et al. 1997; Sotoyama et al. 1997; Burges-Limerick et al. 1998; Psihogios et al. 2001).

Jaschinski-Kruza (1988) conducted a study on the effect of viewing distance on visual fatigue. The ciliary muscles' mechanism, which accommodates the power of the lens of the eyes to form an image on the retina, is strained more as the viewing distance shortens. The study reported increase in visual strain for viewing distance of 50 cm as compared to 100 cm. A study conducted by Chi and Lin (1988) on accommodation mechanism of the human eyes reported a correlation between visual acuity and different work duration on VDT tasks. Other studies also proved correlation between eye strain and duration of daily VDT work (Nakazawa et al., 2002).

Pupil size is one indicator for visual discomfort. Its increase negatively affects the required focus and precision of the eyes' accommodative response system. Saito et al. (1993) observed 10%

smaller pupil size in case of positive CRT displays compared to negative CRT displays and hence concluded that a positive CRT display is better. Taptagaporn and Saito (1990) also arrived at a similar conclusion from observing that positive display caused less strain on the eyes compared to a negative CRT display. However, there is no confirmed report between the relationship of pupil diameter and visual discomfort (Taptagaporn & Saito, 1990).

Another factor to be considered as a cause for visual discomfort among VDT users is eye movements. Saito et al. (1993) found out that VDT work included a relatively high amplitude and frequency of eye movements. Compared to workers who did not VDTs, those using VDTs for their jobs/tasks were found to have 2.5 faster eye movements. Extraocular muscle forces are dependent on fixation position and angle of eye movement (saccadic amplitude) (Hallett, 1986). Torsion could stress the optic nerve and cause discomfort and pain to the eye.

Stereoacuity (also known as visual acuity) is defined as the smallest amount of disparity in the retinal image in the horizontal direction that lets us identify or perceive a sense of depth of an object (Lovasik & Szymkiw, 1985; Schmidt, 1994). It lets us judge the details of an object while viewing with both eyes. So far the study on factors affecting visual acuity has been more in the area of age related changes. There are studies which have reported that age causes only a small change in visual acuity (Brown *et al.* 1993; Yekta *et al.* 1989). Other studies have contradicting conclusions stating that there is a strong correlation between age and visual acuity (Bell *et al.*, 1972; Haegerstrom-Portnoy *et al.*, 1999; Wright and Wormald,1992). The difference may be due to difference in methodology or other factors which might have affected the study which may have been missed out. Hence a general relation cannot be concluded from these studies. Even though the current study does not test for any correlation between age and stereoacuity, the above scenario might give us an idea that research in this field is rather hard due to possible unknown factors.

A lot of research has not been conducted on short term or long term effects of computer or VDT tasks on visual acuity or stereoacuity among VDT users. A three yearlong research study (Yoshikawa *et al.*, 1991) was conducted on 4 different groups of workers at a printing company. The study commenced once VDT tasks were introduced to two groups where first group had routine VDT tasks and second group had comparatively less VDT tasks. The third group were workers from the printing company who had typesetting work which did not involve any VDT tasks. The last group involved workers from a chemical plant with no VDT task. The comparison of visual acuity of workers at the beginning of the study and at the end of 3 years showed that the first group with regular or routine VDT tasks showed most reduction in stereoacuity followed by the second group. The other two group were showing relatively very little reduction. However, since not much more research has been done in this field, it is hard to generalize this effect. The current study will be attempting to observe any change in visual acuity during the relatively short time period of two hours. A Randot Stereo Test is used in this study to measure this. Randot stereo tests are used commonly to measure stereoacuity.. Currently there are different Randot Stereo Test booklets available to test for children and also for adults. One example is the Randot® Preschool Stereoacuity Test (Birch *et al.*, 2008) which is used in particular for children as young as 3 years old to make it easier for them to respond to the test. In the current study a different Randot Stereo Test is used which facilitates testing of different individuals with different comprehension and different levels of disparity.

Switch from CRT to LCD Monitors

Liquid crystal displays (LCDs) have become popular over the past few decades and the number of Cathode Ray Tube (CRT) displays have become less due to a number of reasons. LCDs take up less space compared to CRTs. This gives more flexibility in regard to how you can arrange the computer workstation, how easy it is to move a monitor around and adjust its height and tilt easily to accommodate the users' needs. LCDs also utilize less power compared to CRTs which in turn means reduced emission of heat which reduces the load air conditioning and reduced electromagnetic radiation and its associated problems (Menozzi, Näpflin & Krueger ,1999). LCDs offer better viewability, higher response time, color and brightness (Lessin, 1992). The reduced weight and relatively small size puts them at an advantage when it comes to desk workspace (Ahlstro¨m et al., 1992).

Computer Workstation Standards

ANSI/HFES 100-1988, American National Standards for Human Factors Engineering of Visual Display Terminal Workstations, was the first set of standards for computer workstations established by Human Factors and Ergonomic Society (HFES) in 1988. This standard set up the specifications to be followed as an option while setting up a computer workstation for operations in seated posture. The standard was formed in consideration of specific computer tasks which included data entry, text processing and data inquiry as well as served purpose as guidelines for other tasks which involve working at a computer workstation or a Visual Display Terminal (VDT) (American national standard for human factors engineering of visual display terminal workstations, 1988).

BSR/HFES 100-2002 Human Factors Engineering of Computer Workstations (Draft standard for trial use) was published later in 2002 as a revision to the ANSI/HFES 100-1988. BSR stands for Board of Standards Review. In the 1988 version, the standard focused only on the upright posture as a reference. This led to a misunderstanding and conclusion that this was the only correct posture (Ergoweb, 2002). In the revised version, the standard considered a total of four different primary working postures. These were upright, reclined, declined and standing postures. The reclined posture occurs while leaning back on the backrest so that the chair tilts back, the declined posture occurs when the user leans forward and the standing posture is when the user stands up straight while working at the computer. The addition of the new postures gave attention to posture of the trunk and the legs and gave guidelines taking into consideration postures of different body parts. Also, more input devices are given consideration in the revised standards.

After 5 years after the 2002 version of the standard, American National Standards Institute (ANSI) approved the latest standard ANSI/HFES 100-2007, Human Factors Engineering of Computer Workstations, which includes some of the parts of the 2002 version (Anderson, 2002). The 2007 standard has taken flat panel displays also into consideration compared to CRT monitors of the 1988 version. For the purpose of this study, not all the specifications mentioned in this standard has been used. The standards that have been followed in this study are provided in APPENDIX K.

Numerical Rating Scale

Numerical Rating Scale (NRS) is a very common scale used nowadays to judge pain especially in primary care at hospitals. A study of NRS on adults reported it to be effective in clinical care (Bijur, Latimer, & Gallagher, 2003). Similar conclusions have been reached by other studies (von Baeyer *et al.*, 2009, Hollen et al., 2005, Jensen, Karoly, & Braver, 1986, Williamson & Hoggart, 2005). This method has been adopted in the study for a pain scale questionnaire to understand the perceived pain or discomfort from the participants.

CHAPTER 3
EVALUATION OF COMPUTER WORKSTATION STANDARDS

Midhun Vasan, Iowa State University, Ames, IA, U.S.A.

Richard T. Stone, Iowa State University, Ames, IA, U.S.A.

Abstract

Objective

The study reflects on relevance of existing standards for setting up computer workstations.

Background

Normal human behavior does not always make us assume the best postures as we tend to shift posture to make ourselves comfortable. This often results in inappropriate and awkward postures even if we know it's not best for our body.

Method

A 2 x 2 factorial design which included two different arrangements of a computer workstation and two different chair differing in its features were used to make participants perform a 2-hour computer task during which the postures were measured.

Results

There is no significant difference in postural behavior for different arrangements of workstation and also for interaction effect. Two posture variables showed difference across the two chairs used.

Conclusion

Arranging workstations based on standards does not cause significant effect on postural behavior of subjects. Chair features or design seems to have affect the way they assume their postures.

Keywords: Standards, workstation, posture

Introduction

International Standards Organization (ISO) defines a standard as *"a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose"* as per mentioned in the ISO website ("ISO Standards - ISO", 2016). Standards serve the purpose of ensuring that a system is used or followed across a large population in the same way. It acts a method for sharing specific details or knowledge across the population. Throughout history, standards helped contribute to society in terms of health, safety, infrastructure design and many related fields. With the advancement of time and emerging technologies of the present world, application of standards has reached broader areas such as management techniques in running a good business, measurement of environmental health and so on (Brown, Pyke and Steenhof, 2010).

A major part of this study is regarding the relevancy of one such standard established for setting up computer workstation. The standard used for the purpose of this study is ANSI/HFES 100-2007. Normal human behavior does not always go with healthy behavior. Humans tend to take bad postures to get work done. In a workplace, this causes workers to assume postures that might not be safe and unproductive or which might have negative effects in the long run. Improper posture at workplace is a major cause for Musculoskeletal Disorders (MSDs) such as lower back pain, visual fatigue and other discomforts. Even if people know the long term effects of bad postures, while getting caught up with work people do not think about it often. Leaning forward while having to read something or inputting some important data, computer users do not consider the distance that they place themselves from the screen or how much they bend around their hips while leaning forward. While picking up a heavy object from the ground, a worker might feel lazy to squat down and pick it even though he knows it is the right way to do and ends up bending over the hips which could cause lower back injury. One simple slip while bending down and lifting an object is enough for pulling a muscle or causing a permanent injury on your lower back which results in absenteeism of the worker. With the evolution of technology from the CRT screens taking up the whole area of the workspace to the latest Liquid Crystal Display (LCD)/Light Emitting Diode(LED) screens and also with the many lawsuits faced by companies from employees due to many cases of MSDs, there is increasing research in finding a suitable way to arrange workstations.

Computers have become an integrated part of our everyday lives. From personal to professional levels, it is being used on a major scale. A study in 2003 reported there are 190 million computer users (Gerr, F., Marcus & Monteilh, 2004). Computer use has spread across wide range of age groups, adolescents and school children more frequent than adults according to a 2001 study (DeBell and Chapman, 2006).

MSDs have been described as discomforts, injuries or conditions in which the nerves, tendons or muscles of one's body (Bernard 1997). Work related MSDs or WMSDs can be described with words such as cumulative trauma disorders, repetitive stress or strain injuries which are caused due to repetition of a movement or task which in the long run leads to damage of muscle tissue or joints (Putz-Anderson, 1988). In many industrial countries, among computer users and the general population, musculoskeletal discomfort involving neck, shoulder and arms are common according to two studies (Gerr et al., 2004). When one study reported increase in the number of cases of wrist and eye discomforts among VDT users (Bergqvist, Knave, Voss, & Wibom, 1992), another study could not prove correlation between computer use and upper limb musculoskeletal issues (Waersted, Hanvold & Veiersted, 2010). These contradictions may be explained by the difference in methodology or other compounding factors that could have affected the studies. Previous studies on students using computers have shown computer related musculoskeletal symptoms (MSS) prevalence rates of 52.8% (Dockrell, Bennett & Culleton-Quinn, 2015), 53.4% (Katz, Amick, Carroll, Hollis, Fossel & Coley, 2000), 54.0% (Jenkins, Menéndez, Amick Iii, Tullar, Hupert, Robertson & Katz, 2007), 67% (Hupert, Amick, Fossel, Coley, Robertson & Katz, 2004) and 80.6% (Hamilton, Jacobs & Orsmond, 2005).

Posture is another factor that is of interest when it comes to seated computer work for long duration which is the typical case in white collar jobs. Previous studies have observed that inappropriate postures at VDT workstation is a factor for increasing the chances for MSDs (Ortiz-Hernández, Tamez-González, Martínez-Alcántara, & Méndez-Ramírez, 2003; Carter & Banister, 1994, Bergqvist, Wolgast, Nilsson & Voss, 1995; Yu & Wong, 1996). Ortiz-Hernandez et al. (2003), concluded that long term seating with a slouched spine, leads to increased stress on the discs of the vertebrae and in turn causes muscle pain. A similar conclusion was arrived by another study (Ariëns, Bongers, Hoogendoorn, Van Der Wal & Van Mechelen, 2002) with regard to forward extension of the neck and working in that position for prolonged period of time. Several studies have been performed to understand the effect of monitor height on neck flexion and discomfort which in turn leads to MSDs in the long run. Level of tension felt on the neck was found to be proportionate to the flexion or deviation of the neck or head position according to two studies (Hamilton, 1996; Villanueva, Jonai, Sotoyama, HISANAGA, TAKEUCHI & SAITO, 1997). Lowering the monitor and thus changing the viewing angle from 15º to 40º was found to significant effect and increase muscle activity in the cervical erector spinae muscle (Turville, Psihogios, Ulmer & Mirka, 1998).

Not a lot of literature exists which shows relation between VDT use and muscle activity of the shoulder. Low activity of deltoid muscles was reported in a study (Seghers, Jochem & Spaepen,

2003) where the forearms were supported by the table and also the arm rests of the chair used. Hence the design of office chairs plays some role in discomforts and pain developments of the users. Using different methods, office chairs and seated positions have been studied by previous studies (Andersson and Ortengren, 1974; Baumgartner, Zemp, List, Stoop, Naxera, Elsig & Lorenzetti, 2012; Bendix, Winkel & Jessen, 1985). One study (Carcone and Keir, 2007) reported that by adding an additional backrest to a chair, there was a reduction of 35% and 20% in peak and mean pressure respectively exerted on the back in the upright posture. A study was conducted on 24 participants using 12 different office chairs differing in design with each other to understand the effect of the design features of a chair on posture of the participants and the pressure distribution on the seat pan (Vos, Congleton, Moore, Amendola & Ringer, 2006). The study concluded that the chair design had more effect on the pressure distribution and followed by the posture. Although not considered for this study, it is interesting to note the effect psychological factors have on reported discomforts/pain symptoms. A cross-sectional study of 3475 computer users, conducted to study the relation between stress and self-reported neck and shoulder discomfort/pain, concluded that odds for symptoms involving neck was doubled for users with high job demands while no association was observed for shoulder discomfort/pain (Vos et al., 2002). Another study in Sweden involving 420 medical secretaries observed that poor psychological environment was associated with neck and shoulder symptoms compared to those who have more favorable psychological work environments (Linton & Kamwendo, 1989).

Another issue, the increasing computer usage has brought about is visual fatigue. Eye strain was described as “vague discomfort which may be localized in the head or eyes”, by Tyrrell and Leibowitz (1990) and put it under a category of visual fatigue. Jaschinski-Kruza (1988) conducted a study on the impact of viewing distance on visual fatigue. The ciliary muscles’ mechanism, which accommodates the power of the lens of the eyes to form an image on the retina, is strained more as the viewing distance shortens. The study reported increase in visual strain for viewing distance of 50 cm as compared to 100 cm. Pupil size is one indicator for visual discomfort. Its increase negatively affects the required focus and precision of the eyes' accommodative response system. Saito, Taptagaporn and Salvendy (1993) observed 10% smaller pupil size in case of positive CRT displays compared to negative CRT displays and hence concluded that a positive CRT display is better.

Stereoacuity (also known as visual acuity) is defind as the smallest amount of disparity in the retinal image in the horizontal direction that lets us identify or perceive a sense of depth of an object (Lovasik & Szymkiw, 1985; Schmidt, 1994). There are studies which have reported that age causes only a small change in visual acuity (Brown, Yap & Fan, 1993; Yekta, Pickwell & Jenkins, 1989). Other studies have contradicting conclusions stating that there is a strong correlation between age and visual acuity (Bell, Wolf & Bernholz, 1972; Haegerstrom-Portnoy, Schneck & Brabyn, 1999 and Wright and Wormald,1992). The difference may be due to difference in methodology or other factors which might have affected the study which may have been missed out.

ANSI/HFES 100-1988, American National Standards for Human Factors Engineering of Visual Display Terminal Workstations, was the first set of standards for computer workstations established by Human Factors and Ergonomic Society (HFES) in 1988. BSR/HFES 100-2002 Human Factors Engineering of Computer Workstations (Draft standard for trial use) was published later in 2002 as a revision to the ANSI/HFES 100-1988. BSR stands for Board of Standards Review. In the 1988 version, the standard focused only on the upright posture as a reference. This led to a misunderstanding and conclusion that this was the only correct posture. In the revised version, the standard considered a total of four different primary working postures (Ergoweb, 2002). These were upright, reclined, declined and standing postures. The reclined posture occurs while leaning back on the backrest so that the chair tilts back, the declined posture occurs when the user leans forward and the standing posture is when the user stands up straight while working at the computer. After 5 years after the 2002 version of the standard, American National Standards Institute (ANSI) approved the latest standard ANSI/HFES 100-2007, Human Factors Engineering of Computer Workstations, which includes some of the parts of the 2002 version (Anderson, 2008). The 2007 standard has taken flat panel displays also into consideration compared to CRT monitors of the 1988 version. For the purpose of this study, not all the specifications in this standard have been used. The ones followed have been mentioned in APPENDIX K.

Hypotheses

1. The postural behavior variables measured among the participants are not different for the two different arrangements of workstation (Standard and Non-Standard).
2. The postural behavior variables measured among participants are not different for the two different type of chairs used.
3. Stereoacuity and pupil diameter measured are not different for two different arrangements of workstation (Standard and Non-Standard).
4. Stereoacuity and pupil diameter measured are not different for the two different types of chairs used.

Methodology

Participant selection

There were a total of 36 participants selected for the study out of which the data for 4 were not included due to specific reasons explained in the data collection section. The 32 participants (20 Males and 12 Females), included in the study were students enrolled at Iowa State University (ISU). Participants were called for using three methods. Flyers (APPENDIX F) containing brief of the study details were put on different locations at ISU campus. Second method involved announcement about the study to IE 271 class taken by Dr. Stone (Co PI). Students in his class were given the option of taking part in the study to obtain extra credits. Taking part in the study, whether the students finished the study or not, would earn them extra credits which accounted to 3% of their final grade in the class. If the students from IE 271 chose not to take part in the study, they were provided with an alternative homework assignment which will provide them with the same credits upon submission. An informed consent form template was obtained from Iowa State University website and filled out with all the details as required by the Internal Review Board (IRB). The consent form (APPENDIX C & APPENDIX D) was provided to each participant prior to taking part in the study which explained in details about the tasks to be performed as part of the study. The participants were asked to read and understand the consent form and sign upon agreement of conditions of the study.

Certain restrictions or criteria was attached to the eligibility of participants. Since the study mainly focused on desktop computer use and the standards of the workstation, the participants needed for the study were required to be frequent desktop computer users. People who used laptops alone were filtered out through this criterion. With regard to health issues, people who have migraines, sty or any form of infection on the eye were asked not to participate in the study in order to avoid any chance of worsening their condition/conditions. Participants also needed to be 18 years of age or above.

Materials

An office computer workstation was simulated using an adjustable desk, with a 17-inch LCD screen monitor, a standard keyboard and mouse and an adjustable office chair. Arrangement A involved using an office chair with back rest unlocked and kept unlocked. This chair will be referred as C1 for the remainder of the study. Arrangement B involved using an office chair with a backrest that could be locked or unlocked as the user pleases. This will be referred as C2 for the remainder of the study. The entire workstation is shown in the Figure 1. The 17-inch screen was decided for the study after looking at another study (Seghers, Jochem & Spaepen, 2003), where a 17-inch Cathode Ray Tube (CRT) screen was used to study posture during computer use.

Figure 1. Workstation set up for experiment.

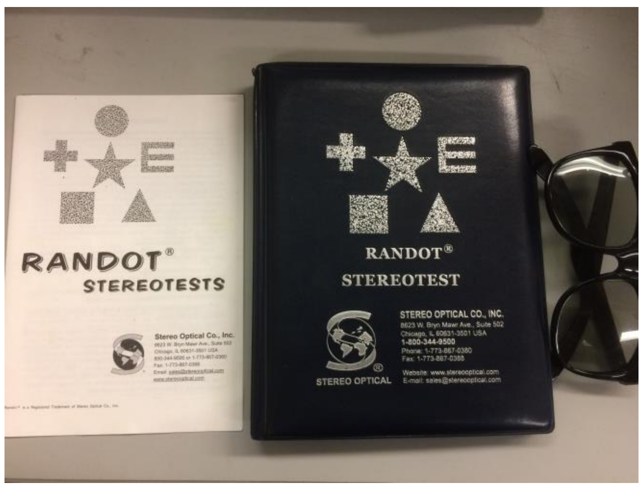


Figure 2. Randot Stereoacuity Test Kit

As part of the study a Randot Stereo Test is used Figure 2. It includes a special pair of glasses used for this test, a booklet and an answer key which will be used to understand and measure the results of the test. From the test it is possible to measure stereoacuity from 500 seconds of arc using different shapes/forms to as high as 20 seconds of arc using circles.

Task

All subjects were asked to play games online at http://www.addictinggames.com/ for a duration of 2 hours. Turville et al., (1998) showed significant increase in postural shifts in a 2 hour computer task. Also in another study (Waongenngarm, Rajaratnam & Janwantanakul, 2016) it was shown that one hour of sitting in three seated postures (upright, slouched and forward leaning) without a backrest or back support induced discomfort in the neck, shoulder, upper and lower back and the buttocks. Since a chair with a back support was used in the current study, after careful consideration of the abovementioned two studies, it was determined that two hours of testing would give a significant result. All participants were asked not to perform any other task on the computer such as checking emails or doing any work. In a previously mentioned study (Seghers, Jochem & Spaepen, 2003), as part of the experimental task, participants were made to play computer games where they were required to use arrow keys on the keyboard using their right hand while the left hand remained at rest. This study was used as a justification for the design of the current study. Participants were allowed to play as many different games as they please during the two-hour time period. This ensured that the use of keyboard and mouse was balanced as the controls were different for different games. Where some games used keyboard’s arrow keys alone for playing, some other games used both keyboard and the mouse at the same time, therefore engaging the use of both hands which would bring the simulated environment closer to a white collar work experience.

Experimental procedure

The initial parts of the study included an initial interview (APPENDIX H) which was aimed at finding out computer usage habits and patterns of the participant, self-reported discomforts, suggestions for eliminating discomforts and posture changes. This was followed by a Randot Stereo Test.

Randot Stereo test was performed to gauge the visual acuity of the participants prior to the main experimental task. The test involved wearing special glasses used for the Randot Stereo test and observing the images on the Randot Stereo Test booklet. Participants were asked to identify and point out or name the image which seemed to be projecting from the plane of the booklet or which showed some amount of depth. The test was scored based on the last image the participant was able to identify. The test is designed in a way that the images with high visual disparity appear first and as the test proceeds, the images decrease in the visual disparity or depth and becomes harder to identify which one appears to be projecting out of the plane of the book.

After the Randot Stereo Test, the experimenter adjusted the workstation according to which group the participant was to be put into. There are primarily two groups for each type of chair used for the study. For first group or Group A, the workstation was set up after making the participant sit at the workstation and observing whether the following were in line with the latest standards ("Human Factors Engineering for Computer Workstations", 2007):

1) The angle between the torso and the thighs were close almost equal to 90^{o},

2) When the participant sat with the feet flat on the ground, the lower legs were vertical to the ground,
3) Participant was asked to look straight ahead while sitting upright and the monitor was lowered till the top of the monitor was below the eyes' horizontal level,
4) The angle between the monitor's center and the horizontal at the eye is called the viewing angle. The design angular viewing envelope is the allowed maximum range of the viewing angle. The span of this measure was checked to be within +40º to -40º and from + 30º to -20º. This was checked after seating the participant at the workstation and taking one second video which was put in Kinoveo software (explained later) and the angle was measured. This ensured the vertical limits of the envelope was within the standard specified range. By keeping the length of the screen parallel to the length of the desk, we could ensure that a normal from the center of the display surface would go through the sagittal plane of the participant. Hence, the design angular envelope at the beginning of the study would be approximately close to 0º.
5) When the participant reaches for the mouse or keyboard, the shoulder flexion (angle between the upper arm and the torso) should not be more than 25º,
6) When the participant reaches for the mouse or keyboard, the elbows are either almost parallel to the ground or the elbow should not deviate more than 20º above the horizontal or 45º below the horizontal,
7) The participant should be able to sit in at least two of the sitting postures which in the case of this study was decided to be the upright position (both the torso and neck should be almost perpendicular to the horizontal and can deviate between 90 to 105 degrees to

the horizontal) and the reclining position (torso and neck can recline between 105 and 120 degrees to the horizontal).

The criterion for the upright position was not taken in the case of the experiment where the chair with unlockable backrest (C2 was used where only the reclining position would be possible.

Once the workstation is set according to the standards, the participant would be seated. The participant was asked to feel free to switch between upright or reclines position of seating, to move the chair closer to the monitor or farther away from it, to take a posture as they wish (they could fold their legs and sit, rotate their chair as they work, slide down on the chair to a lower position and any posture) as long as they do not adjust and/or move the monitor or move the desk as the desk is not an adjustable one. The participants were allowed to relax and stretch during the task if they feel any discomfort as long as they do not stand up in order to stretch. All movements were limited to seated movements.

For Group B, the workstation is arranged in a random way that would be relatively hard or uncomfortable for the participants to normally use. This is achieved by setting the chair to the lowest height and putting the monitor was raised to the highest allowable height and tilted upwards. Then the participant was asked to set the workstation to their preference. The only constraint on setting the workstation themselves was that the desk was not allowed to be moved as the desk was not an adjustable one.

After this, the study proceeded with the main experimental task for two hours. At the end of two hours the participants were asked to stop the task.

Once the task was done, the participants were made to perform the Randot Stereo Test again, followed by a post experimental pain scale rating questionnaire (APPENDIX I). The pain scale rating also known as Numerical Scale Rating (NRS) used here is a 0 to 10 scale rating where

0 represent almost no pain to 10 meaning extreme pain. Since NRS is very commonly used in clinical care for judging pain, participants might be familiar with this rating and hence it would be easier for them to judge and report their perceived pain or discomfort. The questionnaire covered discomfort/pain rating as reported by self for different body parts. This was followed by another interview (APPENDIX J) which covered questions regarding different discomforts faced by the participants which may have been missed out in the pain scale rating questionnaire. The interview questions also covered questions regarding participants' opinion on frequency of breaks, their posture change during the study and the reasons.

Variables

Table 1 shows the dependent and independent variables measured in this study. Also, from the pain scale rating questionnaire at the end of the study helps identify the discomforts as perceived by the participants.

Data Collection

This section will describe the methods used for measuring each of the above mentioned dependent variables. Diameter of the pupil was measured using a diagnostic penlight which was placed at level with the pupil about 1 to 2 inches off the face of the participants without making contact with their face. Once placed in position, the pupil was compared to the pupil gauge which are marked with measurements in millimeter (mm) to denote the diameter of the pupil. The stereoacuity was measured using the Randot Stereoacuity test as explained before. All angles and distance measurements were done through a software called Kinovea. The recorded videos were uploaded in the software and the video frame was captured every 5 minutes from the starting position till the end of 2 hours giving 25 frames. The postures were marked and the angles and viewing distance measured using the tools available in Kinovea. The starting position of the participants or the 0^{th} time point or first frame was also analyzed to understand if the way there was any difference in the way the participants in Group B arrangement arranged the workstation when compared to Group A where the workstation was arranged for them. By comparing these two, the data would show if Group B participants ended up arranging the workstation in a way that was within the standards recommendation. In this study, data collected from 4 participants were not included and/or collected for the following 4 reasons, one for each participant: 1) Memory space issue in the camera did not allow shooting the whole two hours of the study, 2) File got erased while restarting the laptop which was rented from Iowa State University which was programmed to wipe out the hard drive during every restart, 3) Participant was too short to be accommodated properly to the workstation as the desk used was not adjustable to reduce the height, 4) Participant failed to complete the study in the required way due to interruption during the study from the participant's side.

Table 1. Dependent and Independent Variables

Independent Variables	Dependent variables	Units
Arrangement (A&B)	Viewing distance	centimeters
Chair (C1 & C2)	Neck deviation from horizontal	Degrees
	Angle between torso and thighs	Degrees
	Shoulder flexion angle	Degrees
	Deviation of elbow (forearm) from horizontal	Degrees
	Stereoacuity	Seconds of arc
	Pupil diameter	millimeters

Analysis of Variance (ANOVA): One way ANOVA was performed to compare the mean starting posture between the two arrangements keeping the chair design constant. Two way ANOVA was used to study the variances between the groups in each factor. It was also used to study the separate and combined interaction effect of each factor (arrangement and the chair) on the measured dependent variables

Results

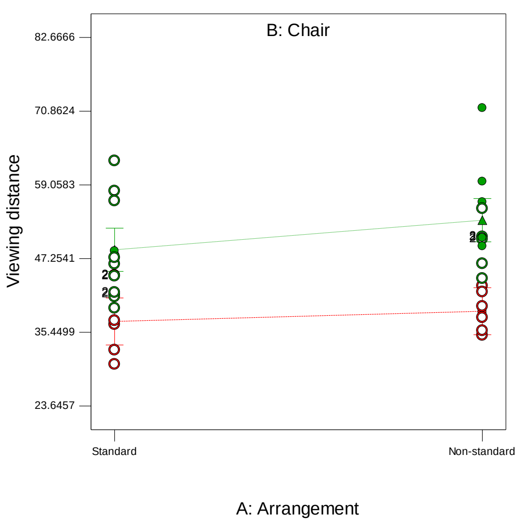
One-way ANOVA was performed to compare the means of starting position between the two groups of arrangement while keeping the chair constant. The results are given in Table 2. Two-way ANOVA on all measured postural variables, pupil diameter and stereoacuity are given in given in Table 3. The interaction plots for all postural variables measured, disparity difference and pupil diameter difference are shown in Figure 3.a. to Figure 3.e., Figure 4.a. and Figure 4.b. respectively.

Table 2. Summary of ANOVA results for postural variables at starting position. Main effects and interactions are given. Asterisk (*) denotes p<0.05

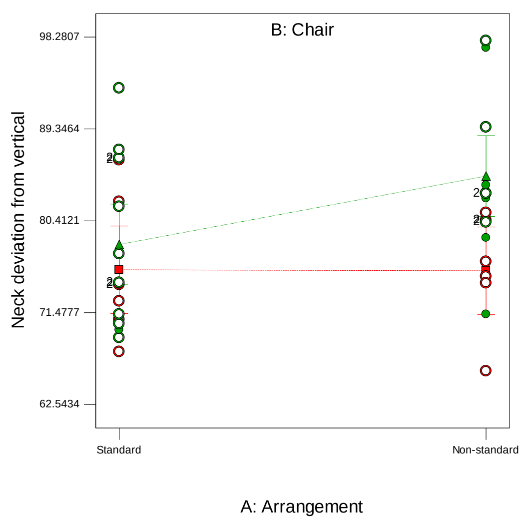
Measured Variables	C1 constant	C2 constant
	F-value	F-value
Viewing distance	0.18	0.26
Neck deviation from vertical	3.26	3.263
Angle between torso & legs	0.01	2.34
Shoulder flexion angle	0.51	1.69
Deviation of elbow from horizontal	0.73	0.19

Table 3. Summary of ANOVA results for the measured variables. Main effects and interactions are given. Asterisk (*) denotes p<0.05

Measured Variables	Arrangement	Chair	Arrangement*Chair
	F-value	F-value	F-value
Viewing distance	1.63	27.16*	0.39
Neck deviation from vertical	1.34	4.26*	1.43
Angle between torso & legs	0.54	3.77	0.23
Shoulder flexion angle	0.99	3.60	0.49
Deviation of elbow from horizontal	1.15	2.52	0.33
Disparity difference	0.20	2.26	0.20
Pupil diameter difference	3.23	0.05	1.76

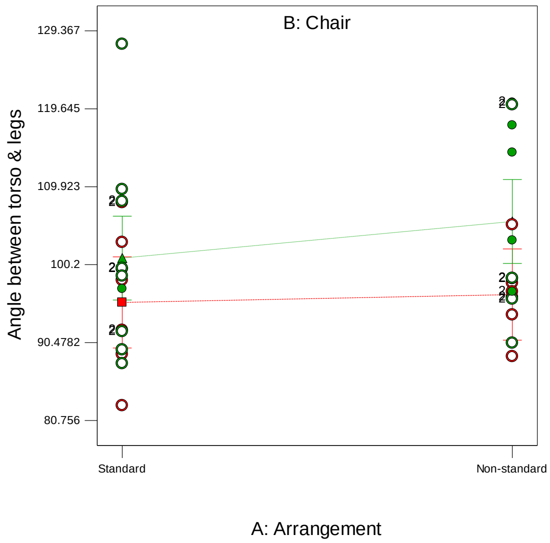


(a)

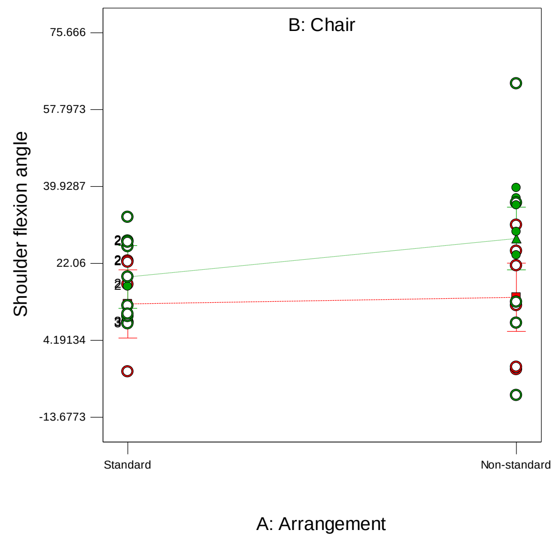


(b)

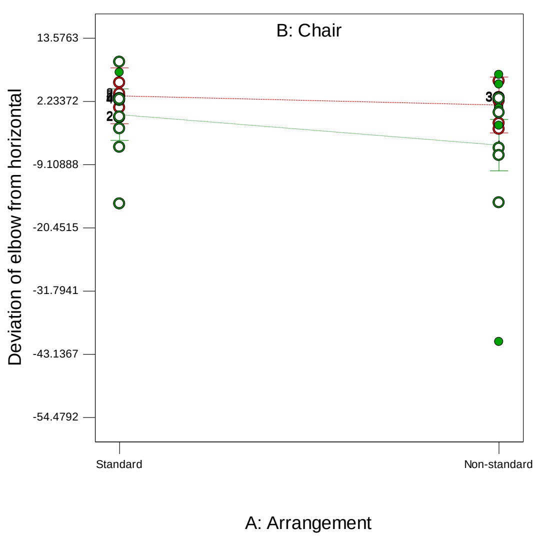
Figure 3. Interaction plots for postural variables (a) Viewing distance, (b) Neck deviation from vertical, (c) Angle between torso & legs, (d) Shoulder flexion angle, (e) Deviation of elbow from horizontal. Red dashed line indicates C1 and green dotted line denotes C2.



(c)

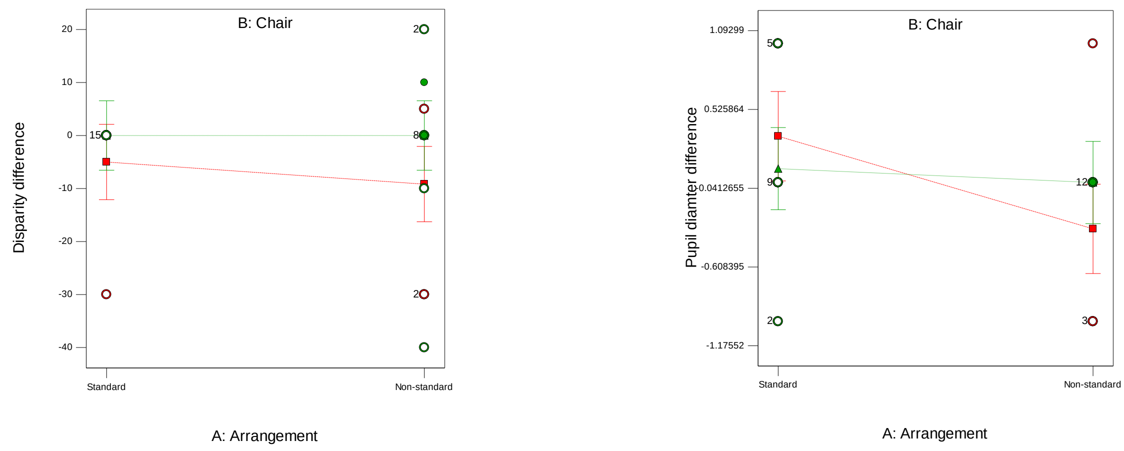


(d)



(e)

Figure 3. (continued)



(a) (b)

Figure 4. Interaction plots: (a) Disparity difference, (b) Pupil diamter difference

Table 2. analysis shows the keeping C1 constant the mean starting position of Group A and B are not significantly different. Similar effect in shown while keeping C2 constant. There is not enough to data or evidence to show that the way Group B arranged the workstation themselves (which in turn in the starting position) is different from how the workstation was arranged for Group A participants.

The two-way ANOVA in Table 3 shows that there is not enough evidence to suggest that the arrangement has significant effect on the postural variables, pupil diameter and stereoacuity. By taking a look at the interaction plots in Figure 2 and Figure 3, it is evident that for both the red and green lines which represent C1 and C2 chair types, the lines are almost parallel to the horizontal. There seem to be not enough evidence to show significant effecct on the measured variables. Therefore, the study fails to reject Hypothesis 1, Hypothesis 3. However, when considering the chair design or type used, the ANOVA table shows that it has a significant impact on the postural behavior of the user in terms of viewing distance and neck deviation from the vertical. Therefore the study rejects the Hypothesis 2 that there mean of postural variables measured is same. There is not enough data or evidence to show that there is a significant effect by chair design on stereoacuity and pupil diameter. Therefore, the study fails to reject Hypothesis 4 that the stereoacuity and pupil diameter measured are not different for the two different types of chairs.

The ANOVA analysis of the pain scale rating questionnaire after the experimental task is given in Table 4.

Table 4. Summary of ANOVA results for pain scale rating. Main effects and interactions are given. Asterisk (*) denotes $p<0.05$

Pain/discomfort symptoms	Arrangement	Chair	Interaction
	F-value	F-value	F-value
Eye strain	4.39*	0.47	0.47
Neck ache	0.06	12.85*	0.06
Rotator cuff	*0.79*	4.35*	*0.98*
Lower back	0.91	0.16	0.73
Elbow	0.17	5.60*	0.022
Wrist	<0.0001	9.00*	0.79
Hips	0.62	1.50	0.047
Knee	0.83	1.57	1.87
Head ache	0.54	0.24	0.089
Mid back	<0.0001	0.72	0.096
Shoulder tension	0.049	3.83	0.16

The arrangement of the workstation is shown to have a significant effect on the reported eye strain pain/discomfort. Also, the chair type is shown to have significant effect on the reported wrist, neck, elbow and rotator cuff pain/discomfort. There is not enough evidence of significant interaction effecct on any of the reported pain symptoms. Figure 3. represents a bar graph showing the mean value of the pain reported by the participants shown in the decreasing order. The highest value of discomfort is shown to be eye strain followed by lower back pain.

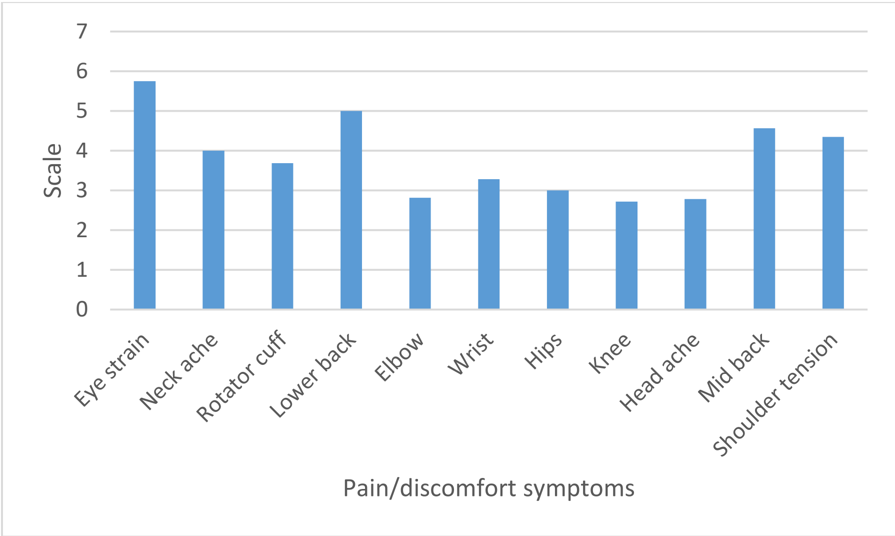


Figure 5. Bar graph of mean reported pain.

During the interview after the experimental study, participants reported the reasons as justified by them for shifting their posture (if at all they did). The various reasons have been categorized in three for the purpose of getting an idea about these reasons 1) Habitual: No apparent reason or generally restless, 2) Discomfort: General discomfort from sitting for long time, 3) Back related pain or discomfort, and 4) Concentration: Whether the change in posture was due to participants being bored or interested in a particular game during the task. The highest counts was noted for Discomfort (16), followed by Back pain (14), Habitual (12) and Concentration (4). It should be noted that each participant gave one or more reasons. This is shown in the Figure 5.

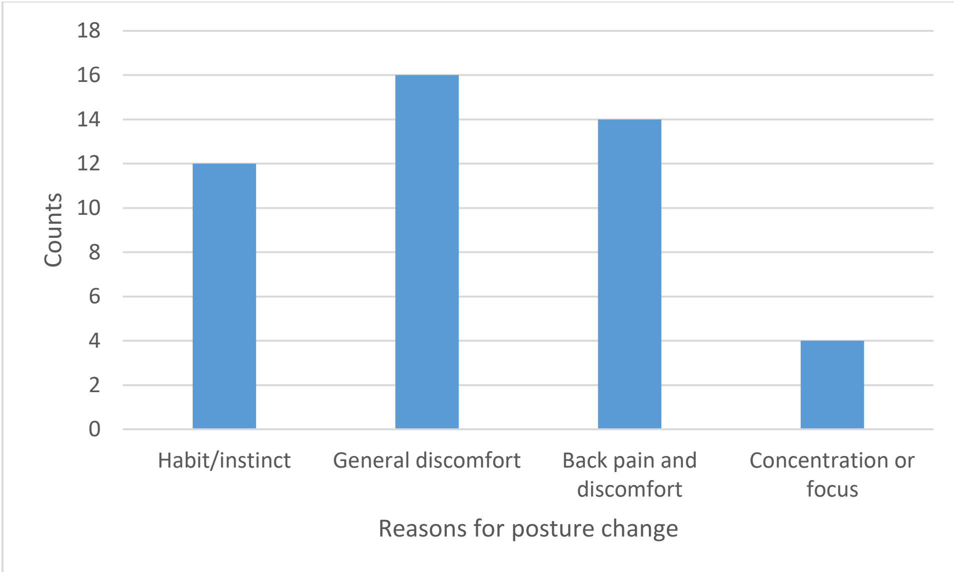


Figure 6. Bar graph of reasons for posture change vs counts

Discussion

From the results, we could come to the conclusion of failing to reject the hypothesis that the postural behavior across two arrangements are same. Since the results shows that the arrangement does not have a significant effect on the postural behavior, we could question the necessity of these standards. Chair design has been shown to have some significant impact or effect on how participants' postural behavior. This could again question whether corporate companies should hire ergonomic consultants, spend money and time to get the office workstations arranged according to the standards. The responses from the final interview indicates that computer users do change their posture a lot, due to the main reason of discomfort to the body. This discomfort as reported by each participant varied from eye strain to back pain. The number of back related pain and discomfort in particular tells us that computer users might encounter a good amount of discomfort to the back which forces them to shift their posture quite often. Another interesting observation is that change in posture due to habit is closely following the major top two reasons.

This could mean that some computer users change their posture due to being restless or natural tendency in addition to discomforts. Further analysis of the data might reveal if the type of arrangement of workstation or the chair has significant effect on the degree to which users change their posture and assume the wrong or bad postures. The standards under review in this study has one major limitation. It does not account for the shift in posture that occurs. Since users tend to move a lot, it is advisable that the workstation be built in such a way as to either prevent awkward shifts in posture or a workstation that adjusts according to the shift in the users' postures. Similar to present-day cameras which can identify your face and change focus as and when you move towards or away from the camera, it might help if the display screen could identify the distance of the user from the screen and alter the brightness. Also, with the advancement of technology, it will help reduce eye strain if the screen could tilt to accommodate to the viewing angle of the user as the user moves or turns in his/her chair.

The results from the NRS analysis shows that eye strain is affected significantly by arrangement of workstation and wrist pain is significantly affected by the chair type. There is not enough data collected to make us understand why these factors in particular are affected in this particular manner.

In the end we could say that it is advisable and makes sense to invest in an ergonomic workstation as it would give the users the option to use it to their preference and also provide them with a chance to use it wisely but treating these standards as a 'must' will not do any significant good or make it worth the investment.

Limitations

A higher sample size (compared to 32 sample size of this study) might have resulted in more promising results. The posture measurements would be more accurate if motion tracking sensors were attached to the participants' body during the whole study. Since motion tracking was not used, the data was extracted completely from the video. The limitation with this technique is the error from not being able to measure angles at awkward postures, such as if a participant rotates the chair by some angle which would not give the most accurate side profile of the participant. The measure of the length of the desk along the edge was used to calibrate the viewing distance measurement in Kinovea software. Since the edge of the desk is not in the same plane as the participants' sagittal plane on which the viewing distance is to be measured, some error arises in its measurement. If the desk used in the study was adjustable, Group B users would have had the option of changing the height of the workstation to their preference. Due to this limitation on the workstation, one participant's data had to be removed as the participant was too short.

Conclusion

The main purpose of this study was to see if the ANSI/HFES standards established for computer workstations impacts the way in which computer users assume work postures at the workstation. The results show that the behavior is not significantly different from the scenario when users just set up workstations according to their personal preference. Chair design however has been seen to have significant effect viewing distance and deviation of the neck from the vertical. Both chair type or workstation arrangement does not seem to have any significant effect on ability to identify disparity (stereoacuity) or the pupil diameter. There is not enough previous work done to give any idea as to whether posture especially viewing distance has any impact on stereoacuity. Even though there are very few studies done on change in stereoacuity from long term computer use, these studies did not focus on the posture or the stress that the users caused themselves through short or long viewing distances (Brown et al. 1993; Yekta et al. 1989; Bell et al., 1972; Haegerstrom-Portnoy et al., 1999; Wright and Wormald,1992).

Future Work

In this study, even though it was observed during the experimental task that participants tend to lean forward, slouch or assume wrong postures at times, there is not enough analysis done to study if the duration for which those postures were assumed might have had some effect on the pain scale rating as received from the participants. Further study can be done where instances where participants assume wrong posture are counted and the duration is noted which could be compared to pain scale rating. This may give an idea about if there is correlation between postures assumed and discomforts developed. Using a higher sample size would give more reliable data. Use of better technology such as motion sensors to track dynamic movement and shift in postures will help identify duration of static posture and also to measure postures with more accuracy.

References

1. Aaras, A., Fostervold, K. I., Ro, O. L. A., Thoresen, M., & Larsen, S. (1997). Postural load during VDU work: a comparison between various work postures. *Ergonomics*, *40*(11), 1255-1268.
2. Ahlstrom, G., Lowden, A., Malmkvist, H., Schenkman, B., Stoht, R., & Weselka, R. (1992). Field study of a new type of computer screen technology. *Work With Display Units*, *92*, 153-157.
3. *American national standard for human factors engineering of visual display terminal workstations*. (1988) (1st ed.). Santa Monica, Calif., USA. Anderson, J. (2008, January 14). New standard now available for computer workstation designers. Retrieved October 11, 2016, from Ergonomics Today, https://ergoweb.com/new-standard-now-available-for-computer-workstation-designers/
4. Andersson, B. J., & Ortengren, R. (1974). Lumbar disc pressure and myoelectric back muscle activity during sitting. II. Studies on an office chair. *Scandinavian Journal of rehabilitation medicine*, *6*(3), 115.
5. Ariëns, G. A., Bongers, P. M., Hoogendoorn, W. E., Van Der Wal, G., & Van Mechelen, W. (2002). High physical and psychosocial load at work and sickness absence due to neck pain. *Scandinavian journal of work, environment & health*, 222-231.
6. Arndt, R. (1983). Working posture and musculoskeletal problems of video display terminal operators—review and reappraisal. *The American Industrial Hygiene Association Journal*, *44*(6), 437-446.

7. Baumgartner, D., Zemp, R., List, R., Stoop, M., Naxera, J., Elsig, J. P., & Lorenzetti, S. (2012). The spinal curvature of three different sitting positions analysed in an open MRI scanner. *The Scientific World Journal*, *2012*.

8. Bell, B., Wolf, E., & Bernholz, C. D. (1972). Depth perception as a function of age. *The International Journal of Aging and Human Development*, *3*(1), 77-81.

9. Bendix, T., Winkel, J., & Jessen, F. (1985). Comparison of office chairs with fixed forwards or backwards inclining, or tiltable seats. *European journal of applied physiology and occupational physiology*, *54*(4), 378-385.

10. Bergqvist, U. (1995). Visual display terminal work—a perspective on long-term changes and discomforts. *International Journal of Industrial Ergonomics*, *16*(3), 201-209.

11. Bergqvist, U., Knave, B., Voss, M., & Wibom, R. (1992). A longitudinal study of VDT work and health. *International Journal of Human-Computer Interaction*, *4*(2), 197-219.

12. Bergqvist, U. O., & Knave, B. G. (1994). Eye discomfort and work with visual display terminals. *Scandinavian journal of work, environment & health*, 27-33.

13. Bergqvist, U., Wolgast, E., Nilsson, B., & Voss, M. (1995). Musculoskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors. *Ergonomics*, *38*(4), 763-776.

14. Bernard, B., Sauter, S., Fine, L., Petersen, M., & Hales, T. (1994). Job task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees. *Scandinavian journal of work, environment & health*, 417-426.

15. Bernard, B. P. (1997). Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. In *Musculoskeletal disorders and workplace factors: a critical*

review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. NIOSH.

16. Bijur, P. E., Latimer, C. T., & Gallagher, E. J. (2003). Validation of a verbally administered numerical rating scale of acute pain for use in the emergency department. *Academic Emergency Medicine*, *10*(4), 390-392.
17. Birch, E., Williams, C., Drover, J., Fu, V., Cheng, C., Northstone, K., ... & Adams, R. (2008). Randot® Preschool Stereoacuity Test: Normative data and validity. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *12*(1), 23-26.
18. Brown, S., Pyke, D., & Steenhof, P. (2010). Electric vehicles: The role and importance of standards in an emerging market. *Energy Policy*, *38*(7), 3797-3806.
19. Brown, B., Yap, M. K., & Fan, W. (1993). Decrease in stereoacuity in the seventh decade of life. *Ophthalmic and Physiological Optics*, *13*(2), 138-142.
20. Bongers, P. M., Ijmker, S., Van den Heuvel, S., & Blatter, B. M. (2006). Epidemiology of work related neck and upper limb problems: psychosocial and personal risk factors (part I) and effective interventions from a bio behavioural perspective (part II). *Journal of occupational rehabilitation*, *16*(3), 272-295.
21. Carcone, S. M., & Keir, P. J. (2007). Effects of backrest design on biomechanics and comfort during seated work. *Applied Ergonomics*, *38*(6), 755-764.
22. Carter, J. B., & Banister, E. W. (1994). Musculoskeletal problems in VDT work: a review. *Ergonomics*, *37*(10), 1623-1648.
23. Chi, C. F., & Lin, F. T. (1998). A comparison of seven visual fatigue assessment techniques in three data-acquisition VDT tasks. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *40*(4), 577-590.

24. DeBell, M. (2005). Rates of Computer and Internet Use by Children in Nursery School and Students in Kindergarten through Twelfth Grade: 2003. Issue Brief. NCES 2005-111. *National Center for Education Statistics*.

25. DeBell, M., & Chapman, C. (2006). Computer and Internet Use by Students in 2003. Statistical Analysis Report. NCES 2006-065. *National Center for Education Statistics*.

26. Dockrell, S., Bennett, K., & Culleton-Quinn, E. (2015). Computer use and musculoskeletal symptoms among undergraduate university students. *Computers & Education*, *85*, 102-109.

27. Eltayeb, S., Staal, J. B., Hassan, A., & De Bie, R. A. (2009). Work related risk factors for neck, shoulder and arms complaints: a cohort study among Dutch computer office workers. *Journal of occupational rehabilitation*, *19*(4), 315-322.

28. Ergoweb. (2002, February 22). Revised ANSI/HFES computer workstation ergonomics standard nearly ready for review. Retrieved October 11, 2016, from Ergonomics Today, https://ergoweb.com/revised-ansihfes-computer-workstation-ergonomics-standard-nearly-ready-for-review/

29. Gerr, F., Marcus, M., & Monteilh, C. (2004). Epidemiology of musculoskeletal disorders among computer users: lesson learned from the role of posture and keyboard use. *Journal of Electromyography and Kinesiology*, *14*(1), 25-31.

30. Groenesteijn, L., Vink, P., de Looze, M., & Krause, F. (2009). Effects of differences in office chair controls, seat and backrest angle design in relation to tasks. *Applied ergonomics*, *40*(3), 362-370.

31. HALLETT, P. (1986). Eye movements((and human visual perception)). *Handbook of perception and human performance.*, *1*, 10-1.

32. Haegerstrom-Portnoy, G., Schneck, M. E., & Brabyn, J. A. (1999). Seeing into old age: vision function beyond acuity. *Optometry & Vision Science*, *76*(3), 141-158.

33. Haider, M., Kundi, M., & Weissenbock, M. (1980). Worker strain related to VDUs with differently colored characters. In E. Grandjean & E. Vigliani (Eds.), Ergonomic aspects of visual display terminals (pp. 53–64). London: Taylor & Francis.

34. Hales, T. R., Sauter, S. L., Peterson, M. R., Fine, L. J., Putz-Anderson, V., Schleifer, L. R., ... & Bernard, B. P. (1994). Musculoskeletal disorders among visual display terminal users in a telecommunications company. *Ergonomics*, *37*(10), 1603-1621.

35. HAMILTON, N. (1996). Source document position as it affects head position and neck muscle tension. *Ergonomics*, *39*(4), 593-610.

36. Hamilton, A. G., Jacobs, K., & Orsmond, G. (2005). The prevalence of computer-related musculoskeletal complaints in female college students. *Work*, *24*(4), 387-394.

37. Hollen, P. J., R. J. Gralla, M. G. Kris, S. McCoy, G. W. Donaldson, and C. M. Moinpour. "A comparison of visual analogue and numerical rating scale formats for the Lung Cancer Symptom Scale (LCSS): does format affect patient ratings of symptoms and quality of life?." *Quality of Life Research* 14, no. 3 (2005): 837-847.

38. *Human factors engineering of computer workstations*. (2002) (1st ed.). Santa Monica, Calif.

39. *Human factors engineering of computer workstations*. (2007) (1st ed.). Santa Monica, CA.

40. Hupert, N., Amick, B. C., Fossel, A. H., Coley, C. M., Robertson, M. M., & Katz, J. N. (2004). Upper extremity musculoskeletal symptoms and functional impairment associated with computer use among college students. *Work*, *23*(2), 85-93.

41. *ISO Standards - ISO*. (2016). *ISO*. Retrieved 17 November 2016, from http://www.iso.org/iso/home/standards.htm

42. JASCHINSKI-KRUZA, W. O. L. F. G. A. N. G. (1988). Visual strain during VDU work: the effect of viewing distance and dark focus. *Ergonomics, 31*(10), 1449-1465.

43. Jenkins, M., Menéndez, C. C., Amick Iii, B. C., Tullar, J., Hupert, N., Robertson, M. M., & Katz, J. N. (2007). Undergraduate college students' upper extremity symptoms and functional limitations related to computer use: A replication study. *Work*, *28*(3), 231-238

44. Jensen, C., Ryholt, C. U., Burr, H., Villadsen, E., & Christensen, H. (2002). Work-related psychosocial, physical and individual factors associated with musculoskeletal symptoms in computer users. *Work & Stress*, *16*(2), 107-120.

45. Jensen, M. P., Karoly, P., & Braver, S. (1986). The measurement of clinical pain intensity: A comparison of six methods. *Pain*, *27*(1), 117–126.

46. Kamieńska-Zyła, M. (1993). Ergonomics evaluation of the work of VDT operators in Poland. *Applied Ergonomics*, *24*(6), 432-433.

47. Katz, J. N., Amick, B. C., Carroll, B. B., Hollis, C., Fossel, A. H., & Coley, C. M. (2000). Prevalence of upper extremity musculoskeletal disorders in college students. *The American journal of medicine*, *109*(7), 586-588.

48. Leibowitz, H. W., & Owens, D. A. (1978). New evidence for the intermediate position of relaxed accommodation. *Documenta Ophthalmologica*, *46*(1), 133-147.

49. Lessin, J. (1992). TFT acting up a storm onscreen. *Computer Technology Review*, *12*(4), 6-30.

50. Linton, S. J., & Kamwendo, K. (1989). Risk factors in the psychosocial work environment for neck and shoulder pain in secretaries. *Journal of Occupational and Environmental Medicine*, *31*(7), 609-613.

51. Lovasik, J. V., & Szymkiw, M. (1985). Effects of aniseikonia, anisometropia, accommodation, retinal illuminance, and pupil size on stereopsis. *Investigative ophthalmology & visual science*, *26*(5), 741-750.

52. Menozzi, M., Näpflin, U., & Krueger, H. (1999). CRT versus LCD: A pilot study on visual performance and suitability of two display technologies for use in office work. *Displays*, *20*(1), 3-10.

53. Nakazawa, T., Okubo, Y., Suwazono, Y., Kobayashi, E., Komine, S., Kato, N., & Nogawa, K. (2002). Association between duration of daily VDT use and subjective symptoms. *American Journal of Industrial Medicine*, *42*(5), 421-426.

54. National Research Council (US). Committee on Information Technology Literacy. (1999). *Being fluent with information technology*. National Academies Press.

55. Ortiz-Hernández, L., Tamez-González, S., Martínez-Alcántara, S., & Méndez-Ramírez, I. (2003). Computer use increases the risk of musculoskeletal disorders among newspaper office workers. *Archives of medical research*, *34*(4), 331-342.

56. Psihogios, J. P., Sommerich, C. M., Mirka, G. A., & Moon, S. D. (2001). A field evaluation of monitor placement effects in VDT users. *Applied Ergonomics*, *32*(4), 313-325.

57. Putz-Anderson, V. (Ed.). (1988). *Cumulative trauma disorders: A manual for musculoskeletal diseases of the upper limbs* (pp. 47-60). London: Taylor & Francis.

58. Saito, S., Taptagaporn, S., & Salvendy, G. (1993). Visual comfort in using different VDT screens. *International Journal of Human-Computer Interaction*, *5*(4), 313-323.

59. Saito, S., & SOTOYAMA, M. (1997). Visual ergonomics problems in VDT workplaces and analysis of vertical gaze direction. In P. Seppälä, T. Luopajärvi, C. H. Nygård, & M. Mattila (Eds.), *Proceedings of 13th Triennial Congress of the International Ergonomics Association* (pp. 56-58).

60. Schmidt, P. P. (1994). Sensitivity of random dot stereoacuity and Snellen acuity to optical blur. *Optometry & Vision Science*, *71*(7), 466-473.

61. Seghers, J., Jochem, A., & Spaepen, A. (2003). Posture, muscle activity and muscle fatigue in prolonged VDT work at different screen height settings. *Ergonomics*, *46*(7), 714-730.

62. Smedley, J., Inskip, H., Trevelyan, F., Buckle, P., Cooper, C., & Coggon, D. (2003). Risk factors for incident neck and shoulder pain in hospital nurses. *Occupational and Environmental Medicine*, *60*(11), 864-869.

63. Sotoyama, M., Abe, S., Jonai, H., Villanueva, M., & Saito, S. (1997). Improvement of visual comfort of VDT workers from the aspects of vertical gaze direction and tear volume. In *Proceedings of the 13th Triennial Congress of the International Ergonomics Association. Tampere* (Vol. 5, pp. 59-61).

64. Sommerich, C. M., Joines, S. M., & Psihogios, J. P. (2001). Effects of computer monitor viewing angle and related factors on strain, performance, and preference outcomes. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *43*(1), 39-55.

65. Taptagaporn, S., & Saito, S. (1990). How display polarity and lighting conditions affect the pupil size of VDT operators. *Ergonomics*, *33*(2), 201-208.

66. Turville, K. L., Psihogios, J. P., Ulmer, T. R., & Mirka, G. A. (1998). The effects of video display terminal height on the operator: a comparison of the 15 and 40 recommendations. *Applied Ergonomics*, *29*(4), 239-246.

67. Tyrrell, R. A., & Leibowitz, H. W. (1990). The relation of vergence effort to reports of visual fatigue following prolonged near work. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *32*(3), 341-357.

68. Villanueva, M. B. G., Jonai, H., Sotoyama, M., HISANAGA, N., TAKEUCHI, Y., & SAITO, S. (1997). Sitting posture and neck and shoulder muscle activities at different screen height settings of the visual display terminal. *Industrial Health*, *35*(3), 330-336.

69. von Baeyer, C. L., Spagrud, L. J., McCormick, J. C., Choo, E., Neville, K., & Connelly, M. A. (2009). Three new datasets supporting use of the Numerical Rating Scale (NRS-11) for children's self-reports of pain intensity. *PAIN®*, *143*(3), 223-227.

70. Vos, G. A., Congleton, J. J., Moore, J. S., Amendola, A. A., & Ringer, L. (2006). Postural versus chair design impacts upon interface pressure. *Applied ergonomics*, *37*(5), 619-628.

71. Waersted, M., Hanvold, T. N., & Veiersted, K. B. (2010). Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review. *BMC musculoskeletal disorders*, *11*(1), 79.

72. Waongenngarm, P., Rajaratnam, B. S., & Janwantanakul, P. (2016). Internal Oblique and Transversus Abdominis Muscle Fatigue Induced by Slumped Sitting Posture after 1 Hour of Sitting in Office Workers. *Safety and health at work*, *7*(1), 49-54.

73. Williamson, A., & Hoggart, B. (2005). Pain: a review of three commonly used pain rating scales. *Journal of clinical nursing*, *14*(7), 798-804.

74. Wright, L. A., & Wormald, R. P. L. (1992). Stereopsis and ageing. *Eye*, *6*(5), 473-476.

75. Yekta, A. A., Pickwell, L. D., & Jenkins, T. C. A. (1989). Binocular vision, age and symptoms. *Ophthalmic and Physiological Optics*, *9*(2), 115-120.

76. Yoshikawa, H., Yoshida, M., & Hara, I. (1991). [Changes in visual acuity observed in VDT workers in a printing company]. *Sangyo igaku. Japanese journal of industrial health*, *33*(6), 519-526.

77. Yu, I. T. S., & Wong, T. W. (1996). Musculoskeletal problems among VDU workers in a Hong Kong bank. *Occupational medicine*, *46*(4), 275-280.

APPENDIX A

IRB FIRST APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 3/18/2016

To: Midhun Vasan
4112 Westbrook Dr Unit 17
Ames, IA 50014

CC: Dr. Richard T Stone
3004 Black Engineering

From: Office for Responsible Research

Title: Evaluation of Latest Computer Workstation Standards

IRB ID: 16-010

Approval Date: 3/18/2016

Date for Continuing Review: 3/17/2018

Submission Type: New

Review Type: Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp**.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B

IRB FINAL APPROVAL AFTER MODIFICATION

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 5/6/2016

To: Midhun Vasan
4112 Westbrook Dr Unit 17
Ames, IA 50014

CC: Dr. Richard T Stone
3004 Black Engineering

From: Office for Responsible Research

Title: Evaluation of Latest Computer Workstation Standards

IRB ID: 16-010

Approval Date: 5/6/2016 **Date for Continuing Review:** 3/17/2018

Submission Type: Modification **Review Type:** Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp**.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX C

INFORMED CONSENT FORM FOR IE 271 STUDENTS

ISU IRB # 1	16-010
Approved Date:	18 March 2016
Expiration Date:	17 March 2018

INFORMED CONSENT DOCUMENT

Title of Study: Evaluation of Latest Computer Workstation Standards

Investigators: Midhun Vasan & Dr. Richard Stone

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Introduction

The purpose of this study is to evaluate the current standards which are used to set up computer workstations. These standards mention the different measurements at which the monitor, keyboard, mouse and seating should be set up for a computer user. The study aims to find out if these standards are effective, relevant and if computer users follow it thoroughly since humans tend to not maintain stationary posture for long duration at work. Understanding this will help in determining whether these standards should be challenged or not. You will be video recorded during the experimental tasks and two interviews will be audio recorded. One interview will be before the experimental task and one will be afterwards. You will also be asked to fill out a questionnaire when you finish the experimental tasks.

You are being invited to participate in this study because you have been identified as an adult who uses desktop computers on a daily basis for more than one hour on an average.
You should not participate if you are not 18 years or above of age, if you have recurring migraines and/or are currently undergoing treatment for ocular inflammatory conditions such as conjunctivitis, scleritis, glaucoma and stye.

Description of Procedures

If you agree to participate, you will be asked to attend two interviews, fill out a questionnaire, play online games for two hours duration while seated at a computer workstation and give two Randot Stereo Tests. The study will begin with the first interview which will be audio recorded and will cover the following area:

1. Duration and type of computer use
2. Discomforts encountered while working at a computer for long durations
3. Your view on probable reasons and solutions for these discomforts
4. Change in seated posture, reasons and frequency.

This is followed by the first part of the experimental task which includes a Randot Stereo Test. During this test you will be asked to wear a pair of Stereo Optical Polarized Glasses. You will be

ISU IRB # 1 16-010
Approved Date: 18 March 2016
Expiration Date: 17 March 2018

provided a material which has images of random dots. You will asked to place the material at normal reading distance and asked to identify images which appear to be sticking towards you. When you are no longer able to identify any more images or if you finish identifying all the images, this test comes to a stop.

After the Randot Stereo Test, you will be asked to perform the second part of the experimental task. This will include playing online games at a computer workstation. The website you are required to play on will be kept open and ready for use.You are free to choose between any of the games and can switch between any number of games as and when you please. Once you are seated at the computer workstation, it will be set up according to the existing standards or you will be asked to set is to your preference, depending on which treatment group you will be assigned to. This will involve setting up the height of the chair, desk, monitor, keyboard and mouse to suit your body's seated posture. You may start the task when you are ready. During the length of this activity you will be video recorded. Three video cameras will be set up. Two of these will be set up in a way to capture your side profile and the computer workstation. One video camera will be placed right behind you in a way to capture your seated posture as viewed from behind. None of these video cameras will be capturing the computer monitor as you perform the given task.

Once the two hour duration is reached, you will be asked to stop performing the task. Now, you will be asked to perform the third part of the experimental task which involves another Randot Stereo Test.

Once the Randot Stereo Test is performed you will be given a questionnaire to be filled out. Please read carefully and fill out the questionnaire taking the time you need. The questionnaire will ask you to rate the pain or discomfort you experienced on different parts of your body during the computer task.

After filling out the questionnaire, you will be interviewed again which will be audio recorded. This interview will ask you questions regarding:

- Discomforts faced during the study and your view of possible causes.
- Need for breaks
- Change in posture, reasons and how it helped you

With this the study will come to an end. The entire length of the study will be 3 hours. This will include total 30 minutes of interviews and questionnaire, 2 hours of computer task, total 15 minutes of Randot Stereo Tests and 15 minutes to set up the computer workstation for the study.

Risks or Discomforts

While participating in this study you may experience the following risks or discomforts:

1. Eye strain arising from using the computer for the duration of the experimental task.
2. Neck and/or back pain due to being seated during the length of the experimental task.

ISU IRB # 1 16-010
Approved Date: 18 March 2016
Expiration Date: 17 March 2018

Benefits

If you decide to participate in this study, there may not be direct benefit to you. It is hoped that the information gained in this study will benefit society by leading to better standards for computer workstations and thus reducing the discomfort for computer users.

Costs and Compensation

You will not have any costs from participating in this study. You will be compensated for participating in this study in the form of credits for your class IE 271. The participation in this study will ensure you credits equivalent to 3% of the total grade for the course. You will get the full compensation even if you wish to quit the study at any point.

Alternatives to Participation

A homework assignment will be provided as an alternative to participation in this study. The homework will be given by the instructor of IE 271 and upon completion will account for the same compensation as that of completing the study in the form of credits equivalent to 3% of the final grade.

Participant Rights

Participating in this study is completely voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer in the interview and questionnaires.

If you have any questions *about the rights of research subjects or research-related injury*, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

Confidentiality

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy study records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken:

- All electronic data collected will be stored in Cybox which is encrypted.
- Consent forms will be the only document where the participant's name will be recorded. Consent forms will not be shared or published and will be stored in combination locked file cabinets in Black 0066.

ISU IRB # 1 16-010
Approved Date: 18 March 2016
Expiration Date: 17 March 2018

- During video recording, the images of your faces will be recorded. However, no video and audio files will be shared or published. Hence these identifiable information will be kept confidential.
- Once the data from the video files are analyzed, the video files will be deleted and will not be stored in Cybox beyond 9 months.
- Only the two principal investigators will have access to identifiable data.
- During the study participants will be given subject numbers such as subject1, subject2 and so on. Hence participant's name or other identifiable information will not be recorded.

Questions

You are encouraged to ask questions at any time during this study. For further information ***about the study,*** contact Midhun Vasan (Cell: 5157083584; email: midhun@iastate.edu) and/or the supervising faculty Dr. Richard Stone (Email: rstone@iastate.edu

Consent and Authorization Provisions

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant's Name (printed) ____

______________________________________ ______________________

Participant's Signature Date

APPENDIX D

INFORMED CONSENT FORM FOR NON-IE 271 STUDENTS

ISU IRB # 1	16-010
Approved Date:	18 March 2016
Expiration Date:	17 March 2018

INFORMED CONSENT DOCUMENT

Title of Study: Evaluation of Latest Computer Workstation Standards

Investigators: Midhun Vasan & Dr. Richard Stone

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Introduction

The purpose of this study is to evaluate the current standards which are used to set up computer workstations. These standards mention the different measurements at which the monitor, keyboard, mouse and seating should be set up for a computer user. The study aims to find out if these standards are effective, relevant and if computer users follow it thoroughly since humans tend to not maintain stationary posture for long duration at work. Understanding this will help in determining whether these standards should be challenged or not. You will be video recorded during the experimental tasks and two interviews will be audio recorded. One interview will be before the experimental task and one will be afterwards. You will also be asked to fill out a questionnaire when you finish the experimental tasks.

You are being invited to participate in this study because you have been identified as an adult who uses desktop computers on a daily basis for more than one hour on an average.
You should not participate if you are not 18 years or above of age, if you have recurring migraines and/or are currently undergoing treatment for ocular inflammatory conditions such as conjunctivitis, scleritis, glaucoma and stye.

Description of Procedures

If you agree to participate, you will be asked to attend two interviews, fill out a questionnaire, play online games for two hours duration while seated at a computer workstation and give two Randot Stereo Tests. The study will begin with the first interview which will be audio recorded and will cover the following area:

1. Duration and type of computer use
2. Discomforts encountered while working at a computer for long durations
3. Your view on probable reasons and solutions for these discomforts
4. Change in seated posture, reasons and frequency.

This is followed by the first part of the experimental task which includes a Randot Stereo Test. During this test you will be asked to wear a pair of Stereo Optical Polarized Glasses. You will be

ISU IRB # 1 16-010
Approved Date: 18 March 2016
Expiration Date: 17 March 2018

provided a material which has images of random dots. You will asked to place the material at normal reading distance and asked to identify images which appear to be sticking towards you. When you are no longer able to identify any more images or if you finish identifying all the imagse, this test comes to a stop.

After the Randot Stereo Test, you will be asked to perform the second part of the experimental task. This will include playing online games at a computer workstation. The website you are required to play on will be kept open and ready for use. You are free to choose between any of the games and can switch between any number of games as and when you please. Once you are seated at the computer workstation, it will be set up according to the existing standards or you will be asked to set is to your preference, depending on which treatment group you will be assigned to. This will involve setting up the height of the chair, desk, monitor, keyboard and mouse to suit your body's seated posture. You may start the task when you are ready. During the length of this activity you will be video recorded. Three video cameras will be set up. Two of these will be set up in a way to capture your side profile and the computer workstation. One video camera will be placed right behind you in a way to capture your seated posture as viewed from behind. None of these video cameras will be capturing the computer monitor as you perform the given task.

Once the two hour duration is reached, you will be asked to stop performing the task. Now, you will be asked to perform the third part of the experimental task which involves another Randot Stereo Test.

Once the Randot Stereo Test is performed you will be given a questionnaire to be filled out. Please read carefully and fill out the questionnaire taking the time you need. The questionnaire will ask you to rate the pain or discomfort you experienced on different parts of your body during the computer task.

After filling out the questionnaire, you will be interviewed again which will be audio recorded. This interview will ask you questions regarding:

- Discomforts faced during the study and your view of possible causes.
- Need for breaks
- Change in posture, reasons and how it helped you

With this the study will come to an end. The entire length of the study will be 3 hours. This will include total 30 minutes of interviews and questionnaire, 2 hours of computer task, total 15 minutes of Randot Stereo Tests and 15 minutes to set up the computer workstation for the study.

Risks or Discomforts

While participating in this study you may experience the following risks or discomforts:

1. Eye strain arising from using the computer for the duration of the experimental task.

2. Neck and/or back pain due to being seated during the length of the experimental task.

Benefits

If you decide to participate in this study, there may not be direct benefit to you. It is hoped that the information gained in this study will benefit society by leading to better standards for computer workstations and thus reducing the discomfort for computer users.

Costs and Compensation

You will not have any costs from participating in this study. You will not be compensated for participating in this study.

Participant Rights

Participating in this study is completely voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer in the interview and questionnaires.

If you have any questions *about the rights of research subjects or research-related injury*, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

Confidentiality

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy study records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken:

- All electronic data collected will be stored in Cybox which is encrypted.
- Consent forms will be the only document where the participant's name will be recorded. Consent forms will not be shared or published and will be stored in combination locked file cabinets in Black 0066.
- During video recording, the images of your faces will be recorded. However, no video and audio files will be shared or published. Hence these identifiable information will be kept confidential.
- Once the data from the video files are analyzed, the video files will be deleted and will not be stored in Cybox beyond 9 months.
- Only the two principal investigators will have access to identifiable data.
- During the study participants will be given subject numbers such as subject1, subject2 and so on. Hence participant's name will not be recorded.

ISU IRB # 1	16-010
Approved Date:	18 March 2016
Expiration Date:	17 March 2018

Questions

You are encouraged to ask questions at any time during this study. For further information ***about the study,*** contact Midhun Vasan (Cell: 5157083584; email: midhun@iastate.edu) and/or the supervising faculty Dr. Richard Stone (Email: rstone@iastate.edu

Consent and Authorization Provisions

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant's Name (printed) ____

______________________________________ ______________________

Participant's Signature Date

APPENDIX E

EXPERIMENTAL SCRIPT

Experimental Script

Topic: Evaluation of Latest Computer Workstation Standards

Experimenter: "Thank you for your participation in this study. Please take your time and read the informed consent form thoroughly. Once you understand all the points mentioned in the informed consent form please sign the document with the date."

Participant signs the form with the date.

Experimenter: " As, mentioned in the consent form, prior to the experimental task of the study there will be a short interview which will be audio recorded. Please speak as clearly as you can."

Interview proceeds.

Experimenter: " Now, the first part of the study involves a Randot Stereo Test. Please put on the glasses provided. Then place the material provided to you at reading distance and point out the images which to be sticking out towards you. When you can no longer identify any more images which appear to stick out, you may place the material on the table and take off the glasses and the test comes to an end."

Participant proceeds with the first part of the experimental study: The randot stereo test. When finished, the material is placed down and glasses are taken off.

Experimenter: "Thank you. Next is the part of the study with the computer task."

Subjects will be assigned either one of the two treatment groups.
For treatment group 1:

Experimenter: " Now we proceed to the next part of the experimental study. Once you are seated on the chair at the workstation, the whole workstation will be arranged to suit your posture following the existing standards. Once the workstation is set, please do not change the settings. You are asked to keep a stationary sitting posture throughout the two hour duration. The website you are to use as part of the study will be kept opened. From the website you are free to play any games and switch between them as and when you please. You may begin your task when you are ready. As mentioned in the informed consent form, this part of the study will be video recorded from behind you and from two sides. Once you hit the 2 hour mark you will be asked to stop performing the task and will move on to the next part of the experimental study."

For treatment group 2:

Experimenter: Now we proceed to the next part of the experimental study. The computer workstation has been arranged according to the existing standards. Once you are seated on the chair at the workstation, the whole workstation will be arranged to suit your sitting posture following the existing standards. Once the workstation has been set, you will be given the freedom to change the settings as you prefer. During the entire 2 hour duration you may change the settings at any point or assume any sitting posture you prefer. The website you are to use as part of the study will be kept opened. From the website you are free to play any games and switch between them as and when you please. You may begin your task when you are ready. As mentioned in the informed consent form, this part of the study will be video recorded from behind you and from two sides. Once you hit the 2 hour mark you will be asked to stop performing the task and will move on to the next part of the experimental study."

For treatment group 3:

Experimenter: Now we proceed to the next part of the experimental study. You are given full freedom to set the computer workstation as you prefer. The website you are to use as part of the study will be kept opened. From the website you are free to play any games and switch between them as and when you please. You may begin your task when you are ready. As mentioned in the informed consent form, this part of the study will be video recorded from behind you and from two sides. Once you hit the 2 hour mark you will be asked to stop performing the task and will move on to the next part of the experimental study."

Proceeds with the second part of the experimental study: Computer task.
At the end of the two hour period:

Experimenter: "You may stop performing the task. Please leave the computer workstation. Next we move on to the third part of the experimental study which is another randot stereo test. Please put on the glasses provided. Then place the material provided to you at reading distance and point out the images which to be sticking out towards you. When you can no longer identify any more images which appear to stick out, you may place the material on the table and take off the glasses and the test comes to an end.

Proceeds with the third part of the experimental study: Randot stereo test. When finished, the material is placed down and glasses are taken off.

Experimenter: " Please fill out the following questionnaire. Take your time and ask if you have any questions."

Participant fills out the questionnaire.

Experimenter: " Now we proceed to the last part of the study which will be another interview which will be audio recorded. Please speak clearly as you can."

Interview proceeds.

Experimenter: "Thank you for taking part in this study. If you have any questions or concerns please you please contact me at midhun@iastate.edu"

APPENDIX F

FLYERS FOR PARTICIPANTS

ISU IRB # 1	16-010
Approved Date:	18 March 2016
Expiration Date:	17 March 2018

Participants needed!!!

Evaluation of Latest Computer Workstation Standards

Study aims to find out if the current existing standards for setting up computer workstations are relevant, efficient and if they should be challenged. Looking for participants who are 18 years old or above, who use desktop computers (not laptops) at least one hour daily and who do not have recurring migraines and/or are not currently undergoing treatment for ocular inflammatory conditions such as conjunctivitis, scleritis, glaucoma and stye. The study will be for 3 hours which will include 2 hours and 15 minutes of experimental task, 15 minutes for setting up the experiment and 30 minutes for interviews and questionnaires. The experiment will involve an initial randot stereo test followed by two hours computer task and another randot stereo test at the end of the computer task. The computer task will involve playing online games using a mouse while being seated at a computer workstation which will be set up according to specific standards. Depending on the treatment groups you are assigned you may/may not have to sit in the same posture for the entire duration of the study. The whole study will be video recorded from behind and the sides to capture the participant's postures while performing the task. The interviews will be audio recorded.

Participation will be voluntary and you may quit the study at any time if you do not wish to finish the study. There will be no compensation provided for this study. All identifying details such as names, video and audio information will be kept confidential and will not be used in publication.

If interested or if you require more information, please contact:

Midhun Vasan

Email: midhun@iastate.edu

Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu	Contact: midhun@iastate.edu

APPENDIX G

SCRIPT FOR ANNOUNCEMENT IN IE 271 CLASS

ISU IRB # 1 16-010
Approved Date: 18 March 2016
Expiration Date: 17 March 2018

Script for Announcement in IE 271 Class

"Hello everyone. My name is Midhun Vasan. I am a graduate student here at Iowa State University, pursuing my masters in Industrial Engineering. I am conducting a study as part of my Masters thesis topic: Evaluation of Latest Computer Workstation Standards. The study aims to find out if the current existing standards for setting up computer workstations are relevant, efficient, if they should be challenged and if anyone even follows it strictly. I am looking for participants who are 18 years old or above, who use desktop computers (not laptops) at least one hour daily and who do not have recurring migraines and/or are not currently undergoing treatment for ocular inflammatory conditions such as conjunctivitis, scleritis, glaucoma and stye. The study will be for 3 hours which will include 2 hours and 15 minutes of experimental task, 15 minutes for setting up the experiment and 30 minutes for interviews and questionnaires. The experiment will involve an initial randot stereo test followed by two hours computer task and another randot stereo test at the end of the computer task. The computer task will involve playing online games using a mouse while being seated at a computer workstation which will be set up according to specific standards. Depending on the treatment groups you are assigned you may/may not have to sit in the same posture for the entire duration of the study. The whole study will be video recorded from behind and the sides to capture the participant's postures while performing the task. The interviews will be audio recorded.

Participation will be voluntary and you may quit the study at any time if you do not wish to finish the study. Compensation will be in the form of credits. Each participant will be assigned credits equivalent to 3% of the final grade. In the event any participant taking part in the study decides to quit before the study is completed, the participant will still be awarded the full credits equivalent to 3% of your final grade for IE 271. If you do not wish to take part in the study, you have an alternative of doing a homework assignment which will be provided by Dr. Stone upon completion of which you will be given credits equivalent to 3% of the final grade. All identifying details such as names, video and audio information will be kept confidential and will not be used in publication.

If interested or if you require more information please contact me. My email id is midhun@iastate.edu. Thank you. "

APPENDIX H

FIRST INTERVIEW QUESTIONS

First Interview Questions

1. Do you own a desktop computer?
2. How many hours per day on an average do you work at a computer?
3. What kind of work/tasks do you use a computer for?
4. Do you usually experience any discomfort while you work at a computer for long time?
5. What are these discomforts?
6. What do you think could be probable reasons for such discomforts?
7. According to you is there anything that could be done to make your time spent at a computer more comfortable, in terms of the computer or the setting?
8. Do you change your sitting posture while you use a computer?
9. How often would you say you change your posture?
10. Why do you think you change your posture?

APPENDIX I

POST EXPERIMENTAL QUESTIONNAIRE

Post Experimental Questionnaire

The following questions are based on a pain scale rating with '0' being 'No pain' to '10' being 'Unbearable pain'

No.	Question	Pain scale rating
1.	Strain on eyes due to computer use	
2.	Ache on neck	
3.	Rotator cuff pain	
4.	Lower back pain	
5.	Elbow pain	
6.	Wrist pain	
7.	Pain on the hips	
8.	Pain on the knee	
9.	Head ache	
10.	Mid back pain	
11.	Shoulder tension	

APPENXIX J

POST EXPERIMENTAL INTERVIEW QUESTIONS

Post experimental interview questions

1. Did you face any discomfort during the whole study?
2. What were these discomforts?
3. What do you think are the possible causes for these?
4. How often do you think you need to take a break?
5. Would you prefer short breaks with higher frequency or longer breaks with low frequency?
6. Did you change your body's sitting posture during the length of the study? Why?

APPENDIX K

ANSI/HFES 100-2007 SPEFICICATIONS FOLLOWED FOR THE STUDY

	Measure	Range	Remarks/Definition
1	Angle of neck deviation from vertical	0º	Neck should be almost vertical
2	Shoulder flexion angle	0º to 25º	Upper arm deviation from neutral position towards the front
3	Angle between forearm and horizontal	-45º to 20º	-45º below to 20º above the horizontal
4	Thigh to torso	90º	On sitting upright posture
5	Thigh to torso	105º to 120º	On reclining or leaning back posture
6	Designer viewing envelope angle in vertical	-20º to 30º	Span of angle between nasal bridge and a normal at the center of the display screen
7	Designer viewing envelope angle in horizontal	-80º to 80º	Span of angle between nasal bridge and a normal at the center of the display screen
8	Angle between eye's horizontal and line from eyes to center of the display screen	15º to 20 º	