EFFECTS OF A VIBRATING MOUSE ON COMPUTER USERS' WORK BEHAVIOR AND PERFORMANCE

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ABSTRACT

Frequent brief rest breaks, known as micro-breaks, have been shown to benefit computer users by reducing fatigue and possibly preventing musculoskeletal disorders. Various methods of reminding users to take rest breaks have been developed. Initially, efforts focused on the use of break reminder computer software, although potentially this may be disruptive to work patterns. More recently, micro-break reminders have been incorporated into computer equipment and these have been indexed to work activity, and this approach may offer less potential for disrupting work activities.

A computer mouse has been developed that vibrates in the user's hand after 10 seconds of inactivity. The vibration is intended to remind the user to rest his or her hand in a neutral position while not actively engaging the mouse rather than maintaining a grip on the mouse that requires static muscle contraction.

A laboratory experiment was conducted to test this vibrating mouse against a conventional mouse to see how it affected subjects' task performance, task behaviors, and mouse preference. It was hypothesized that the vibrating mouse would increase the number of times subjects removed their hands from the mouse, be minimally disruptive and have no adverse effect on task performance. The study also explored what subjects did with their hand when this was removed from the mouse.

Eleven female and seven male subjects participated in the experiment. Use of the vibrating mouse (experimental condition) was compared to use of a conventional mouse (control condition) for five consecutive tasks. The first three tasks required the finding and correcting of duplicate words, the finding and correcting of duplicate sentences and the finding and correcting of

misspelled words from text passages. The final two tasks were a reading comprehension task, where the subjects answered four multiple-choice questions about a text passage, and a composition task in response to a business scenario.

Subjects were videotaped to collect data on their behavior while completing the tasks under both conditions. Task time and number of errors were collected as performance measures. User preferences and musculoskeletal discomfort were gathered using two questionnaires, one administered pre test and one post test.

No differences were found in performance between the two conditions. The vibrating mouse induced more positive task behaviors than the conventional mouse, including significantly more resting behavior ($p=0.02$) and slightly more hand removals ($p=0.06$). The vibrating mouse, however, also induced significantly more negative task behaviors than the conventional mouse, such as increasing the frequency of unsupported hand hovering ($p=0.00$).

Nine subjects found that the vibrating mouse was disruptive to their performance during the duplicate word and reading tasks; and eight found that the vibrating mouse was disruptive during the duplicate word task. The effectiveness of the mouse seemed to correspond to task type and also to subjects' mouse use technique.

Because of technological limitations and a desire to limit extraneous distractions to the subjects during the tasks, the vibration occurrence data was collected by subjects' self reporting the number of vibration occurrences they experienced. This subjectiveness may have compromised the reliability of the vibration frequency data.

The vibrating mouse shows promise but more research is needed to understand the conditions under which a vibration occurs and therefore when a user would gain benefits from this mouse. The effects of task type and user technique need to be examined in more detail to determine the nature of these effects before recommendations can be made as to the proper implementation of the vibrating mouse.

BIOGRAPHICAL SKETCH

Chris Moe was born in Washington State and completed a Bachelor of Arts degree in business administration at Western Washington University. This thesis will partially fulfill degree requirements for a Master of Science in Human Environment relations with a concentration in Human Factors and Ergonomics.

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Chapter I. INTRODUCTION

Ninety million adults in the United States used a computer in 1997 and approximately half of employed adults used a computer at work (US Census Bureau, 1999). According to the World Health Organization 150 million computers are being used worldwide as of 1998. As computers have become ubiquitous in many work environments, researchers have analyzed the relationship between computer use and the development of musculoskeletal disorders (MSDs). Studies have shown an association between the amount of time spent at a computer and the development of musculoskeletal disorders (Gerr et al., 2002; Lassen et al., 2004).

Mouse use is implicated in the development of musculoskeletal disorders in upper extremities of computer users in some studies (Cook, Burgess-Limerick, & Chang, 2000). Other researchers (Blatter & Bongers, 2002) however, have not found an association between increased mouse use and the development of musculoskeletal disorders. Computer mice are used for cursor placement, scrolling, drawing and item selection in a range of computing applications such as word processing, internet browsing, computer aided design, spreadsheet software, presentation software and database software amongst many others. In order to operate these applications with a conventional computer mouse, users are required grasp the mouse, click buttons and move the position of the mouse, all while maintaining a seated posture and a flexed arm. The following table lists the upper extremity muscles and the main actions performed by them, the nerve that innervates the muscle, and the nerve origin (Loyola University Medical Education Network, 1996; Blumenfeld, n.d.).

Table 1.1 Upper Extremity Muscles, Actions and Innervations

Muscle	**Action**	**Nerve**	**Nerve Origin**
Abductor pollicis brevis	Thumb abduction perpendicular to plane of palm	Median nerve	C8, T1
Abductor pollicis longus	Thumb abduction in plane of palm	Radial nerve (posterior interosseous nerve)	C7, C8
Adductor pollicis, Palmar interossei	Finger and thumb adduction in plane of palm	Ulnar nerve	C8, T1
Anconeus	Weak extensor of elbow. Moves (abducts) ulna in pronation	Radial nerve	C7, 8
Articularis Cubiti	Lifts capsule away from joint	Radial nerve	C6, 7 , 8
Biceps, Brachialis	Elbow flexion (with forearm supinated)	Musculocutaneous nerve	C5, C6
Brachioradialis	Flexes arm at elbow and brings forearm into midprone position	Radial nerve	C5, 6
Coracobrachialis	Flexes and weakly adducts arm	Musculocutaneous nerve	C5, 6, 7
Deltoid	Arm abduction at shoulder	Axillary nerve	C5, C6
Dorsal Interossei	Abduct from axis of middle finger. Flex metacarpophalangeal joint while extending interphalangeal joints	Deep branch of ulnar nerve	T1
Dorsal interossei, Abductor digiti minimi	Finger abduction	Ulnar nerve	C8, T1
Extensor carpi radialis	Wrist extension and hand abduction	Radial nerve	C5, C6
Extensor Carpi Ulnaris	Extends and adducts hand at wrist	Posterior interosseous	C5. C6
Extensor digitorum, indicis, digiti minimi	Finger extension	Radial nerve (posterior interosseous nerve)	C7, C8

Table 1.1 (Continued)

Extensor Pollicis Brevis	Extends metacarpophalangeal joint of thumb	Posterior interosseous nerve	C7, C8
Extensor Pollicis Longus	Extends interphalangeal and metacarpophalangeal joints of thumb	Posterior interosseous nerve	C7, C8
Flexor carpi radialis	Wrist flexion and hand abduction	Median nerve	C6, C7
Flexor carpi ulnaris	Wrist flexion and hand adduction	Ulnar nerve	C7, C8, T1
Flexor Digiti Minimi Brevis	Flexes metacarpophalangeal joint of little finger	Deep branch of ulnar nerve	C8, T1
Flexor digitorum profundus to digits 2, 3	Flexion at distal interphalangeal joints digits 2, 3	Median nerve	C7, C8
Flexor digitorum profundus to digits 4, 5	Flexion at distal interphalangeal joints digits 4, 5	Ulnar nerve	C7, C8
Flexor Digitorum Superficialis	Flexes proximal interphalangeal joints and secondarily metacarpophalangeal joints and wrist	Median nerve (from medial and lateral cords)	C7, C8
Flexor Pollicis Brevis	Flexes metacarpophalangeal joint of thumb	Recurrent (muscular) branch of median nerve (may also be from deep branch of ulnar nerve	C8, T1
Flexor Pollicis Longus	Flexes distal phalanx of thumb	Anterior interosseous nerve	C7, C8
Infraspinatus	Laterally rotates arm and stabilizes shoulder joint	Suprascapular nerve (from upper trunk)	C5, C6

Table 1.1 (Continued)

Latissimus Dorsi	Extends, adducts and medially rotates arm. Costal attachment helps with deep inspiration and forced expiration	Thoracodorsal nerve (from posterior cord)	C6, C7, C8
Lumbricals	Flex metacarpophalangeal joints and extend interphalangeal joints of fingers	Lateral 2: median nerve. medial 2: deep branch of ulnar nerve	C8, T1
Opponen Digiti Minimi Hand	Opposes (flexes and laterally rotates) carpometacarpal and metacarpophalangeal joints of little finger	Deep branch of ulnar nerve	C8, T1
Opponens pollicis	Thumb opposition	Median nerve	C8, T1
Palmar Interossei	Adduct to axis of middle finger. Flex metacarpophalangeal joint while extending interphalangeal joints	Deep branch of ulnar nerve	T1
Palmaris Brevis	Steadies and corrugates skin of palm to help with grip	Superficial branch of ulnar nerve	C8, T1
Palmaris Longus	Flexes wrist and tenses palmar aponeurosis	Median nerve (from medial and lateral cords)	C7, C8
Pectoralis Major	Clavicular head:flexes and adducts arm. Sternal head: adducts and medially rotates arm . Accessory for inspiration	Medial pectoral nerve (from medial cord) and lateral pectoral nerve (from lateral cord)	C6, C7, C9
Pectoralis Minor	Elevates ribs if scapula fixed, protracts scapula (assists serratus anterior)	Medial pectoral nerve (from medial cord)	C8, T1

Table 1.1 (Continued)

Pronator Quadratus	Pronates forearm and maintains ulna and radius opposed	Anterior interosseous nerve	C8
Serratus Anterior	Laterally rotates and protracts scapula	Long thoracic nerve (from roots) slips from ribs 1 and 2; 3 and 4:	C5, C6, C7
Subscapularis	Medially rotates arm and stabilizes shoulder joint	Upper and lower subscapular nerves (from posterior cord)	C5, C6
Supinator	Supinates forearm. Only acts alone when elbow extended	Posterior interosseous nerve	C5, C6
Supraspinatus	Abducts arm and stabilizes shoulder joint	Suprascapular nerve (from upper trunk)	C5, C6
Teres Major	Medially rotates and adducts arm. Stabilizes shoulder joint	Lower subscapular nerve (from posterior cord)	C5, C6
Teres Minor	laterally rotates arm and stabilizes shoulder joint	Axillary nerve	C5, C6
Triceps	Elbow extension	Radial nerve	C6, C7, C8
Trapezius	laterally rotates, elevates and retracts scapula. If scapula is fixed, extends and laterally flexes neck	Spinal accessory nerve	(C1-5)(spinal nerves C3 and C4 for proprioception

The Extensor Carpi Ulnaris (ECU), Extensor Digitorum (ED), Pronator Quadratus (PQ), Pronator Teres (PT), Flexor Digitorum Superficialis (FDS), First Dorsal Interosseus (FDI), and Second Dorsal Interosseus (SDI) are the dominant muscles involved with grasping the mouse and are susceptible to injury (Agarabi, Bonato, De Luca, 2004). Occupational exposure to static muscle loading will cause damage to poorly vascularized areas of muscle and tendons even at 10% to 20% of maximal voluntary contraction levels (Sjogaard, Lunderg, & Kadefors, 2000). This is due to the fact that static muscle contractions restrict blood flow to the muscle, and thus the supply of oxygen to muscle fibers, because of the extended time of contraction (Pulat, 1997). In contrast to static muscle contraction, dynamic muscle contraction increases blood flow to the muscle, thus allowing muscle fibers to receive oxygen and reduce the level of fatigue in the muscle. As a consequence, longer periods of rest are needed during static muscle contraction to allow for increased muscle recovery time (Ibid.).

Recovery time is important because it allows the muscles to replenish depleted muscle energy stores such as ATP and muscle glycogen and repair damaged muscle tissue. After muscle activity, fluid begins to build up in the damaged cells in order to bring immune cells, such as neutrophils and macrophages, to the site of injury to clear away damaged tissue (Muscle, n.d.). Thus rest breaks from muscle activity such as during computer work are important and have been shown to improve performance, decrease fatigue, and reduce musculoskeletal injury risk in a variety of jobs (Tucker, 2003).

A computer mouse (vibrating mouse by Hoverstop BV) has recently been developed in an attempt to reduce risk of developing musculoskeletal disorders during computer work by encouraging users to release the mouse when not in use rather than maintaining a grip on the mouse. The mouse is designed to remind users to take more rest breaks by gently vibrating in the user's hand after 10 seconds of mouse inactivity. This vibration is to remind the user to remove his or her hand from the mouse and relax the hand in a neutral position, thus allowing the muscle to recover from prolonged static contraction.

This mouse has been examined in a laboratory test (de Korte, de Kraker, Bongers, & van Lingen, 2005), and a field study with call-center workers (de Kraker, de Korte, van Mil, Rijs, & Bongers, 2006). These studies found that users took more rest breaks with the vibrating mouse than when using a conventional mouse but found the vibrating mouse to be somewhat disruptive to the completion of work tasks. These studies examined user preference, number of rest breaks induced, and muscle activity differences (M. trapezius pars descendens, M deltiodeus pars anterior, M. deltiodeus pars acromialis, M. extensor carpi radialis longus, M. extensor digitorum communis and M. flexor digitorum superficialis) between the two different input devices. The computer tasks in these studies consisted only of information retrieval tasks that would be most likely to induce a vibration when using the vibrating mouse. This may limit the generalizability of the findings to only those situations where computers are used for information searching and retrieval. The vibrating mouse needs to be evaluated in a wide variety of computer tasks to determine its effectiveness in promoting rest breaks and other aspects of its use.

Objectives

The purpose of the present research is to evaluate the effects of feedback from a vibrating mouse on computer task performance and mouse usability as compared to a conventional mouse.

The following issues were explored:

1. Does the use of an activity-related vibrational feedback mouse improve computer task behaviors especially the frequency of micro breaks?

2. How does task design effect the initiation of vibrational feedback from the mouse?

3. What do users do with their hands after they receive vibrational feedback from the vibrating mouse?

4. How does vibrational feedback from the mouse impact the user's concentration on the task?

Chapter II. BACKGROUND

2.1 Computer Work and Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) refer to a range of symptoms, injuries and degenerative problems in the body's musculoskeletal system. These can include injuries to the muscles, tendons, ligaments, nerves, and bone. While some studies have shown that Injury risks from computer use are difficult to accurately determine (Punnett & Wegman, 2004), others have shown that musculoskeletal injuries are associated with repetitive work, such as using a computer keyboard and mouse (see below).

Evans and Patterson (2000) tested whether poor typing skill, hours of computer use, work stress, such as time pressure, and poor workstation setup were factors in reports of neck and shoulder complaints. They found that only tension and gender were predictors of neck and shoulder pain. In this study several workstation setups were used: screen distance and horizontal and vertical screen position; keyboard and mouse vertical position and distance; seat height and depth; relative size of the back support and back rest inclination and wrist rests. Working posture was also included in the workstation setup category. None of the setup factors were significant.

Other studies have found different results with no relationship between amount of mouse use per day and reported symptoms of neck and upper extremity discomfort (Cook et al., 2000). They did, however, find an association between the amount subjects abducted their arms and neck symptoms. Additionally, they found a relationship between stress and reported symptoms, along with associations between screen height, shoulder elevation and symptoms. These contradictory results suggest a need for further research especially with respect to differences in study time periods.

One prospective longitudinal study examined 632 computer workers in the US for up to three years (Gerr et al., 2002; Marcus et al., 2002). The workers reported an annual incidence rate of 58 cases per 100 person-years of neck/shoulder musculoskeletal symptoms and 35 cases per 100 person-years for neck/shoulder and musculoskeletal disorders. Hand/arm symptoms were reported and 39 cases per 100 person-years and 21 cases per 100 person-years for hand/arm musculoskeletal disorders. Age, gender, prior history of neck/shoulder pain and, different from other studies, ethnicity was associated with neck/shoulder problems. Gender, prior history of hand/arm pain and prior extensive computer use were among the factors associated with hand and arm problems. Posture and workstation factors were also looked at and the results showed an association with an inner elbow angle greater than 121°, greater downward head tilt and armrests were associated with a lower risk of neck/shoulder problems while keying with a low elbow height and the presence of a telephone shoulder rest were associated with a greater risk of the same problems. The study also showed an association between users having a greater risk of hand and arm problems with a high keyboard height, activating the keys with a force greater than 48 g and radial wrist deviation greater than 5° while using a mouse. Similar to other studies, the number of hours spent keying per week was associated with hand and arm symptoms and disorders.

Jensen, Finsen, Sogaard and Christensen (2002) studied Danish computer workers and reported that working almost the whole day with a computer was associated with neck symptoms and shoulder symptoms for women and hand symptoms for men. The differences between the genders might be explained by different work techniques as well as different job tasks and size and strength differences. In addition, workers who used a mouse for more than half of the time had more hand/wrist symptoms. One longitudinal cohort study (Kryger et al., 2003) looked at 6943 computer users initially, and with a one-year follow-up, and found 4.3% to have moderate to severe forearm pain. Mouse use over 30 hours per week and keyboard use over 15 hours per week and, to a lesser extent, job stressors were found to be risk factors for development of forearm pain.

Predictors for neck pain have also been examined with poor physical work environment, such as computer monitors at incorrect angles or heights, and poor placement of the keyboard, emerging as risk factors for neck pain (Korhonen, 2003). Women also reported more neck pain than men and higher mental stress and less physical exercise showing in interaction effect for the risk of neck pain (ibid.).

Other researchers have used longitudinal studies to gauge the risk factors for developing computer related injuries. Jensen (2003) examined 5033 computer users in Denmark and found that previous symptoms, women's low influence at work, poor screen placement, men's short time in the same job, and being skilled at the computer were associated with neck symptoms. He also found a significant association between mouse use and the development of carpal tunnel syndrome. Low influence at work was also a good predictor of injury development which indicates psychosocial factors may be important.

In a follow-up study of the injured computer workers (Juul-Kristensen et al., 2004), the subjects reported symptoms more often in the elbow (10%), shoulder (18%) and low back (23%) and reported more intense pain in the problem body areas after nearly 2 years. There were gender differences as well, with the women reporting more symptoms in all body areas than men. Computer work time, psychosocial dimensions, such as stress and influence at work were considered but found not to be significant predictors of symptoms.

2.2 Computer Work and Muscle Use

A motor unit is one motor neuron and all of the muscle fibers it innervates. When a motor unit fires, the impulse, an action potential, is carried down the motor neuron to the muscle. After the action potential is transmitted across the neuromuscular junction, an action potential is elicited in all of the innervated muscle fibers of that particular motor unit. Motor unit recruitment occurs when more motor neurons are activated. As the muscle contraction becomes stronger, more motor units are recruited and generally recruited in order of smallest to largest. The force exerted by the muscle is controlled by varying the frequency at which action potentials are sent to muscle fibers. Action potentials do not arrive at muscles at the same time, and during a contraction some fraction of the fibers in the muscle will be firing at any given time. When a human is exerting a muscle as hard as they are able, roughly one-third of the fibers in that muscle will be firing at once. This is referred to as a 'low' level of contraction and is a protective mechanism to prevent injury to the tendon. Motor unit potential is the sum of all the electrical activity and is recorded and evaluated using an EMG (Muscle, n.d.).

Electromyography (EMG) is a technique for evaluating and recording physiologic properties of muscles and is carried out using an instrument called an electromyograph which detects the electrical potential generated by muscle resting and contracting cells (Electromyography, n.d.). EMG can be done at the surface or deeper in the muscle tissue using either fine wire electrodes or surface electrodes inserted into the muscle (Morrish, 1999). This method is better for detecting single motor unit activity but is painful for subjects. Techniques such as high special resolution EMGs may help detect single motor unit activity in an effective non-invasive manner (Disselhorst-Klug, Bahm, Ramaekers, Trachterna, & Rau, 2000). EMG is reported in percentages of a baseline maximal voluntary isometric contraction (MVIC) to account for test to test variations.

One explanation for injury during computer has been the Cinderella hypothesis. The Cinderella hypothesis states that muscle overload may be attributable to prolonged, single motor unit activity which is not detected by surface electromyography. According to this hypothesis, the continuous activity of specific muscle-units during low-level contraction, such as during computer work, may overload specific muscle-units because of lack of recovery. This can cause myopathy, a neuromuscular disease in which the muscle fibers become dysfunctional, resulting in pain and muscular weakness and/or muscle strain where the muscle fibers tear as a result of being overstretched. (Hägg, 1991).

The following table lists relevant studies and the muscles examined in each study:

Table 2.1 Computer Work Studies and Related Muscles

Researchers/Year	**Muscles Involved**
Kitahara, Schnoz, Laubli, Wellig and Kruger, 2000	Trapezius
Forsman, Kadefors, Zhang, Birch and Plamerud, 1999	Trapezius
Cooper & Straker, 1998	Trapezius

Table 2.1 (Continued)

Thorn et al., 2006	Trapezius
Jensen, Finsen, Hansen, & Christensen, 1999	Trapezius
Sandfeld & Jensen, 2005	extensor carpi radialis, m. extensor digitorum superficialis, m. extensor carpi ulnaris, m. flexor carpi radialis, right and left mm. trapezius and right neck extensor muscle (upper part of m. trapezius) and m. splenius capitis
Laursen, Jensen, & Ratkevicius, 2001	extensor digitorum muscle
Wahlstrom, Hagberg, Johnson, Svensson, & Rempel, 2002	right first interosseus, right extensor digitorum, and the pars descendens of the right and left trapezius
Heiden, Lyskov, Djupsjobacka, Hellstrom, and Crenshaw, 2005	extensor carpi radialis
Blangsted, Hansen, & Jensen, 2003	upper trapezius and extensor digitorum communis
Fernstrom and Ericson, 1997	left m. trapezium, pars descendens, the right m. trapezium, pars descendens, the right m. deltoideus, the right, m. flexor digitorum superficialis, the right m. extensor digitorum, and the right m. extensor carpi ulnaris
Karlqvist et al., 1999	left m. trapezium, pars descendens, the right m. trapezium, pars descendens, the right m. deltoideus and the right m. extensor digitorum
Agarabi, Bonato, De Luca, 2004	extensor carpi ulnaris, extensor digitorum, pronator quadratus, pronator teres, flexor digitorum superficialis, first dorsal interosseus, and second dorsal interosseus
Ullman, Kangas, Ullman, Wartenberg & Ericson, 2003	m. pronator teres, m. extensor digitorum, m. trapezius, and m. levator scapulae
Gustafsson & Hagberg, 2003	right extensor digitorum and right extensor carpi ulnaris
Lindegard et al., 2003	m. extensor digitorum, m. extensor carpi ulnaris, trapezius pars desecendens
Crenshaw, Djupsjobacka, & Svedmark, 2006	extensor carpi radialis

Table 2.1 (Continued)

de Korte, de Kraker, Bongers, & van Lingen, 2005	m. trapezius pars descendens, m deltiodeus pars anterior, m. deltiodeus pars acromialis, m. extensor carpi radialis longus, m. extensor digitorum communis and m. flexor digitorum superficialis

2.2.1 Computer Work and Trapezius Muscle Use

The trapezius muscle has an upper and lower part and is located on the left and right side of the body. It laterally rotates, elevates and retracts the scapula. If scapula is fixed, it extends and laterally flexes neck. Several studies have examined the relationship between computer work and trapezius muscle activity and found evidence to support the Cinderella hypothesis. Kitahara, Schnoz, Laubli, Wellig and Kruger (2000) showed continuous single motor unit firing in the trapezius muscles of two out of six subjects while performing a simple data input task and one subject during a finger tapping task. The rest of the subjects showed intermittent muscle activity. Some computer users may therefore be more susceptible to muscle overuse than others but more research is needed in this area. Forsman, Kadefors, Zhang, Birch and Plamerud (1999) recorded trapezius muscle activity in subjects who performed a shoulder movement exercise and in subjects who performed computer work. They did this to see whether they would find continuously active motor units during the computer work which would demonstrate that even the small amount of shoulder activity found during computer work to maintain postures and move the mouse could cause users to have continuously active motor units. They found that the computer work and the shoulder exercise showed continuously active motor units (1999). While these studies support the Cinderella hypothesis, they only show a small part of a possible cause and effect relationship between low-level muscle use during computer work and the development of musculoskeletal problems from computer work. They also did not address differences between keyboarding and mousing, which have shown different levels of trapezius muscle activity in other studies (Cooper & Straker, 1998).

Thorn et al. (2006) also examined trapezius muscle activity but, in contrast to previous studies, they looked at the differences in muscle activity between subjects with self-reported neck and/or shoulder complaints and a control group during a stress reaction task that consisted of the subject clicking on one of four icons that represented the name of a color in which a word was written and presented to them on the computer screen. If the subject answered incorrectly an audio alarm sounded or if a 5 minute time limit was exceeded. During the experiment the subjects also completed typing, editing, and mouse precision tasks. Subjects experiencing symptoms were found to have less muscle rest time while performing the color stress task. The experimental group also showed higher muscle activity amplitude during this task, however, there were no differences in muscle activity between the experimental and control groups while performing typing, editing or mouse precision tasks.

Studies that have examined the role of muscle activity in computer work have shown differences between computer aided drafting (CAD) work and other non-computer repetitive tasks, such as producing ends for metal cans (Jensen, Finsen, Hansen, & Christensen, 1999). CAD work is extremely mouse intensive because it is used as the primary input device to draw diagrams and blueprints. CAD work is also very repetitive because the mouse is used to click, drag, and position items repeatedly to complete the drawings.

The production can-making work was used as a comparison non-computer repetitive task because it involved repeatedly collecting stacks of metal ends and then packing the ends in containers. The production work showed more repetitive muscle activity whereas the CAD work showed more static muscle activity patterns for the upper trapezius muscle. Also, the median length of pauses in upper arm movements was shorter for CAD work than production work. This means that the production workers were able to allow their muscles to have more of an opportunity to recover, while the CAD workers, theoretically, were at greater risk for injury because of less muscle recovery time.

2.2.2 Computer Work and Forearm Muscle Use

Significant levels of forearm muscle activity during concentrated mouse work have been found (Sandfeld & Jensen, 2005). It has been hypothesized that this could be due to job stress, which would lead to a lack of relaxation and thus possibly causing more damage to muscle and small tissue than a high absolute level of muscle contraction or high frequency of muscle activation (Sjogaard, Lunderg, & Kadefors, 2000).

Age effects on muscle activity during computer mouse tasks have been studied (Laursen, Jensen, & Ratkevicius, 2001). A group of elderly computer users, with a mean age of 63 years, showed a mean increase of maximal electrical activity of 10.4% in the extensor digitorum muscle, while the group of young computer users showed an 8.1% increase in maximal electrical activity in the same muscle (ibid). Gender differences have also been examined but this does not significantly affect muscle activity (Blangstred, Hansen, & Jensen, 2003).

2.3 Psychosocial Factors in Injury Risks from Computer Use

Psychosocial issues are also thought to contribute to musculoskeletal disorders and have been examined in a number of research studies. These factors include items, such as job stress, social support, job control, job satisfaction and others. In a review of the literature on psychosocial factors, Bongers, Kremer, & ter Laak (2002) noted that high levels of job stress and non-work-related stress reactions were consistently associated with upper extremity problems in most studies, and high job demands are also associated with upper extremity problems in some studies. Most of the studies reviewed were cross-sectional rather than longitudinal. Therefore, they show stress at a specific time period rather than tracking the effects of stress over time which would better simulate work conditions. Bongers, Kremer, & ter Laak also called for more investigation into the mechanisms underlying the specific pathways between psychosocial factors in the development of many musculoskeletal disorders, as well as longitudinal studies that examine the development of these disorders over the long term.

One reason that it has been difficult to investigate the exact mechanisms involved in the development of musculoskeletal disorders from psychosocial factors has been the lack of improvement during stress reduction and ergonomic interventions, as evidenced by the conclusions of Pransky, Robertson, and Moon (2002). From their literature review of the outcomes of stress prevention and intervention techniques to reduce work-related upper extremity disorders (WRUED), they noted no studies that showed a link between stress-reducing ergonomic interventions and a reduction in WRUED symptoms.

The effects of stress on physiological measures including blood pressure, heart rate, and heart rate variability along with forces applied to the mouse, wrist movement, mood and exertion were examined in a controlled laboratory study where subjects were given a repetitive text editing task to be completed in five minutes (Wahlstrom, Hagberg, Johnson, Svensson, & Rempel, 2002). The highest force applied to the computer mouse button by subjects increased by 0.7% of maximal voluntary contraction in the right first interosseus, right extensor digitorum, and the pars descendens of the right and left trapezius muscles during the stress (time pressure and verbal provocation) situation, compared to no stress. The study has several limitations including a short time period and non-randomized situations.

Time pressure and precision demands were studied by Heiden, Lyskov, Djupsjobacka, Hellstrom, and Crenshaw (2005). Precision demands consisted of a buzzer that activated when subjects painted outside a rectangle. The researchers then tested the effects of those two stressors on muscle oxygenation and position sense of the upper extremities. During the more stressful task, with time pressure and precision demands, oxygen saturation in the extensor carpi radialis decreased ($p<0.05$), electrodermal activity increased ($p<0.05$), blood flow to the skin increased ($p<0.05$), subjects had higher tenseness and fatigue ratings ($p<0.01$), and performance increased ($p<0.01$).

Other researchers studied the effects of self-reported quantitative job demands including work pace, distribution of work loads, time pressure, ability to keep up with deadlines, and the need to do overtime, on upper trapezius and extensor digitorum communis muscle activity and found no increase in muscle activity. Electromyographical readings of the two muscles remained

5% and 2.5% of maximal voluntary contraction (Blangsted, Hansen, & Jensen, 2003).

2.4 Computer Mouse Design and Injury Risks

There are many important aspects to consider in the design of a computer mouse. A computer mouse needs to be able to fit a wide variety of hand shapes and sizes, while allowing users to move the mouse in such a way as to position the cursor, move objects around the screen, interact with menus and scroll through application windows. Computer mice are configured with one to three or more buttons and/or one or two scroll wheels, in order to select items on the screen, move the cursor and perform the wide variety of tasks required by different computing applications.

2.4.1 Computer Input Device Designs

Trackball input devices are a popular alternative to the standard computer mouse and have been examined in several studies. They typically consist of a plastic base with some sort of a sphere that performs cursor movements and scrolling tasks along with various button configurations that operate similar to a conventional mouse. Trackball type input devices minimize the need to grasp the device and move its position.

Fernstrom and Ericson (1997) examined the muscle activity differences between computer users while using a conventional computer mouse and a trackball input device. The left M. trapezium, pars descendens, the right M. trapezium, pars descendens, the right M. deltoideus, the right, M. flexor digitorum superficialis, the right M. extensor digitorum, and the right M. extensor carpi ulnaris were measured in twenty subjects, ten men and ten women. The subjects completed a word processing task that consisted of correcting a document for 15 minutes under each condition. Approximately 75% of the time involved pointing during the task. Median muscle activity was calculated in %RVC which is a standardized reference contraction using electromyography. A significant, ($p<0.05$), decrease in group median muscular activity from 2.4 (%RVC) with the conventional mouse to 2.1 (%RVC) with the trackball in the left M. trapezium, pars descendens, and from 2.7 (%RVC) to 1.8 (&RVC) in the right M. trapezium, pars descendens was found. The researchers also found a significant, ($p<0.05$), increase in the right flexor digitorum superficialis from 1.05 (%RVC) with the conventional mouse to 1.03 (%RVC) with the trackball and in the right M. extensor carpi ulnaris from 3.3 (%RVC) to 4 (%RVC). No significant differences were found in the right M. deltoideus and in the right M. extensor digitorum between the two input devices.

Another study (Karlqvist et al., 1999), examined whether trackball use leads to an improvement in computer work postures and less muscular activity in the left M. trapezium, pars descendens, the right M. trapezium, pars descendens, the right M. deltoideus and the right M. extensor digitorum. Ten men and ten women performed an editing task for 15 minutes with a conventional mouse and 15 minutes with a trackball. The results showed an increase of 4° of wrist extension for men and 7° for the women with the trackball compared with a conventional mouse ($p=0.00$). There was only a significant, ($p=0.02$), decrease in mean MVE (% Maximal Voluntary Electrical activity – MVE) in the right M. trapezium, pars descendens; for men there was a decrease of 0.5 in %MVE and a decrease of 2.2 in %MVE for women when using the trackball compared to a conventional mouse.

Wrist posture differences between using a mouse and a trackball have also been examined by Burgess-Limerick, Shemmel, Scadden, & Plooy, (1999). They found some differences in wrist posture due to the different designs, and the trackball showed an average of 4° decreased ulnar deviation and an average of 6° increased wrist extension, but individual differences varied to such a degree that it was difficult to draw any specific conclusions about injury risks associated with the different input devices.

Age differences have also been studied between ratings of perceived exertion and muscle load and the trackball may be preferable for older computer users because of a lower perceived exertion and smaller range of motion (Chaparro, Bohan, Fernandez, Choi, & Kattle, 1999).

One study tested whether the design of a mouse plays a role in increased carpal tunnel pressure, which could, in turn, lead to an increase in carpal tunnel syndrome risks (Keir, Bach, & Rempel, 1999). Carpal tunnel syndrome is a nerve compression disorder that is a result of the median nerve being compressed at the wrist during activities such as computer work (National Institute of Neurological Disorders and Stroke, 2002). The median nerve is a nerve that carries nerve impulses to small muscles such as the abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, and lumbricals I & II that are part of thumb and finger movement. It also controls sensations to the palm side of the thumb and the fingers except the little finger and half of the ring finger. It originates in the brachial plexus and continues down the arm and passes through a small channel made of ligament and bones at the base of the hand called the carpal tunnel before extending through to the hand and fingers. Carpal tunnel syndrome is often the result of a combination of factors that increase pressure on the median nerve and tendons in the carpal tunnel.

Symptoms include frequent burning, tingling, or itching numbness in the palm of the hand and the fingers, especially the thumb and the index and middle fingers (ibid.; Fagarasanu & Kumar, 2003).

The researchers tested three different mouse designs each of which differed in shape and size. The three mice designs altered radioulnar deviation (bending of the wrist left and right) by a slight amount: 0.5°±1.9° towards the smallest finger of the hand and away from the thumb (ulnar deviation) for mouse A, 4.1°± 2.1° of ulnar deviation for mouse B, and 2.7° ± 1.8° of ulnar deviation for mouse C, (all under active conditions). They found no influence on wrist extension postures and carpal tunnel pressure between the different mice designs. Also, carpal tunnel pressure was greater for dragging and pointing tasks than a static hand posture which indicates the importance of relating computer task type to musculoskeletal disorder risks.

Some studies have examined whether a joystick shaped mouse, the Anir, reduces the pain experienced by injured computer users (Aaras, Dainoff, & Ro, 2002). After six months of using the Anir mouse, injured workers reported significantly less neck, shoulder, forearm, wrist and hand pain compared to controls (ibid). The researchers attributed the lower levels of reported pain because the users maintained a more neutral position of the forearm when using the mouse because the vertical orientation of the mouse allows users to grasp the mouse with less downward rotation of the forearm that is required to use a conventional mouse with the palm down (ibid.).

In another study of mouse shape, a vertically oriented mouse scored lower than a conventional mouse on usability and performance measures, but subjects experienced slightly less discomfort (Straker, Pollock, & Frosh, 2000). Other mouse designs have been tested that resemble a pen, with a vertical orientation for the hand, and have shown decreased ulnar deviation and wrist pronation but increased wrist extension when compared to a conventional mouse (Chao & Hedge, 2004). The conventional mouse was found to be easier to use than the pen mouse designs (ibid.). Another pen mouse study, showed a decrease in muscle activity in the M. pronator teres by 46%, M. extensor digitorum by 46%, M. trapezius by 69%, and M. levator scapulae by 82% compared to a conventional mouse (Ullman, Kangas, Ullman, Wartenberg, & Ericson 2003).

2.4.2 Computer Mouse Feedback

Zhai and MacKenzie (1998) traced the development of the mouse and examined ways in which the mouse could be improved. At the time of their paper they called for more development of three-dimensional mouse capabilities, better methods of scrolling and incorporating tactile feedback into mouse design. They speculated that a mouse with force feedback would help with the fine precision tasks associated with mousing and that vibration could be explored but offered no specific suggestions.

Other researchers have shown tactile feedback to be superior to other types of feedback in a cursor positioning task (Akamatsu, MacKenzie, & Hasbroucq, 1995). They examined normal, auditory, color, tactile and combined feedback and found no difference in overall response times, bandwidths, or error rates, but did find the tactile feedback to be the quickest in final positioning time. Tactile feedback was the second most preferred mode of feedback. These results corroborated earlier findings (Akamatsu, Sato, & MacKenzie, 1994) that were limited to a comparison between tactile and no feedback.

The effects of force feedback in computer mouse design on self-reported user discomfort and pain have also been examined (Dennerlein & Yang, 1999). Subjects completed a point and click task using a mouse that gave the user force feedback by incorporating electromagnetic actuators that produced tactile feedback when the user was closer to the intended on-screen target. Subjects then completed the task with the feedback turned off. Under the force feedback condition, users experienced less discomfort and pain ($p < 0.05$) across all measures except perceived soreness. The number of errors, as measured by mouse clicks outside the target area, decreased by 43% with force feedback. The researchers attributed the results specifically to the algorithm which helped guide the cursor to the target by giving the user tactile feedback as the cursor moved closer to the target. According to the researchers, this type of feedback should reduce the strain on the musculoskeletal system compared with friction-based force feedback and non-feedback scenarios that make the user use more force and precision movements to move the mouse as they get closer to an intended target. Friction-based force feedback would require extra force and therefore possibly put extra strain on the upper extremities (ibid.).

2.5 Computer Mouse Use Technique

Computer mouse shape can dictate hand and wrist postures, and one study examined the effects of two different hand positions while using a mouse (Gustafsson & Hagberg, 2003). The study showed that in a vertical hand position, with palm facing inward and top of hand outward (referred to as neutral by the researchers but not necessarily a neutral finger, wrist or shoulder position), there was decreased or unchanged muscle activity in the right extensor digitorum and right extensor carpi ulnaris compared to using a conventional mouse with the palm facing down (pronated). However, subjects' productivity, measured by the number of pages edited, decreased by 24% and they were less comfortable working in the vertical hand posture. This may indicate a need for training and/or further practice with the vertical hand position or a fundamental problem with mousing in this posture (ibid.).

In a survey of 1000 computer workstations, the computer mouse was located to the right of the keyboard in 92% of the workstations (Dennerlein & Johnson, 2003). Some researchers have proposed and studied the use of the mouse on the left side of the keyboard because it potentially allows a right-handed user to mouse with his or her left hand and to keep the mouse closer to the center line of the body rather than extended far out to the right side of the keyboard (Delisle, Imbeau, Santos, Plamondon, & Montpetit, 2004). The results of their study showed that using the mouse in this manner for one month reduced shoulder flexion and abduction and wrist extension, but also increased the time to complete tasks by 22% during the initial measurement session and 15% one month later. While these results are promising in terms of posture and after one month 16 of 27 subjects converted to using the mouse with his or her left hand, it would take considerable retraining and commitment on the part of computer users to implement this technique (ibid.).

The impact of working technique, gender and prior musculoskeletal symptoms on muscular load during computer work on mouse use has been studied by Lindegard et al. (2003). The working technique in this study was rated on a scale which consisted of nine areas including support of the arms during keyboard work, support of the mouse arm during input device work, lifting of the computer mouse, range of movements during input device work, velocity of movements during input device work, type of working technique during input device work (fast, jerky, and whole arm) sitting in a tense position, lifting the shoulders during keyboard work, lifting the shoulders during input device work. Working technique was considered good if subjects scored greater than 15 out of 25, intermediate between 14 and 15 and poor if less than 14. Subjects were classified as working with good technique (score of greater than 15 out of 25 on nine point working technique scale) or with poor technique (score of less than 14 out of 25 on nine point working technique scale). They found that subjects who worked with a good technique placed less load on the forearm (p=0.03) and trapezius muscles (p=0.02) and used less wrist extension (p=0.04). They found no difference in time or frequency of muscular rests between those with poor or good technique (ibid.)..

2.6 Strategies to Prevent Work-Related Injuries

2.6.1 Rest Breaks and Work

Time spent resting while allowing the muscles to recover from use, known as rest breaks, have been shown to improve performance, decrease fatigue, and reduce the accumulation of musculoskeletal injury risk in a variety of jobs (Tucker, 2003). Tucker also discussed the importance of additional micro-breaks, those being less than 60 seconds beyond a break of ten or fifteen minutes after two hours of continuous work. More frequent shorter breaks such as 10 minutes for every hour of work versus 15 minutes for every 90 minutes of work have generally been found to lead to improved performance and decreased fatigue. However, he notes that optimum work rest schedules depend upon the type of tasks because tasks have different muscular expenditure requirements and, therefore, different recovery times, and consideration has to be given to minimizing work disruption. Tucker also examined the issue of the timing of rest breaks, and concluded that self managed breaks are adequate to manage fatigue because skilled workers learn to take breaks when appropriate to maintain concentration. These types of discretionary breaks may not adequately help to avoid discomfort from computer work. This leads to a difficult question as to whether rest breaks should be preplanned, which may lead to optimum injury risk reduction, or should be discretionary so as to not disrupt task concentration.

2.6.2 Rest Breaks and Computer Use

Rest break schedules from computer use have been examined in data entry workers (Galinsky, Swanson, Sauter, Hurrell, & Schleifer, 2000). The 42 workers in the study alternated between a schedule that contained a 15 minute rest break during the first half of the work shift and another 15 minute rest break during the second half of the work shift and a schedule that contained the same two 15 minute breaks and additional 5 minute breaks spaced through each hour, totaling 20 extra minutes of rest break time. The workers performed their normal data entry tasks for four weeks on one schedule and four weeks on the other schedule. The results showed a reduction in self-reported discomfort in neck, back, right forearm/hand, right shoulder/upper arm, left shoulder/upper arm, right elbow, buttocks, left elbow, and eye soreness with the extra rest break schedule versus the regular schedule with no reduction in performance.

McLean, Tingley, Scott, and Richards (2001) studied the effects of different types of rest breaks on muscle activity among computer users, and the frequency of reporting discomfort in the neck, shoulder, back and forearm.

The different types of rest breaks were: at their own discretion, micro-breaks (30 seconds) at 20 minute intervals and micro-breaks (30 seconds) at 40 minute intervals. Additionally, they performed a second session in which subjects were asked to leave their workstation during the micro-breaks. They found that in all cases discomfort increased over time during computer terminal work ($p<0.001$), but that the introduction of micro-breaks produced lower discomfort scores ($p<0.05$). The results showed a 20 minute work with micro-break pattern to be the most effective at decreasing discomfort. Productivity was measured by counts of words produced during the work period and no difference between the groups was found.

Balci and Aghazadeh (2000, 2003, 2004) have published a number of studies related to work-rest schedules and computer use. They promote proper work-rest scheduling as an effective ergonomic intervention because it is inexpensive and relatively easy to implement. The objective of one of their studies (Balci and Aghazadeh, 2003) was to find the optimum work rest schedule for computer workers doing data entry and mental arithmetic tasks. They looked at the following schedules: 60 minutes of work/10 minute rest, 30 minute work/5-minute rest, and four breaks during one hour of computer work in addition to a 14 minute break after two hours, three of the micro-breaks were 30 seconds and the fourth was three minutes (called 15 minute/ micro schedule). The results of this study indicated significant differences for discomfort of the neck, shoulder, upper and lower back, chest and elbow/arm, eyestrain, blurred vision, speed, accuracy and performance, depending upon the different work rest schedules, with the 15 minute/micro break performing the best. There were also differences for the various combinations of these variables among the different work rest schedules. These findings correspond well to the previously discussed research which shows that the different parts of the body respond differently to activity and rest.

The 15 minute/micro break schedule produced the highest speed, as measured by dividing total number of problems answered by overall maximum output, accuracy, measured by number of correct answers divided by total number of problems and performance, measured by multiplying speed and accuracy scores, for both the data entry and mental arithmetic tasks compared with the other two schedules. The 15 minute/micro schedule also produced significantly lower discomfort in the neck, lower back and chest than the other schedules for the data entry task. The 30/5 schedule however resulted in the lowest discomfort scores for eyestrain and blurred vision. There was also a difference found between the two tasks. Lower eyestrain and blurred vision symptoms were reported for the mental arithmetic task while lower upper extremity discomfort was reported for the data entry task.

Balci and Aghazadeh's other studies (2000, 2004) examined work rest schedules in other settings and with mental and data entry tasks, and found that a 15 minute work/micro break schedule was generally superior to the other types of schedules.

Feedback has been examined as a way to manage computer worker rest breaks with positive results (Henning et al., 1996). In two experiments, thirty one and thirty subjects, respectively, entered lines of text for hour while taking rest breaks at their discretion to attain a target of 30 seconds of break for every 10 minutes of work. If subjects did not meet this target they were prompted to take rest breaks until the target was met. For one condition subjects were given feedback as to how their discretionary breaks matched the target and subjects under the other condition did not receive the feedback.

Feedback was adjusted to fit within the tasks so as to not disrupt work flow in the second experiment. The results showed that under the feedback condition subjects managed breaks better than those without feedback and those with feedback integrated into the task reported less back discomfort and less task disruption. Error rates were also lower for the feedback group.

In another study on rest breaks, (Henning, Jacques, Kissel, Sullivan, & Alteras-Webb, 1997) workers who processed written insurance claims on a computer were examined for differences between types of rest breaks. All subjects took 30 minute breaks for lunch and 15 minute breaks in morning and afternoon while performing their normal job functions. Under both experimental conditions workers were prompted by a red light to take three 30 second breaks plus one three minute break per hour. One group did exercises during the breaks and the other was told to relax during the rest breaks. Mood and self-reported discomfort were measured along with number of claims processed per hour as a measure of productivity. Productivity was approximately 15% higher for breaks and exercise ($p=0.018$). Eye and leg and foot comfort were also higher in the breaks and exercise condition than baseline but only eye comfort was significant ($p=0.041$).

In a five week field study of computer workers using ergonomic work pacing software a significant increase in keying accuracy was found 13.4% between the test and control groups (Hedge, 1999). There was also a before-after reduction in keying errors and accuracy improved with increased daily keystroke rate while accuracy decreased with increased daily keystroke rate in the control group. No differences in musculoskeletal comfort were found.

Fifty-six skilled computer workers used ergonomic work pacing software for a four week baseline period and then a four week test period (Hedge &

Evans, 2001). Keying error data was collected for one week. Software provided micro-break reminders only if workers did not adequately self pace their work. The results showed 59% improvement in work accuracy ($p=0.0001$) as measured by number of keystroke errors.

In contrast to Henning et al. and Balci and Aghazadeh, other researchers have examined the effects of micro-breaks on upper extremity discomfort in computer operators and found no differences between break type (de Looze, van den Heuvel, & Hildebrandt, 2002). They studied a group of 268 computer workers in three groups, a control group, an experimental group with break reminder software, and an experimental group with break reminder software that reminded them to perform exercises during breaks. The subjects were given a questionnaire about the location and severity of bodily discomfort before and after the interventions. The results showed no significant differences in the severity of discomfort, pre- and post- intervention, according to self-reported quantitative scores of discomfort levels. Additionally, there was no difference for different body regions and no difference was found between the two groups due to the performance of exercises during breaks. Subjects perceived more recovery due to the break reminder software when asked about recovery. However, when subjects were asked to quantify the recovery level, there was no difference between the intervention and non-intervention groups. The contrasting results between these and the other studies might be due to the fact that the subjects in the other studies rated discomfort at the end of the day whereas in this study subjects rated their discomfort at the end of the eight week study period. Also the phrasing was different where in other the previous studies subjects were asked to rate level of discomfort in this study subjects were asked to rate level of recovery. Finally, the control group was more stringently managed in other studies whereas in this study the control group may or may not have taken discretionary breaks equivalent to the experimental group.

Crenshaw, Djupsjobacka, & Svedmark (2006) also looked at the effects of active versus passive micro-breaks in 15 female subjects. Subjects completed one 60 minute computer task painting rectangles on two occasions. The subjects took two 1 minute micro-breaks after 20 minutes of work. They extended their forearms repeatedly for the active break on one occasion and rested during the breaks on the other occasion. The researchers' findings looked at the extensor carpi radialis (ECR - a muscle in the forearm used to extend the forearm). There was also an overall increase in oxygen saturation in the ECR ($p<0.001$). However, there was no difference in EMG amplitude ($p=0.08$) and median frequency of muscle activation in the ECR ($p=0.05$). Subject ratings of fatigue in the ECR increased with time ($p<0.001$). Performance as measured by number of rectangles painted per minute showed no effect ($p=0.55$).

2.7 Vibrating Mouse Development and Design

The first vibrating mouse was developed in the Netherlands by Hoverstop B.V. because one of the company founders developed musculoskeletal problems. The original model is a standard shaped two button mouse with scroll wheel and was introduced in April 2005. Its main feature is a vibration that occurs after a mouse user keeps his or her hand on the mouse for 10 seconds without any activity. The vibration is designed to remind the user to remove his/her hand from the mouse, and it is assumed that this will allow shoulder, forearm and hand muscles to recuperate for a brief time. These micro-breaks are intended to be minimally distractive and allow users to maintain maximum productivity as they can continue to read and/or search for information on the computer screen while resting their upper extremity muscles (Hoverstop B.V.).

2.8 Vibrating Mouse Research

The vibrating mouse has been examined in a laboratory test (de Korte, de Kraker, Bongers, & van Lingen, 2005), and a field study with call-center workers (de Kraker, de Korte, van Mil, Rijs, & Bongers, 2006). These studies found that users did take more rest breaks when using the vibrating mouse than when using a conventional mouse, but also produced more hand removal and immediate return behavior (hovering). The subjects also found the mouse to be somewhat disruptive with averages around 6 out of 10 on a level of work disruptiveness scale where 10 equaled the highest level of disruptiveness to work. These studies examined user preference, number of rest breaks induced, and muscle activity with a limited range of users and computer tasks. The computer tasks in these studies consisted only of information retrieval tasks that would be most likely to induce a vibration when using the vibrating mouse. This limits the applicability of the findings to only those situations where computers are used for information searching and retrieval. Therefore the vibrating mouse needs to be evaluated in a wider variety of computer tasks to determine its effectiveness in promoting rest breaks and other aspects of its use.

2.9 Research Rationale and Hypotheses

The present study was designed to first determine under what conditions vibrational feedback would occur with the Hoverstop mouse. If it is to be implemented as a widespread ergonomic intervention to reduce musculoskeletal disorders, the vibrating mouse needs to produce break-taking behavior. However, to do this the vibrational feedback needs to be produced under a variety of conditions which would then in turn induce users to take micro-breaks from computer work. Conversely, the vibrating mouse would have very little effect as an ergonomic intervention if, while being used in a variety of conditions, vibrational feedback does not occur, thus producing no difference between the break-taking effects from the vibrating mouse and a conventional mouse. Secondly, the study was designed to explore the vibrating mouse's effects on user behavior, performance, work disruption, and discomfort, as compared to a conventional computer mouse, while subjects performed a wide variety of computer tasks.

The hypotheses tested in this study are as follows:

1. Users will remove their hands more often and take more rest breaks when using the vibrating mouse as compared to the conventional mouse.
2. Users will move their hands and rest them in a neutral position more often when using the vibrating mouse as compared to the conventional mouse.
3. Users' work performance will not be disrupted by the tactile feedback of the vibrating mouse.
4. Users will prefer to work with the vibrating mouse instead of the conventional mouse.

Chapter III. MATERIALS and METHODS

3.1 Pilot Study

A pilot study was conducted to determine the most appropriate tasks to include in the experiment. Several iterations of the pilot study, using three male and one female graduate student subjects, were used to determine the appropriate conditions under which maximum and minimum vibration feedback occurred from the vibrating mouse.

The results of the pilot study indicated that task design is crucial to mouse vibration activation. Therefore, a variety of tasks were developed for the experimental procedure based on potential for mouse vibration activation. The pilot study also showed that mouse vibration activation could potentially be related to user mousing technique, as one subject experienced no vibration regardless of task.

3.2 Main Study

3.2.1 Subjects

Subjects were recruited from the Cornell University community through fliers, e-mail and word-of-mouth. They were screened to determine that they were over the age of 18, used computer mice with their right hand, and had some experience using a computer mouse. As many of the experimental procedure tasks required proficiency in reading and writing English, participants were screened for this ability as well.

Eighteen subjects, eleven female and seven male, completed all sections of the experiment and all were paid for their participation. Ten subjects were between the ages of 18 and 24, five from 25 to 31 years and 2 were older than 32 years of age. They average 5.8 hours of computer use per day as primarily students or administrative staff.

3.2.2 Experiment Equipment and Conditions

The Human Factors and Ergonomics Laboratory at Cornell University was used to conduct the experiment. The laboratory air temperature averaged 27.8°C (82°F) as the experimental procedure took place during the summer. All subjects used an identical workstation that consisted of an ergonomic chair (Sitmatic Boss Task), an electronic adjustable table (WorkRite/LINAK), keyboard and mouse tray, Dell AT101W QWERTY keyboard and a Dell 19 inch flat-panel monitor (Appendix A).

Participants were allowed to adjust all aspects of the workstation including chair, keyboard tray and mouse position, monitor height and distance and table height, until they were comfortable.

A Dell conventional mouse and the vibrating mouse by Hoverstop B.V. (figure 3.3) were used. Both mice featured two buttons, a scroll wheel, and approximately equal dimensions. The Hoverstop mouse contains a small vibrating motor that starts to vibrate when the user’s hand is kept on or above the mouse for more than 10 seconds of inactivity. The vibration occurs for a maximum of four seconds.

Figure 3.1 Conventional Mouse (Left), Vibrating Mouse (Right)

3.2.3 Experimental Tasks

Two conditions were tested: conventional mouse and vibrating mouse. Five tasks for each condition were presented to subjects as Microsoft Word documents. Both sets of tasks (Appendices B and C) utilized similar text passages for editing and reading and were adapted from Cornell University's policy documents. The two sets of tasks contained identical numbers of errors and were very similar in length and difficulty level. Instructions, with examples, were presented as an introduction to each task. The first task consisted of seven misspelled words contained within three paragraphs of text. The Microsoft Word spell check function highlighted each misspelled word with a red squiggly underline. Subjects were instructed to select and correct each misspelled word.

The second task required subjects to locate three duplicate sentences contained within three paragraphs of text. Subjects then were instructed to select and delete each duplicate sentence. Five duplicate words were presented in three paragraphs of text for the third task. Subjects were asked to select and delete the duplicate words. For the fourth task subjects were instructed to read approximately 1.5 pages of text and then answer four multiple-choice questions presented at the end of the text. Subjects were allowed to scroll back through the passage to find answers to the questions. For the fifth task subjects were given a fictional business scenario and asked to compose a brief e-mail in response to the scenario. Overall each set of tasks was designed to take around twenty minutes to complete and subjects were instructed to focus on completing the tasks accurately.

3.2.4 Questionnaires

Subjects completed two questionnaires; both administered using a Microsoft Word document. The first questionnaire contained questions regarding demographic information, such as age, gender, amount of computer use time, and input device usage. They were also asked about the composition of tasks and input devices while using the computer, musculoskeletal problems and work break schedules (Appendix D). This questionnaire was administered after subjects were seated at the workstation, but before completing the tasks.

The second questionnaire (Appendix E) was administered after the tasks were completed to collect information about user preferences and changes in musculoskeletal discomfort during the experiment. Subjects were asked to respond to questions using a five-level scale regarding how disruptive the vibrating mouse was compared to the conventional mouse in completing each task. The next section of the questionnaire contained questions regarding user preference for the conventional mouse versus the vibrating mouse in terms of maximizing comfort, minimizing fatigue, and maximizing productivity. Subjects were then asked about the characteristics of the vibrating mouse such as whether or not they would like to be able to set the vibration interval. Finally, the last section contained a text box for subjects to contribute additional information about the vibrating mouse.

3.2.5 Procedure

The experiment was a repeated measures design so that each subject acted as his or her own control. Each subject completed a set of five tasks using either the control or vibrating mouse first, and then continued in the same session to complete an additional set of five tasks using the other mouse. Condition order and task order were randomly assigned and counterbalanced (Appendix F).

Subjects began the procedure by completing a consent form and then were assisted by the experimenter in adjusting the workstation to their comfort. Next, subjects were asked to complete the demographic and computer use questionnaire, which was administered via computer. Then subjects were given an overview of the experiment and were presented with the first set of tasks to complete. They were asked to complete each task to the best of their abilities with no time limit. Subjects were instructed to work as they normally would and were allowed to take breaks as often and as long as desired. Instructions were given verbally and presented on the screen and subjects were encouraged to ask questions for assistance and clarification.

Upon completion of the first set of tasks subjects were allowed a break while the experimenter switched mice which took approximately five minutes. Next, subjects completed the second set of tasks. After the use of the vibrating mouse, subjects were asked verbally by the experimenter to recall approximately the number of vibrations that occurred during the tasks. They were then asked to estimate during which task or tasks they received the most vibrations. The vibration activity data was collected utilizing this method so as to not disrupt subjects during the completion of the tasks, which would have altered normal working patterns and the results of the level of disruptiveness of the vibrating mouse. Responses were noted by the experimenter in a notebook along with additional relevant comments made by subjects.

After subjects were finished with both sets of tasks they completed the user preference questionnaire, which was also administered by computer. Subjects were videotaped during the procedure to collect data regarding posture and work behavior under the two conditions.

3.2.6 Data Analysis

Data from the two questionnaires was collected and analyzed using Microsoft Word and Excel computer programs and the VassarStats website (http://faculty.vassar.edu/lowry/VassarStats.html) was used to perform further statistical analysis. The completed tasks were printed and checked for errors, and this was used, along with time to complete each set of tasks, as a dependent measure of productivity. Time data was collected using video playback timing equipment.

The videotaped data was gathered by watching each user's video from the right side of their body, and the occurrence of each category of activity was recorded using a score sheet to count the number of occurrences of a specific work behavior and/or posture. The work behaviors are defined in Table 3.1 where a behavior was defined as being positive because subjects were resting in a neutral posture which would allow upper extremity muscles to recover from the computer work. Other behaviors were defined as negative because they showed insufficient or no resting time or exhibited static muscle loading. The fourth behavior, remove to go to keyboard, was defined as neither positive nor negative because this behavior was neither resting nor involved mouse work.

Table 3.1 User Behavior Definitions

User Behavior	Definition
Positive Behavior	
Resting	User removes hand completely from mouse and rests hand elsewhere in a horizontal, palm-down neutral posture for greater than 60 seconds.
Negative Behaviors	
Removed and Returned	User removes hand completely from mouse and immediately returns hand to mouse without resting elsewhere.
Hovering	User slightly removes palm and/or fingers from mouse. Palm and/or fingers are kept slightly above mouse or immediately returned to mouse.
Other Behavior	
Keyboard Action	User removes hand from mouse to utilize keyboard.

Responses to the question of which task produced the greatest number of vibrations were divided into three categories that represent typical computing tasks. The three categories were information searching which contained spelling and duplicate words and sentences tasks, reading, and composition.

Chapter IV. RESULTS

The data for the current study were collected from pre-and post-experiment questionnaires, video analysis to determine work behaviors, and direct interviewing during the experiment. Demographic data was examined to determine the test subject characteristics. The central aspects of the study focused on the conditions under which vibration feedback of the mouse occurred, the behaviors induced by that feedback and the subjects' impressions of those effects. Mouse usage was examined to determine the amount of vibration activity experienced by subjects, and the effects of this on productivity and work behaviors. The post experiment questionnaires collected data on the effects of the vibrating mouse regarding user comfort, fatigue, productivity, and characteristics of using the mouse including its disruptiveness to work performance.

4.1 Subjects' Computer Use

Eleven subjects use a laptop as their primary computing device, of these; seven use the touchpad rather than a mouse. No subjects reported currently using any break reminder technology. Six subjects estimated that they use the keyboard more than the mouse; five subjects estimated they used the keyboard and mouse device about the same percentage, while seven estimated they used the mouse more than the keyboard.

Nine subjects reported no history of musculoskeletal pain or discomfort while the other nine reported problems in the following areas (figure 3.1):

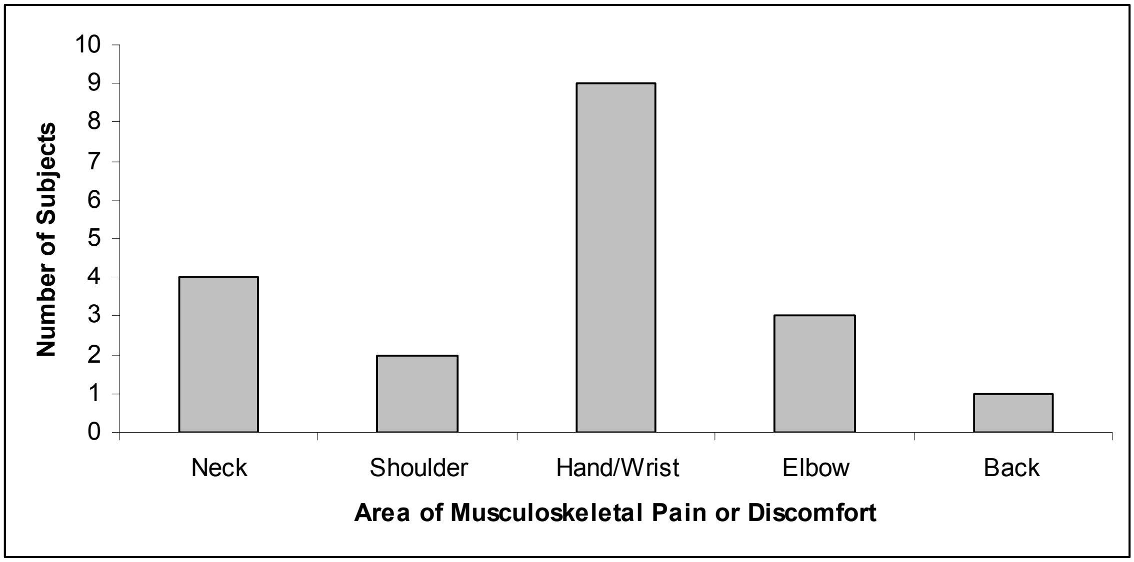

Figure 4.1 Subjects' Self-Reported Musculoskeletal Pain or Discomfort

Subjects report working extended periods of time at a computer without taking a rest break as shown the following chart (figure 3.2):

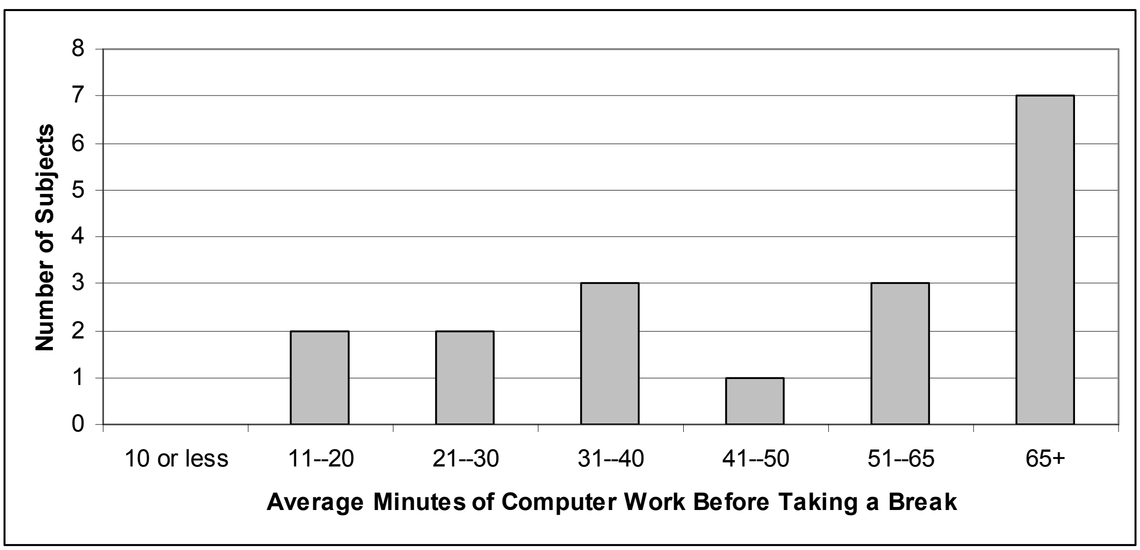

Figure 4.2 Subjects' Self-Reported Computer Time Before Taking a Break

4.2 Mouse Use Characteristics

4.2.1 Vibration Activity

After completing all tasks using the vibrating mouse subjects were asked by the experimenter to estimate the number of vibration occurrences they experienced during the test sessions.

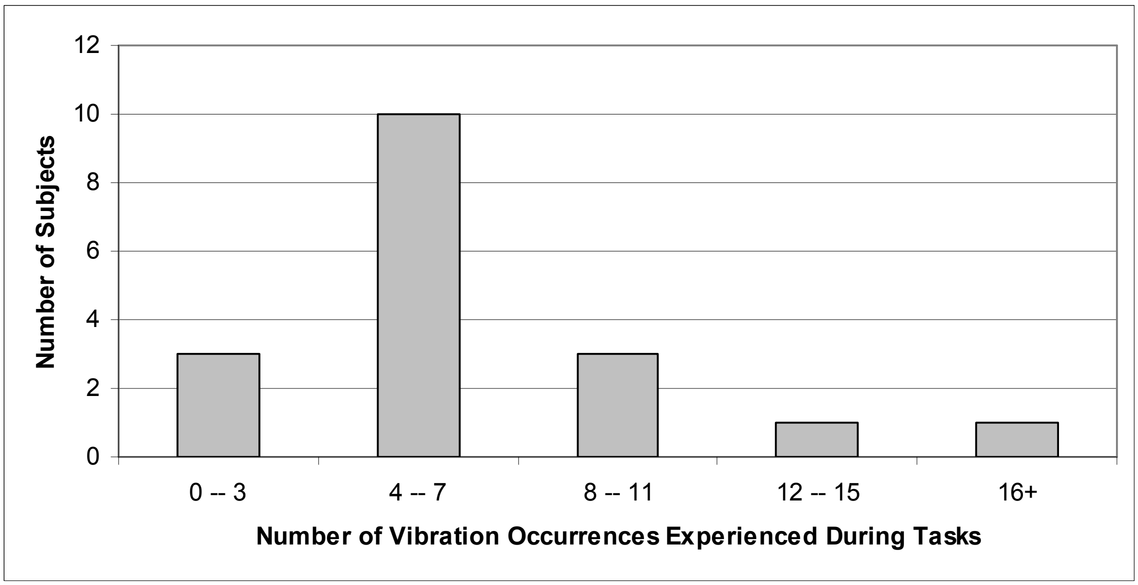

Figure 4.3 Range of Vibration Occurrences Experienced by Subjects

Immediately following their use of the vibrating mouse, subjects were asked during which task they experienced the most number of vibrations. Many subjects indicated experiencing the most number of vibration occurrences during two or three out of the five tasks and therefore responses were tabulated by adding the total number of mentions of vibrations for each task. Eight subjects reported experiencing the most number of vibrations during the reading task while nine subjects reported experiencing the most number of vibrations during the information searching tasks. Information searching tasks were defined as the spelling correction, duplicate word, and duplicate sentence tasks. No subject reported experiencing the most vibrations during the writing task.

4.2.2 Performance

Performance was measured by the total time taken to complete all tasks, the number of errors committed during the spelling correction, sentence and word duplication tasks, and the number of incorrect answers given to the multiple-choice questions as a part of the reading task. Tasks took nearly an identical amount of time to complete, 14.15 minutes for the conventional mouse condition and 14.47 for the vibrating mouse condition. A paired t-test was used but no effect of mouse type on total task time, $t(32)=-0.24$, $p=0.811$, was found. In total, one subject committed three errors and one committed two errors while no other subjects committed any errors during the spelling correction, duplicate sentence and word and reading tasks, therefore no statistical analysis of errors was conducted.

4.2.3 Work Behaviors

Subjects were videotaped during the experiment and the videotapes were analyzed to determine the number of occurrences of four relevant mousing behaviors exhibited by subjects upon feeling a mouse vibration during the experiment. Table 4.1 shows the number of times each of these behaviors occurred under the two conditions.

Table 4.1 Subjects' Mousing Behaviors

Behavior	Conventional mouse	Vibrating Mouse
Positive Behavior		
Hand completely off mouse and resting in neutral posture > 60 seconds.	36	68
Negative Behaviors		
Hand removed and immediately returned to mouse.	9	21
Hand slightly lifted from mouse (hovering).	5	31
Other Behavior		
Hand removed to utilize keyboard.	83	105

A Wilcoxon Signed Ranks test was used to determine the significance of the effect of mouse type on behavior differences. A significant effect, Z(-52) = -2.02, p = 0.02, was found for taking the hand completely off mouse and resting it elsewhere. A significant effect was also found for the hand slightly lifted from mouse (Z(-45) = N/A, p = 0.00). The hand removed and immediately returned to mouse was marginally significant (Z(-44) = -1.52, p = 0.06). The hand removed to utilize keyboard was not significant (Z(-49) = -1.52, p = 0.13).

Order effects, gender effects, and subjects who had experienced musculoskeletal discomfort in the past, were also tested using either a Chi-Square test or Fisher Exact Probability test. For resting behavior an order effect was found for those who used the vibrating mouse first then the conventional mouse (χ^2(1, n = 18) = 4.17, p = 0.04), but not for gender (χ^2(1, n = 18) = 2.72, p = 0.10), or MSD history (χ^2(1, n = 18) = 0.15, p = 0.70). No effects were found for gender, (Fisher 1-tail = 0.30, 2-tail = 0.39), order, (Fisher 1-tail = 0.34, 2-tail = 0.67), or MSD history, (Fisher 1-tail = 0.57, 2-tail = 1.00) for hand removal and return behavior. No effects were found for gender, (Fisher 1-tail = 0.24, 2-tail = 0.33), order, (Fisher 1-tail = 0.25, 2-tail = 0.35), or MSD history, (Fisher 1-tail = 0.61, 2-tail = 1.00) for hovering behavior and no effects were found for gender ($\chi^2(1, n = 18) = 1.41$, $p = 0.24$), order ($\chi^2(1, n = 18) = 0.14$, $p = 0.71$), or MSD history ($\chi^2(1, n = 18) = 0.01$, $p = 0.92$), for keyboard action behavior.

4.3 Subjective Measures and User Preferences

4.3.1 Disruptiveness to Work Performance

For the spelling correction task, four subjects reported the vibrating mouse to be more disruptive to performance than the conventional mouse, while thirteen reported the mice to be equally disruptive and one found the vibrating mouse to be less disruptive than the conventional mouse.

For the duplicate sentence task, eight subjects found the vibrating mouse to be more or significantly more disruptive to performance than the conventional mouse, eight found the mice to be equally disruptive and two thought the vibrating mouse was less disruptive than the conventional mouse.

For the duplicate word task, nine subjects indicated the vibrating mouse was “more” or “significantly more” disruptive than the conventional mouse, six indicated it was the same, while four indicated the vibrating mouse was “less” or “significantly less” disruptive than the conventional mouse.

For the reading task, eight subjects reported that the vibrating mouse was “more” or “significantly more” disruptive than the conventional mouse. On the same task, eight subjects reported the same level of disruptiveness for the two mice while four reported the vibrating mouse to be less disruptive than the conventional mouse.

One subject felt the vibrating mouse was more disruptive during the writing task than the conventional mouse, while fourteen found no difference in disruptiveness between the two mice and three subjects felt the vibrating mouse was significantly less or less disruptive than the conventional mouse on the writing task.

4.3.2 Comfort

Thirteen subjects would prefer to use the conventional mouse to maximize comfort, while four preferred the vibrating mouse and one indicated no preference.

4.3.3 Fatigue

Twelve subjects said they would prefer to use the vibrating mouse to minimize fatigue during computer work, while five would choose the conventional mouse, and one indicated no preference.

4.3.4 Productivity Maximization

Thirteen subjects said they would prefer to use the conventional mouse to maximize their productivity, four would choose the vibrating mouse, and one had no preference.

4.3.5 Vibrating Mouse Characteristics

A majority of subjects, fourteen, felt that the vibration was set at the correct level. Three reported the vibration as being too high, and one too low. Eight subjects reported the vibration as occurring too frequently, nine at the correct frequency, and one not frequently enough. All eighteen subjects indicated they would like to be able to set the vibration interval.

4.3.6 Musculoskeletal Discomfort

Two subjects reported neck discomfort during the whole experiment, one subject experienced shoulder discomfort, one subject experienced back discomfort, and eight subjects experienced hand or wrist discomfort during the experiment. Of those who experienced hand or wrist discomfort two also experienced elbow discomfort and one reported additional back discomfort.

Subjects were then asked whether the discomfort they experienced during the experiment was any different between the two types of mice. One subject with hand/wrist and back discomfort reported more discomfort with the vibrating mouse, one subject with hand/wrist and elbow discomfort reported more discomfort with the vibrating mouse, and one subject with back discomfort reported more discomfort with the vibrating mouse. In contrast, one subject reported more hand/wrist discomfort with the conventional mouse, while the remaining eight subjects indicated no difference in discomfort between the two mice.

4.3.7 Subjects' Comments

Subjects were asked to provide additional comments related to their experiences using the vibrating mouse.

Table 4.2 Subjects' Comments Regarding the Vibrating Mouse

My shoulder hurts from using a mouse at work, so the discomfort I felt didn't have anything to do with this study. The idea of a vibrating mouse to remind you to take your hand off from it to get a break is an interesting one. It's hard to know which one would make me more productive but the vibrating mouse was not that distracting.

Table 4.2 (Continued)

Vibrating mouse is annoying. It caused a disruption in train of thought and focus. It's also not a pleasant feeling. However, this may go away with time…it becoming a second- natured feeling. However, the vibrating mouse may be beneficial if used for a longer period of time at the computer. If vibrating mouses were provided as an option to be used with the computer based standardized tests (ex. GRE, MCAT, ect…), I would choose to use the conventional mouse.
After using the vibrating mouse for sometime, I sub-consciously learned to from time to time rest my hand on my lap or table when inactive, before the mouse even vibrated to inform me. That was kind of interesting.
Other than taking my hand off the mouse for about 1 second each time it vibrated, I did not use the vibrating mouse any differently than a conventional mouse. I wanted to get through the tasks and did not want to stop to take a break each time it vibrated.
Some of my discomfort may have been due to my overall position, not the mice.
The mouse never vibrated for me. I tend to use keyboard commands rather than the mouse in word processing and email programs. However, when I use the internet, spreadsheets or databases I use the mouse more. It may have kicked in if I was using one of those.
With only a 10 second interval, I found the vibrating mouse to be annoying and unnecessary. It seems that with a significantly longer time interval the vibrating mouse would serve a much better purpose.
Because I tested with the vibrating mouse first, I was more aware of not moving my hand when using the conventional mouse and compensated for that.
The two mice are pretty comparable, but the getting used to the slight shock was a little uncomfortable.
The vibration of the mouse was rather erratic in the sense that it did not seem to vibrate at regular intervals.
I do not know how much it might affect any outcomes, but I do not commonly use a conventional mouse, but rather the mouse button on my laptop, so I am plainly not used to the conventional mouse and computer setup.
The conventional mouse had a slightly more comfortable shape for my hand: it was a little fuller (especially on the sides) and more rounded.
Yeah, the mouse definitely disrupted my productivity; i think that the 10 second interval was a little too short. The vibrating mouse corrected my posture too, it kept reminding me to sit up right for some reason. Plus i was always anticipating the buzz. its actually really quite annoying, a lighter buzz would be nice.

Two subjects mentioned some sort of learning effect in that they learned to anticipate vibrations; two other subjects commented that the mouse was annoying while other comments highlighted behavior issues such as ignoring the vibration so as to finish the tasks as quickly as possible.

Chapter V. DISCUSSION

The purpose of the vibrating mouse is to remind users to take micro-rest breaks during computing work, which could reduce the risk of developing a musculoskeletal disorder. In addition the mouse is intended to do this with a minimum of disruption to work performance and productivity. The vibrating mouse is designed to accomplish these goals by giving the user a vibration after ten seconds of mouse inactivity. The user can then continue being productive by reading items or searching for information on the computer screen.

Vibration activity was examined in the current study to determine how often and under what conditions vibrations occur. This was the central focus of the current study, as no previous studies have examined this issue, and it is the basis upon which the effectiveness of the mouse was evaluated. The current study also examined work behaviors exhibited by subjects using the vibrating mouse. Increases were seen in hovering, a potentially harmful computer work behavior, with 600% more hand removals and returns with vibrating mouse than conventional mouse, and this agrees with previous research (de Kraker et al., 2006) that showed a significant increase in the rate of hovering behavior (frequency of hovering not stated).

No differences were found in performance and discomfort measures between vibrating mouse and conventional mouse conditions. These results are also similar to the results of previous research (de Korte et al., 2005; de Kraker et al., 2006). Users in the current study showed a preference for a conventional mouse over the vibrating mouse to maximize comfort (22%), a conventional mouse to maximize productivity (22%), but preferred the vibrating mouse to minimize fatigue (66.7%). These preferences are also similar to previous research where 35.7% of the subjects would like to use the vibrating mouse often in the future (de Korte et al., 2005) and another study (de Kraker et al., 2006) where 29.7% of subjects would prefer to use the vibrating mouse over a conventional mouse.

5.1 Vibration Activity

Vibration activity is critical to the study of the vibrating mouse as an effective ergonomic device because changes in user behavior are only going to occur if the vibrating mouse is actually producing vibrating feedback. This issue has not been specifically addressed in previous research. The results of the current study showed a wide variation in the number of vibration occurrences experienced by each subject, from 0 to more than 15 for the same set of tasks. The tasks in which vibration occurrences mostly occurred also varied widely. Eight subjects experienced the most vibration occurrences during the reading task and nine subjects experienced the most vibration occurrences during the information searching tasks. No subject reported experiencing the most vibration occurrences during the writing task.

The wide range in the number of vibration episodes experienced by subjects seems to indicate a large difference in subject behavior and in the mouse technique used to complete the experiment tasks. Subjects were not given any explicit training as to how to complete tasks so that subjects would complete tasks using their own working technique.

The results of the present study also indicate that task type is a strong determinant of vibration activity. No subject reported experiencing the most number of vibration occurrences during the writing task, despite the fact that subjects were observed actively using the mouse for cursor placement and word selection during editing. Task type was also shown to be an important factor in a previous study (Van den Ven et al., 2005) where hover time decreased from 57% during easy tasks to 46% of the time during difficult tasks.

In the current study task variety, not studied in previous research, was examined rather than task difficulty. The results showed subjects actively used the mouse during the reading and information searching tasks but experienced many more vibration episodes than during the composition task. This is likely due to the fact that users would spend time grasping the mouse waiting to find appropriate information during the information searching tasks or to click the down arrow and scroll down during the reading task.

It is possible that computer users are not able to anticipate when they next need to use the mouse during these types of tasks and therefore are more susceptible to holding their hand on the mouse in preparation for using it to scroll or click. These types of tasks might be the most effective type of task situation for the vibrating mouse to be activated, thereby reducing the static holding of the mouse and subsequently reducing the risk of musculoskeletal injury, depending on what the user with his or her hand.

5.2 Computer Work Behavior

5.2.1 Hovering Behavior

The developers of the vibrating mouse define hovering as a user holding his or her hand immediately above the mouse or maintaining his or her hand on the mouse while not actively moving the mouse. This definition is confusing and is particularly problematic as these two postures pose different risk factors for the development of musculoskeletal disorders. The user's hand could theoretically be rested on the mouse while not actively using it, but be held in a relaxed manner with little muscle activity or it could be grasping the mouse thus maintaining a stat muscle load. In contrast, under the same definition of hovering, a user could hold his or her hand and/or fingers directly above the mouse. This type of posture requires a great deal of static muscle activity and is the kind of activity that could possibly lead to a musculoskeletal disorder.

For the purposes of this study hovering behavior was defined as occurring only when the user's hand was held directly above the mouse which would create significant static muscle activity, thus increasing the risk of a musculoskeletal disorder, and a deviated wrist posture, which also increases the risk of developing a musculoskeletal disorder. The results of the current study show the vibrating mouse was actually responsible for an increase in this negative behavior (31 times with the vibrating mouse versus 5 with the conventional mouse, $p = 0.00$). This can be attributed to the fact that users would feel the vibration and respond by removing their fingers and/or hand and immediately return them to the mouse to continue working because they felt the need to finish the tasks. Had the vibration not occurred it is likely that the user would have continued to work without this behavior.

This finding corresponds to earlier studies (de Kraker et al. 2006) showing that the vibrating mouse significantly increased the rate of hovering behavior (exact figures not given, $p<0.03$). This is problematic because this type of hovering behavior creates static muscle loading, thus increasing the risk of developing a musculoskeletal behavior. It also creates a deviated wrist posture, another item that increases the risk of developing a musculoskeletal disorder. The researchers argue that this is a preferable behavior because it is working in a more active manner as opposed to a static work pattern. In both the current study and previous studies users were not given any instruction as to what to do when they received a vibration, but this should be included in future studies so as to determine what additional effects these instructions would have on subject behavior.

5.2.2 Rest Breaks

The results of the present study indicate that the vibrating mouse induced more rest breaks than the conventional mouse (68 times with vibrating mouse versus 36 with the conventional mouse). Previous studies have found a similar increase in the number of rest breaks taken with the vibrating mouse compared to a conventional mouse (de Kraker et al., 2006). In a study of a blinking light to remind users to take rest breaks, Henning, Jacques, Kissel, Sullivan, and Alteras-Webb (1997) found only a 45% rate of compliance with a blinking light break reminder. Micro-breaks could potentially be beneficial to the users of the vibrating mouse as studies on break reminder software have shown improvements in perceived recovery from musculoskeletal disorders (Heuvel, van den, Looze, de, Hildebrandt, & The, 2003) and increases in keying accuracy (Hedge, 1999; Hedge & Evans, 2001).

Time pressure may be an important factor as well. The vibrating mouse only reminds the user to take a break. The length of the break is at the user's discretion as opposed to break reminder software that promotes breaks of a specific length. As demonstrated by the current study, some users responded to the reminder by releasing the mouse for only a few seconds and immediately returning to the mouse. In total, subjects did this 21 times with the vibrating mouse and 9 times with the conventional mouse. These differences can possibly be explained by some users wanting to complete the task as quickly as possible, though they were instructed to focus on accuracy not speed. This concept is supported by research showing that subjects under time pressure demonstrate a change in work behavior (Sudhakaran & Mirka, 2005; Nicholas, Feuerstein, & Suchday, 2005).

During the course of task completion, subjects removed their hands more often to work on the keyboard with both the vibrating mouse (105 times), and the conventional mouse (83 times), than any of the other behaviors. This fact potentially demonstrates a greater impact for the specific requirements of completing a task as an influence on user behavior over the effects of the vibrating mouse. The tasks required users to delete items and this was frequently done by using the backspace or delete keys on the keyboard. Other tasks also required keyboard input and in order to use the keyboard subjects needed to remove their hands from the mouse whether prompted by the vibrating mouse or not. If computer users were completing tasks such as those in the current study they would not have their hand on the mouse long enough to receive a vibration because they would need to use they keyboard. This idea is supported by similar comments from de Korte et al. (2005) who note that vibration feedback would be "especially effective in computer tasks with intensive mouse use alternated with reading tasks and/or looking at the computer screen, such as browsing and searching databases".

While some musculoskeletal problems are associated with an increase in mouse use, (Jensen et al., 2002; Fagarasanu & Kumar, 2003; Cooper & Straker, 1998) it is not clear whether a mouse vibration that induces the user to use the keyboard rather than the mouse will be particularly beneficial because no studies have been able to link keyboard or mouse preferences to specific increases in a risk for musculoskeletal disorders because it may by that working with a keyboard and or a mouse places similar loads and injury risks on the musculoskeletal system.

5.3 Performance

Time and number of errors were collected in the present study to determine any effects of the vibrating mouse on performance. The results indicate that there were no effects of the vibrating mouse on performance. This result is consistent with earlier research on the vibrating mouse that also found no effects on productivity (de Korte et al., 2005; de Kraker et al., 2006).

Thirteen subjects reported that they would prefer to use the conventional mouse to maximize their productivity in general while only four would choose the vibrating mouse. This suggests that the vibrating mouse might be difficult to implement if users feel it is detrimental to their productivity. These results are also consistent with previous research on subjects' subjective rating of productivity (de Korte et al., 2005). In the study some subjects reported the vibrating mouse to be distracting and thus detrimental to productivity and only 57% estimate attaining the same level of productivity from the vibrating mouse as a conventional mouse. In another study 45.9% of the subjects reported working slower with a vibrating mouse than a conventional mouse, though 33.3% mentioned working slower in the control group (de Kraker et al., 2006). These results are also similar to previous work on break reminder software that showed improvements in productivity as a measure of keying accuracy (Hedge & Evans, 2001).

5.4 Work Concentration

One of the central aspects of the design of the vibrating mouse is the idea that the vibration is unobtrusive and therefore will allow users to maintain work concentration and not be interrupted during critical tasks unlike rigidly scheduled breaks that may adversely affect work performance by interrupting workers in the middle of highly demanding tasks (Henning et al., 1996). In the current study, 44.4% of subjects reported the vibrating mouse has been more disruptive to work concentration than the conventional mouse during the reading and duplicate sentence tasks, and 50% found the vibrating mouse to be more disruptive during the duplicate word task while the vibrating mouse and conventional mouse were found to be equally disruptive during composition and spelling correction tasks. These results are similar to a previous study where participants rated a vibrating mouse a 6.4 on a 10 point scale level of distraction as well as 6.4 out of 10 in agreeing with the statement that the vibrating mouse is irritating (de Kraker et al., 2006).

There are many possible explanations for why some of the subjects of both the current study and previous studies of the vibrating mouse found the mouse to be disruptive and irritating. It is not clear whether the degree of disruptiveness would be acceptable to users if the potential long-term health benefits of using the vibrating mouse were great enough to justify its implementation. There is no clear evidence as to whether users would adapt to disruptiveness over time; De Kraker et al. (2006) note some potential adaptation of facts at the end of the second week of using the vibrating mouse in a field study.

5.5 Conclusions

Vibrating mouse feedback has the potential to help with computer related musculoskeletal disorders by reminding computer users to take rest breaks. However, to be widely adopted the vibrating mouse should remind users to take rest breaks without being too disruptive or annoying. The current vibrating mouse may be too distracting for widespread application. Its application also appears limited to situations where the vibrating feedback would occur such as those that involve extensive reading or information searching. It also may be limited to users who do not actively use the mouse while doing these activities. Despite these limitations, the present study demonstrates that vibrating feedback as a reminder to take rest breaks may be an important characteristic of future computer input device design.

5.6 Limitations of Present Study

One of the most important aspects of evaluating the vibrating mouse is the condition under which a user receives a vibration signal. The current study was limited in this regard because it relied on the subjects to self-report an estimate of the number of vibration occurrences they experienced and the task which induced the most number of vibration occurrences. Subjects were not told to specifically keep track of the number of vibration occurrences so as to not add additional work disruption which would affect essential aspects of the study. More sophisticated technology linking vibration activity to user behavior would help in this regard.

The current study was designed to examine specific aspects of the vibrating mouse in a laboratory as the laboratory setting provided a way to limit extraneous variables. By performing the study in a laboratory, however, the results are limited to a short time period. The effects of the vibrating mouse on musculoskeletal disorders would likely be seen in a longer study. Two previous vibrating mouse studies have shown a difference between laboratory results and those of a field study (de Kraker et al., 2006; de Korte et al., 2005).

In the current study the emphasis was placed on examining a wide a variety of tasks rather than a variety of task difficulty levels. An emphasis on the latter would have had too many interaction effects to determine whether effects were due to mental loading or task type. For instance, time pressure could have been included to increase stress but was not. This allowed subjects to self pace work so that work style would be as close to normal as possible. This idea was demonstrated in the results showing different amounts of hovering rates in a previous lab study (de Korte et al., 2005) where users faced time pressure and a field study (de Kraker et al., 2006) where subjects did not.

The present study was conducted primarily in the afternoon and early evening due to scheduling issues. This variable was not a central component in the study but does limit the applicability of the results to those times of day. There is some evidence that time of day may influence rest break taking behavior as people in one study were more likely to take rest breaks in the afternoon (Boucsein & Thum, 1997). This is likely due to the fact that workers become more fatigued later in the day which is consistent with the body's circadian rhythm which follows this pattern of becoming tired in the afternoon (ibid.).

5.7 Future Research

Computers are used for a huge variety of tasks in the workplace ranging from composition and communication to information storage, analysis, and retrieval. While the current study expanded on previous studies by examining a wider range of tasks including information searching, composition, and editing tasks, this wider scope can now be used as a basis for a more diversified study. This study might look at task difficulty and stress in more detail so that recommendations can be made as to the types of tasks that would be most likely to induce a vibration from the vibrating mouse.

Field studies would allow further research to investigate the type of task that would be most likely to induce a vibration and also allow studying of the effects of the vibrating mouse over time. One field study has been conducted on the vibrating mouse, (de Kraker et al., 2006) but this study was limited to call-center workers. Call-center workers in the study primarily complete information searching tasks which have been demonstrated in the current study to be the most likely to induce a vibration. Field studies should be expanded to fields such as computer-aided design (CAD) where computer mice are intensively used for drawing input. This would provide a venue for more active mouse work than the information searching of call center workers. General office work, where composition and editing tasks are interspersed with information searching and retrieval tasks, would also provide a valuable format for a field study.

Reception to break inducements such as level of fatigue and time of day variables were not looked at in the current study because of an emphasis on other areas; these variables should be looked at in future studies to improve knowledge in the area of break inducement technology. Some studies looking at time of day and reception to break reminders (Boucsein & Thum, 1997) have demonstrated that time-of-day and fatigue (Chang, Johnson, Ibbotson, & Dennerlein, 2005) may be an important area to consider when forming proper work rest schedules as workers may be more receptive to break inducements and less likely to work through the vibrational feedback if they are more fatigued from more intensive work. Also they might not feel the feedback is as disruptive to work if they feel they need a rest break to combat afternoon fatigue.

There was an order effect found in the current study for subjects that used the vibrating mouse followed by the conventional mouse. These subjects showed more resting behavior while using the conventional mouse than those who used the mice in reverse order. This might demonstrate a training effect that could be useful if explored further.

The current study and previous vibrating mouse studies (de Korte et al., 2006; de Kraker et al., 2006) have demonstrated that intra-individual mouse and keyboard work methods are an important component in the amount of vibration occurrences experienced by users. More knowledge is needed in this area to help determine what type of users may benefit the most from the vibrating mouse. Some researchers have begun to develop the appropriate instruments examining the differences between how users operate simple computing tasks such as deleting items e.g. in navigating computer screen windows with keyboard arrows versus mouse scroll button versus window scroll buttons (Baker & Redfern, 2005). These tools could eventually be applied to vibrating mouse studies so as to help determine which work methods would benefit most from vibrating mouse break-reminder feedback.

APPENDIX A. Experiment Workstation

APPENDIX B. Task 1

1. Please correct the seven spelling mistakes in the following four paragraphs.

INVESTIGATION

Should the allegations, in the judgment of the Inquirer, warrant further investigation, s/he will refer the matter to the Dean of the college or the head of the appropriate administrative unit in which the subject is appointed, within thirty days of the completion of the Inquiry. Upon receiving such a report, the Dean or unit head will conduct an Investigation into the allegation. If the Dean or unit head has a real or apparrent conflict of interest with the case, the Provost will appoint a member of the professorial faculty to serve as the Investigator. An Investigation must be undertaken if the Inquiry finds that the allegation has substance.

The Inquirer will also notify the Vice Provost for Research and University Counsel of the upcoming Investigation. Before the Investigation begins but after the Inquiry ends, the Vice Provost for Research will notify sponsors of the affected research as required by sponsor regulations. The Vice Provost for Research may choose, in his or her discretion, to notify all sponsors of the individual(s) under investtigation. The Vice Provost for Research will seek assurances that information regarding the Investigation will be kept confidential by the sponsors. At this time, the Vice Provost for Research will also advise the Investigator of appllicable government regulations regarding the investigation of Academic Misconduct (see the "Government Procedures" segment of this document).

The Investigator will conduct a thorough examination and evaluation of all relevant information to determine if academic misconduct has occurred. The Investigator may designate an ad hoc committee, a standing committee, or other personnel to assist in the Investigation. The Investigator will ensure that perssonnel with the necessary and appropriate expertise are included in the Investigation, and that no person with a real or apparent conflict of interest is appointed to the Investiigation.

Should the Investigator be informed that the alleged incident will probably be publicly reported, s/he will notify the Vice Provost for Research if the allegations involve sponssored funds. During the course of the Investigation, the Vice Provost for Research will notify sponsors and submit reports as requiired by sponsor regulations.

2. The following three paragraphs contain three duplicate sentences, total, please delete them.

Whether or not the allegations involve sponsored research, should the Investigator become aware of immediate health hazards or the need to protect any individuals, funds, or equipment affected by the Investigation, s/he shall notify the Vice Provost for Research who shall undertake the appropriate interim actions. Should reasonable indications of irregularities in university or sponsor finances be found during the Investigation, the Investigator will notify University Audit. Should reasonable indications of possible criminal violations be found during the Investigation, the Investigator will notify the Vice Provost for Research and University Counsel within 24 hours. The Vice Provost for Research will notify sponsors of these actions or violations as required by sponsor regulations. The Vice Provost for Research will notify sponsors of these actions or violations as required by sponsor regulations. The Vice Provost for Research will notify sponsors of these actions or violations as required by sponsor regulations.

Should the Investigator uncover facts that 1) may affect current or potential sponsored funding for the individuals under investigation; or that 2) the research sponsors may need to know to ensure appropriate use of funds or to otherwise protect the public interest, the Investigator will promptly notify the Vice Provost for Research, who will notify sponsors of these facts as required by sponsor regulations.

A final written report, including the comments, if any, of the subject, will be submitted by the Investigator to the Inquirer. The final report will be made available to sponsors as required by sponsor regulations. The final report will be made available to sponsors as required by sponsor regulations. The Investigation should normally be completed within 120 days after referral by the Inquirer. If, based upon the report, the Inquirer concludes that academic misconduct has not occurred, the Investigation is terminated. In such case, the report of the Investigation will be maintained in the confidential file of the Dean of the Faculty for a period of three years, after which, the report will be destroyed. If, based upon the report, the Inquirer concludes that academic misconduct has not occurred, the Investigation is terminated.

3. Please delete the five duplicate words in the following three paragraphs. For example, delete the extra "the" in …explanation for the *the* delay.

Should the nature of the Investigation make it impossible to meet the 120 day time limit, the Investigator will prepare an interim report. This report will include an explanation for the the delay, a report on progress to date, an outline of what what remains to be done, and an estimated date of completion. The Investigator will supply this report to the Vice Provost for Research, who will submit the report to the sponsors, as as required by sponsor regulations.

If the Investigator decides to terminate an Investigation involving sponsored research for any reason, a report of the planned termination, including a description of the the reasons for the termination, will be submitted to the Vice Provost for Research. The Vice Provost for Research will notify sponsors of this decision as required by sponsor regulations.

DISCIPLINARY ACTION

The Inquirer may, at his or her discretion, either accept or modify the findings and recommendations and prepare findings or recommendations of his/her own. Before reaching a final decision concerning any any modifications, however, s/he will explain the rationale for the decision in a written communication to the Investigator and will consider the Investigator's response to those modifications.

4. Please read the following passage and answer the multiple-choice questions at the end.

FORMULATING AND APPROVING A POLICY

The need for new university policies and procedures may arise anywhere, but every policy must fall within the jurisdiction of a responsible executive. The responsible executive takes charge of contacting the University Policy Office to begin the formulation process.

The responsible executive will designate a responsible office, which is listed in the header of the written policy document. The responsible office will generally be the office that develops and administers the policy and procedures, and will be accountable for the accurate formulation, issuance, and timely updating of the document.

Under the direction of the responsible executive, and with the assistance of the University Policy Office, an individual from the responsible office who wishes to propose a new policy must:

1. Draft a Policy Statement, a Reason for Policy, and an impact statement.

2. Submit these documents to the responsible executive who will then submit them to the Executive Policy Review Group for review and preliminary approval.

Note: At the discretion of the CFO, it will be necessary to submit these documents to Senior Staff.

3. Obtain guidance from the University Policy Office, as to appropriate review processes, including input from groups such as the Faculty Senate, University Assemblies, etc.

4. Establish an editorial group to formulate the entire document using the standard format.

The purpose of the editorial group is to assure that each policy, along with its procedures, is clearly written using the standard format, is easily understandable to all who must comply with it, and is practical and applicable. The editorial group should consist of appropriate individuals who can provide a broad perspective on the content and application of the policy. Members of the editorial group may choose to contact the University Policy Office for guidance and assistance at any time during the editorial process.

The responsible office should arrange for the appropriate deans and senior administrators to review the policy during the editorial process.

5. When the editorial group has finished its work on a particular policy and procedures, the University Policy Office will distribute the draft policy to members of the Policy Advisory Group for review and recommendation to the responsible executive.

6. After Policy Advisory Group approval, the University Policy Office will distribute the document to the Executive Policy Review Group, where the responsible executive secures final approval, prior to issuance to the campus community.

Note: Concurrent with the process described above, existing university policies that are not yet in the standard format will be placed into this format, utilizing the procedures contained herein. For more information, contact the University Policy Office.

UNIVERSITY POLICY OFFICE

The University Policy Office is charged with defining and implementing an effective university administrative policy formulation, issuance, and cataloguing process. The office works closely with two standing university committees: the Policy Advisory Group (PAG), comprised of individuals with extensive institutional perspective representing the decentralized operating units of the institution; and the Executive Policy Review Group (EPRG), comprised of senior administrators and deans who give initial as well as final approval to each policy prior to its dissemination.

The University Policy Office maintains a web site that includes a complete list of all university policies, whether standardized or not. For more information, go to: http://www.policy.cornell.edu.

THE POLICY ADVISORY GROUP (PAG)

PAG reviews all policies and operating procedures arising from offices responsible for each policy and their respective editorial groups. PAG focuses on policy and procedural clarification and provides editorial input. The responsible executive office considers the feedback, recommendations and/or questions of clarification as the final draft is prepared for the Executive Policy Review Group.

PAG is made up of individuals from a broad section of central, college, and departmental administrative units. PAG will develop its own rules regarding conduct and operations.

The Vice President for Financial Affairs and University Controller must approve all appointments to the Policy Advisory Group.

STANDARD FORMAT FOR POLICIES

To ensure consistency, a standard format for policies was created. Use of the standard format facilitates the adoption of clear, concise policies and procedures at all levels of university organization. The first page of each policy carries the seal of the university.

INTERIM POLICIES

Responsible executives are empowered to issue interim policies through the University Policy Office in situations where a university policy must be established in a time period too short to permit the completion of the process delineated in this policy. Each interim policy will include only the Policy Statement and Reason for Policy, and may remain in force up to six months from the date of issuance. They may be extended as necessary.

Please check the box next to the correct answer regarding the previous passage.

1. Who takes charge of contacting the University Policy Office to begin the formulation process?

☐ policy adviser

☐ policy formulator

☐ responsible executive

☐ policy executive

2. What three documents are required when proposing a new policy?

☐ policy formulation plan, impact statement, policy recommendation

☐ impact statement, reason for policy, policy implementation plan

☐ policy implementation plan, reason for policy, policy advisory board roster

☐ policy statement, reason for policy, impact statement

3. After Policy Advisory Group approval, which group gives the final approval to a policy?

☐ Faculty Senate

☐ Executive Policy Review Group

☐ University Assembly

☐ Final Policy Group

4. According to the standard format, what must be put on the first page of each policy?

☐ The seal of the University

☐ The signature of the responsible executive

☐ The name of the office responsible for the policy

☐ The date of the policy

5. You work in the sales office of an automobile company and your supervisor would like to know the third quarter sales figures. Use the text box below to compose a one paragraph note that tells her what the figures were and gives an explanation for why they were up or down. The figures are as follows: blue cars were up 12%, red cars were down 15% and trucks were down 30%.

APPENDIX C. Task 2

1. Please correct the seven spelling mistakes in the following four paragraphs.

ACADEMIC POLICY

Members of the Cornell University community are expected to perform their scholarly and scientific activities with honesty, to meet the highest ethical standards, and to respect the facts, the appropriate standards of evidence, and the contrributions and scholarship of others. The university will vigorously investigate allegations of academic misconduct, taking all reasonable steps to protect the rights and interests of individuals whose work or performance is questioned.

The search for truth underlies our academic values as an educational institution. Academic misconduct on the part of any members of the Cornell University community threatens and subverts the fundamental values of the insttitution as a whole. Each member is expected to promote such standards of integrity in interactions with other scholars, and to participate in review procedures and disciplinary actions as may be appropriate in the case of reported violations of these staandards.

WHAT IS ACADEMIC MISCONDUCT?

Academic misconduct includes any act that violates the standards of integrity in the conduct of scholarly and scientific research and communication. This includes, but is not limited to, plagiarizing the work of others, i.e., intentionally or knowingly representing other people's words or ideas as one's own; deliberately fallsifying or fabricating data, citations, or information; forging academic documents; abusing the confidentiality of information obtained from colleagues or other persons; intentionally or knowingly helping another to commit an act of academic misconduct, or otherwise facilitating such acts; or other practices that seriously deviate from ethical standards that are commonly accepted within the scientific and scholarly communities for propossing, conducting, or reporting research. Academic misconduct also iincludes any form of retaliation against a person who, while acting in good faith, provides information about suspected or alleged misconduct.

All members of the Cornell University community are obligated to report suspected acts of academic misconduct. The initial report of such an allegation, whether on the part of a faculty member, a member of the staff, a student (including those with university appointments), or any other person with a uniiversity appointment, should be made to the Dean of the Faculty.

2. The following three paragraphs contain three duplicate sentences, total, please delete them.

Whether or not the allegations involve sponsored research, should the Inquirer become aware of immediate health hazards or the need to protect any individuals, funds, or equipment affected by the Inquiry, s/he shall notify the Vice Provost for Research who shall undertake the appropriate interim actions. Should reasonable indications of irregularities in university finances be found during the Inquiry, the Inquirer will notify University Audit. Should reasonable indications of irregularities in university finances be found during the Inquiry, the Inquirer will notify University Audit. Should reasonable indications of possible criminal violations be found during the Inquiry, the Inquirer will notify the Vice Provost for Research and University Counsel within 24 hours. The Vice Provost for Research will notify sponsors of these actions or violations as required by sponsor regulations.

A conclusion that an Investigation is not warranted requires a determination either that 1) the facts alleged, if true, do not constitute an act of academic misconduct, or 2) the Inquiry established that there is no reasonable cause to believe that academic misconduct has occurred.
In the event the Inquirer concludes that further investigation is not warranted, s/he will terminate the Inquiry. In the event the Inquirer concludes that further investigation is not warranted, s/he will terminate the Inquiry. In such case, the report of the Inquiry will be maintained in the confidential file of the Dean of the Faculty for a period of three years, after which the file will be destroyed.

Should the Inquirer decide to terminate an Inquiry involving sponsored research for any reason before its completion, a report of the planned termination, including a description of the reasons for the termination, will be submitted to the Vice Provost for Research. The Vice Provost for Research will notify sponsors of this decision as required by sponsor regulations. The Vice Provost for Research will notify sponsors of this decision as required by sponsor regulations.

3. Please delete the five duplicate words in the following three paragraphs. For example, delete the extra "shall" in …explanation for shall *shall* take.

CONFIDENTIALITY

All individuals who are involved in the complaint reporting and/or investigation process are obliged to maintain confidentiality of the proceedings. Throughout the Inquiry and Investigation of alleged academic misconduct, those conducting the reviews shall shall take all reasonable precautions, consistent with the need for a complete and comprehensive review, to maintain confidentiality and to protect the rights and legitimate interests of both the person making the disclosure and the subject(s) of the the review.

After the Investigation (or Inquiry, in the case where the Inquirer determines that no Investigation is warranted) has concluded, the Inquirer in concurrence with with the Vice Provost for Research may publicly release information regarding the findings of the Investigation if warranted by the circumstances.

The Dean or unit head will undertake diligent efforts to protect the positions and reputations of those persons who, in good faith, make allegations of scientific misconduct. When the allegations are not confirmed by the Investigation, or when the Inquirer determines that an Investigation is not warranted, the Dean or or unit head will also undertake diligent efforts to restore the reputations of persons alleged to have engaged in misconduct.

4. Please read the following passage and answer the multiple-choice questions at the end of the passage.

FORMULATION AND ISSUANCE OF UNIVERSITY POLICIES

Cornell University formally approves, promulgates in a consistent format, and centrally maintains all official university policies. People responsible for writing, updating, and distributing university policies must comply with the conditions and procedures that are outlined in this document, which defines a university policy, explains the standardized policy format, outlines the steps for formulating, approving, issuing, and amending policies and procedures, and describes the roles of the Policy Advisory Group and the Executive Policy Review Group.

University policies must be kept current, and made available electronically to all relevant operating units in a timely manner, to assure compliance with policy objectives and to establish the accountability of operating units and individuals affected by each policy.

WHAT IS A UNIVERSITY POLICY?

A university policy is defined by all of the following criteria:
- It has broad application throughout the university.
- It helps ensure compliance with applicable laws and regulations, promotes operational efficiencies, enhances the university's mission, or reduces institutional risks.
- It mandates actions or constraints, contains specific procedures for compliance, and articulates desired outcomes.
- The subject matter requires university president and/or executive officer review and approval for policy issuance and major changes.

All policies that meet the above criteria should be included in the electronic university policy library and are governed by this policy.

Many other important college or local operating unit policies and procedures do not meet all of the above criteria. They are not considered to be university policies and are not governed by this document. However, these local policies should be clearly written and well communicated. For more information, contact the University Policy Office.

Many policies adopted pursuant to the process set forth in this document are applicable to the Joan and Sanford I. Weill Medical College of Cornell University departments and divisions located in New York City. In addition, some university policies may also be applicable to the Joan and Sanford I. Weill Medical College of Cornell University in Qatar. The Section entitled "Entities Affected by this Policy," which appears on the cover page of university policies issued pursuant to the process covered by this document, states whether a particular policy applies to the Medical College units of the university. Other policies applicable to the Medical College departments and divisions are maintained by the Office of the Dean of the Medical College and Provost for Medical Affairs, the Associate Provost, the Dean of the Joan and Sanford I. Weill Graduate School of Medical Sciences of Cornell University, and, in some cases, the Medical College Office of the Secretary.

POLICY VERSUS OPERATING PROCEDURES

The prescribed format of a policy contains two sections, the "Policy Statement" and the "Reason for Policy." Operating procedures (or "procedures") are the means—sometimes simple, sometimes complex—by which policies are carried out.

For those who merely need to know the university's policy on a given question, the "Policy Statement" and the "Reason for Policy" on the first page of each document can easily be excerpted. However, the official versions of university policies will also include operating procedures. These policies are available on the World Wide Web at the University Policy Office website, at http://www.policy.cornell.edu. See the Flow Chart in the "Appendix" Section of this document for an explanation of how policies and procedures are formulated.

AMENDING A POLICY

From time to time, policies and procedures will need to be amended or updated. The responsible office is charged with keeping a policy up to date. Policies should be periodically reviewed and the need for amendment assessed. A detailed review should occur at least once every five years.
When changes are necessary to a university policy, the responsible office must contact the University Policy Office to determine whether the changes require the review and approval of PAG and EPRG.
Amendment of policies applicable to the Medical College units of the university should be directed to the Associate Provost or the Medical College Office of University Counsel.

The University Policy Office will make a broad university announcement of the availability of the policy and procedures on the World Wide Web. The announcement will include a brief explanation of the policy, the responsible office, and how to access the policy. The announcement will receive wide distribution utilizing the universitypolicies-l listserv.

Please check the box next to the correct answer regarding the previous passage.

1. Which office should be contacted for more information about local policies?

☐ Office of University Council

☐ Local Policy Office

☐ Policy Review Office

☐ University Policy Office

2. In addition to the *policy statement* and the *reason for policy*, what else is included in the official version of university policies?

☐ operating procedures

☐ policy protocol

☐ policy recommendations

☐ administrative policy procedures

3. Who is charged with keeping a policy up to date?

☐ University Assembly

☐ Executive Policy Review Group

☐ Responsible Office

☐ Final Policy Group

4. How often should a detailed review of a policy occur?

☐ at least once every three years

☐ at least once every two years

☐ at least once every four years

☐ at least once every five years

5. You work as a sales representative for a toy company. One of your customers would like information about the toy trucks your company sells. Use the text box below to compose a one paragraph note that tells her about the trucks. Include the following information: the trucks are red or green, the wheels are 2.5 inches in diameter, the price is $39.95. Try to convince her to buy one by telling her why it is better than your competitor's toy truck.

APPENDIX D. Pre-Experiment Questionnaire

Computer Use Questionnaire

You may skip any questions you do not wish to answer.

1. Age (check) ☐18-24 ☐25-31 ☐32-38 ☐38+

2. Dominant hand: (check) ☐Right-Handed ☐Left-Handed

3. Gender (check) ☐ Female ☐ Male

4. During a typical day, how many hours do you use a computer? hours

5. Which hand do you typically use to operate the mouse? ☐R ☐L

6. Aside from a mouse, do you use any other device for cursor positioning (such as a touchpad)?
☐no ☐yes, specify

7. Which type of computer do you most often use?
☐desktop ☐laptop

8. What percentage of your computer time is spent with each of the following applications?

e-mail internet word processing spreadsheet
presentation (PowerPoint) CAD other (specify)

9. During a typical day when using a computer, what percentage of time is spent using the mouse and what percentage of time is spent using the keyboard?
% keyboard use % mouse use

10. Have you experienced any musculoskeletal discomfort or pain in the following areas from using a computer mouse: (please check all that apply)
☐neck ☐none/never
☐shoulder
☐hand/wrist
☐elbow
☐back

11. On a typical day how often would you estimate you average using a computer before taking a break?
☐ 10 min.or less ☐ 11-20 min. ☐ 21-30 min. ☐ 31-40 min. ☐ 41 – 50 min.
☐ 51-65 min. ☐ more than 65 min.

12. Do you currently use any technology to remind you to take a rest break from the computer? ☐no ☐yes, (specify)

APPENDIX E. Post-Experiment Questionnaire

Post-Survey

Please feel free to skip any questions you do not wish to answer.

1. Compared to the standard computer setup how disruptive to completing the spelling task was the vibrating mouse? (check)

☐significantly less,☐ less,☐ the same,☐ more,☐ significantly more

2. Compared to the standard computer setup how disruptive to completing the duplicate sentence task was the vibrating mouse? (check)

☐significantly less,☐ less,☐ the same,☐ more,☐ significantly more

3. Compared to the standard computer setup how disruptive to completing the duplicate word task was the vibrating mouse? (check)

☐significantly less,☐ less,☐ the same,☐ more,☐ significantly more

4. Compared to the standard computer setup how disruptive to completing the questionnaire task was the vibrating mouse? (check)

☐significantly less,☐ less,☐ the same,☐ more,☐ significantly more

5. Compared to the standard computer setup how disruptive to completing the paragraph composition task was the vibrating mouse? (check)

☐significantly less,☐ less,☐ the same,☐ more,☐ significantly more

6. Which setup would you prefer to use to maximize comfort in your daily work?

☐Conventional mouse, ☐vibrating mouse

7. Which setup would you prefer to use to minimize fatigue in your daily work?

☐Conventional mouse, ☐vibrating mouse

8. Which setup would you prefer to use to make yourself most productive?

☐Conventional mouse, ☐vibrating mouse

9. How would you characterize the frequency of the vibration of the vibrating mouse?
☐too frequently
☐not frequently enough
☐vibration occurred at the correct level of frequency

10. How would you characterize the level of vibration of the vibrating mouse?
☐ too high, a smaller vibration would be noticeable enough
☐ correct level of vibration
☐ too low, a higher level of vibration is needed

11. Would you like to be able to set the vibration interval (how often a vibration occurs)?
☐ yes
☐ no

12. During the experiment did you experience any discomfort in the following: (please check)
☐ neck
☐ shoulders
☐ hand/wrist
☐ elbow
☐ back

13. If yes, did you experience any difference in discomfort between the two mice?
☐ yes, more with vibrating mouse
☐ yes, more with conventional mouse
☐ no, same level of discomfort

14. Additional comments:

APPENDIX F. Subject Condition and Task Order

Subject 1	A 1	B 2
Subject 2	B 1	A 2
Subject 3	A 2	B 1
Subject 4	B 2	A 1
Subject 5	A 1	B 2
Subject 6	B 1	A 2
Subject 7	A 2	B 1
Subject 8	B 2	A 1
Subject 9	A 1	B 2
Subject 10	B 1	A 2
Subject 11	A 2	B 1
Subject 12	B 2	A 1
Subject 13	A 1	B 2
Subject 14	B 1	A 2
Subject 15	A 2	B 1
Subject 16	B 2	A 1
Subject 17	A 1	B 2
Subject 18	B 1	A 2

A: Conventional Mouse
B: Vibrating Mouse

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