Fall 1-31-2017

Get a grip: Analysis of muscle activity and perceived comfort in using stylus grips

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ABSTRACT

GET A GRIP: ANALYSIS OF MUSCLE ACTIVITY AND PERCEIVED COMFORT IN USING STYLUS GRIPS

by
Evanda Vanease Henry

The design of handwriting instruments has been based primarily on touch, feel, aesthetics, and muscle exertion. Previous studies make it clear that different pen characteristics have to be considered along with hand–instrument interaction in the design of writing instruments. This should include pens designed for touch screens and computer based writing surfaces. Hence, this study focuses primarily on evaluating grip style's impact on user comfort and muscle activity associated with handgrip while using a stylus-pen.

Surface EMG measures were taken approximate to the adductor pollicis, flexor digitorum, and extensor indicis of eight participants while they performed writing, drawing, and point-and-click tasks on a tablet using a standard stylus and two grip options. Participants were also timed and surveyed on comfort level for each trial. Results of this study indicate that participants overall felt using a grip was more comfortable than using a stylus alone. The claw grip was the preferred choice for writing and drawing, and the crossover grip was preferred for pointing and clicking. There was reduction in muscle activity of the extensor indicis using the claw or crossover grip for the drawing and point and click tasks. The reduced muscle activity and the perceived comfort shows the claw grip to be a viable option for improving comfort for writing or drawing on a touchscreen device.

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by
Evanda Vanease Henry

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Occupational Safety and Health Engineering

Department of Mechanical and Industrial Engineering

January 2017

APPROVAL PAGE

GET A GRIP: ANALYSIS OF MUSCLE ACTIVITY AND PERCEIVED COMFORT IN USING STYLUS GRIPS

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This thesis is dedicated to those that have been there with me through thick and thin.

…To my mother, whose love and strength has guided me to grow into the woman I have become.
…To my father, whose memory is my inspiration for being a person that will change the world.
…To my sister whose candor and drive has pushed me to pave a way for her.

…To my brother for seeing the bright side in my many adventures.

…To my mentor, Bo, for getting me through the doubts and woes to push through to the finish line.

ACKNOWLEDGMENT

Foremost, I would like to express my sincere gratitude to my advisor Dr. Arijit Sengupta for the continuous support of my Master's study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my studies.

Besides my advisor, I would like to thank the rest of my thesis committee: Dr. Athanassios Bladikas and Dr. George Olsen, for their encouragement, insightful comments, and hard questions.

I thank my fellow classmates in the Occupational Safety Laboratory: Eman Asknew, Russell Brown, Stephanie Richmond, and Nashrah Shah, for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last few years. Last, but not the least, I would like to thank my family, especially my parents Curtis and Vivia Henry for having me and supporting me spiritually throughout my life.

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CHAPTER 1

INTRODUCTION

1.1 Background Information

With the integration of touch screen devices in the workplace, increasing number of employees use tablets or smartphones to read, view and edit documents that address the needs of their line of business (Cisco Systems, 2012). While the application of mobile devices in the workplace have a similar look and feel to the consumer devices already used by this population, they need to be engineered differently to meet the growing demands for productivity in a work environment. The variety of the use of these tools call for a combination of the intuitive handling of fingers and the accuracy of a writing instrument on the screen (Panasonic, 2013).

Mobile devices are ideal for workers that are expected to perform job tasks from commuting locations (e.g., healthcare professionals, field service engineers, educators, etc.). In these applications, stylus use is often relied on as a tool; a means of efficiently preforming tasks. Constant use of an improperly designed tool is uncomfortable for the worker may affect productivity, and can lead to musculoskeletal disorders (MSDs). MSDs are distinguished as conditions as a result of chronic overuse injuries to the affected soft tissues, in contrast to acute traumatic injuries following the near instant transfer of high energy. For the upper extremities, MSDs are often the result of repetitive motion for the tendons, excessive pressure on the muscle, and entrapment of the nerve (Lowe, 1997). The incidence of MSDs of the hand, wrist, forearm, arm, and neck has been increasing all over the world due to prolonged, forceful, low amplitude, repetitive use of mobile devices (Eapen, Kumar, & Bhat, 2010). Sustained gripping and repetitive movements of the thumb and fingers has been identified as risk factors that may lead to further disorders of the thumb and thumb musculature in the forearm. Studies have shown a relation between mobile design and anthropometry of the user in causing discomfort and fatigue of the hand, elbow, and shoulder while using a mobile device. Phrases have already been coined due to mobile device use such as “blackberry thumb”, “iPod finger”, “Wii injury”, “nintenditinits”, and “sms thumb” (Sharan, Mahandoss, Ranganathan, & Jose, 2014). The widespread use of this technology from private use to work related activities further increase the risk of suffering these types of MSDs.

Ergonomics is the study of fitting the job to the worker by understanding how human anatomy interacts with the physical environment during functional tasks. When possible, ergonomic arrangements should be adjustable, allowing workers of various anatomic proportions to modify the tool to fit the task demands (Foye, Cianca, & Prather, 2002). In the case of precision handling, the grasp pattern could contain additional adjustability among tool users. The grasp for precision tools is the same as the pencil grasp taught to school aged children.

Handwriting is an occupational performance that is mastered as school aged children. The motor planning that becomes automatic for children is then simultaneously used with cognitive skills as adults (Schwellnus, 2012). This is associated with the fine motor development of the hand, the writing tool used and the effect of stress placed on the writing instrument, as well as the speed at which writing occurs. When children have handwriting difficulties, the inefficient pencil grasp is one of the problems that teachers and occupational therapists regularly identify. Occupational therapists commonly use a plastic grip on the pencil as a therapy aide to adjust the pencil grasp and place the child's fingers in the natural physiological position for writing that would prevent cramping and enhance writing action. Early intervention with this aid can remediate handwriting difficulties among children (Smit, 2014). It can also be hypothesized that the use of these same aids by adults could remediate difficulties while using a stylus.

The design of handwriting instruments has been based primarily on touch, feel, aesthetics and muscle exertion. Kao (1976) has investigated the effect on handwriting quality of lead pencils, ballpoint pens and fountain pens. In two studies, Kao (1977; 1979) investigated the effects on writing time, writing pressure and writing efficiency of ballpoint pens, pencils, felt pens, fountain pens and of pen point shape variations. These studies make it clear that different instrument characteristics have to be considered along with hand–instrument interaction in the design of writing instruments. This should include pens designed for touch screens and computer based writing interfaces. In addition to the standard handwriting instruments, the design of the stylus may present additional discomfort when auxiliary controls limit its use to a few specific handgrips and pen rotations (Song, Benko, Guimbretiere, Izadi, Cao, & Hinckley, 2011).

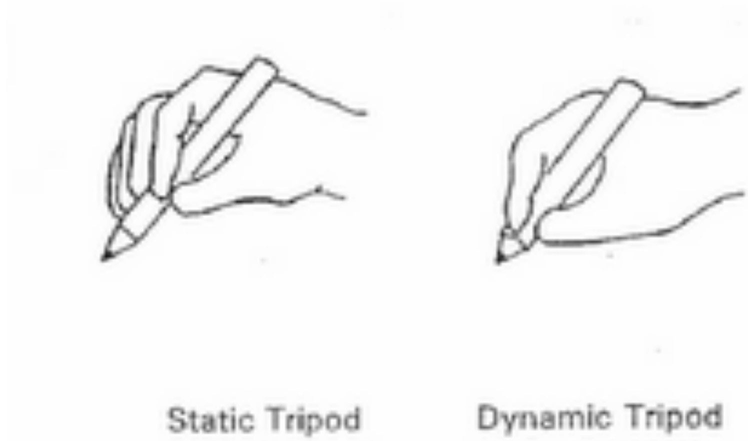

Figure 1.1 Illustration of two mature grasp patterns.

Note: The right illustration shows the dynamic tripod that consists of the ring and pinkie finger being tucked into the palm of the hand with the thumb and the index finger pinching the writing tool and the middle finger supporting the underside of the writing tool. The left illustration shows the static tripod grasp, which resembles the dynamic tripod in structure with the distinction of movement of the entire arm instead of individualized finger movements.

Source: Erhardt, R. P., & Meade, V. (1994). Handwriting: Anatomy of a Collaborative Assessment/Intervention Model. Stillwater, MN, USA: Pileated Press.

The 'dynamic-tripod', shown in Figure 1.1, is one of the most common ways to hold a writing instrument (Wu & Luo, 2006a) (Wynn-Parry, 1966). This is where the thumb, index finger and middle finger grasp the writing instrument so that they function together. Rosenbloom and Horton (1971) found that such a grip requires fine motor coordination. Callewaert (1963) described a grip where the writing instrument is held between the index and middle fingers with the wrist more canted was superior as the muscles would be more relaxed.

Handwriting performance appears to be directly affected by finger pressure on the writing instrument, point pressure of the writing implement on the writing surface, and the pressure of the hand on the writing surface (Bailey, 1988). High point pressure is related to high grip pressures (Herrick & Otto, 1961). It is generally understood that wider points of support for the hand are healthier and more ergonomic. When holding a stylus, the point of support for the user's hand is at the place grasping the stylus with the fingers. The smaller the point of support, the greater pressure the user must apply to hold the stylus. The greater the pressure, the more strain and discomfort the user experiences in their hand. Kurtz (1994) indicated that fingers should be fixed when holding a pen for writing to control for movements of the fingers that would affect writing quality. Pen designs that aimed to achieve the adequate points of support include a pen constructed in equilibrium with no net forces or torques (Mackenzie, 1994) and a five-point grip pen (Wu & Luo, 2006b).

Due to different hand sizes, pens or tasks pens are held in different ways. Styli are popular for digital tasks such as writing and drawing, due to their ability to leverage the fine precision of a pen tip and the dexterity of the user's hand. In addition to the fine control of a physical pen, the stylus also supports common interface tasks such as pointing and scrolling. It has been theorized that a pen of too thin diameter would negatively affect writing because not enough surface area would be available to properly control the pen, but a too thick pen would inhibit dynamic control (Wu & Luo, 2006b). The movements for writing involve control from the hand, wrist, and arm for two velocity generating oscillators in the horizontal and vertical direction (Longstaff & Heath, 1997). Wu and Luo also found the grip posture of drawing greatly differ from the posture of writing.

In the mechanics of drawing, the hand must sustain constant force to maintain pen stability. This posture is referred to as 'static tripod' and is characterized by shoulder movement, not finger movement. In this case, a pen of wide diameter would allow for additional finger contact and provide added stability while drawing. Conversely, for point-and-clicking tasks, finger movement does not rely on joint control, but instead relies on agile forward motion to click and a pinching motion to hold the pen at the upper end of its shaft. For tasks of this nature, thin pens are ideal because it provides the user with flexibility (Wu & Luo, 2006a). Other parameters of hand writing instruments have been studied for their effect on performance and efficiency:

- hand grip strength variations with grip size
- diameter, length and shape (Wu & Luo, 2006a)
- taper on the shank and the friction coefficient of the material used in the shank to reduce grip force (Udo, Otani, Udo, & Yoshinaga, 2000)
- penpoint shape (Kao, 1977)
- barrel shapes (triangular, square, elliptical, hexagonal, octagonal, circular) (Goonetilleke, Hoffmann, & Luximon, 2009)

Many studies have evaluated pens, but few have considered the unique task factors that apply to the use of a stylus. Wu and Luo have a series of studies that observed upper limb posture and pen characteristics while performing screen activities in order to design a touch pen. The studies consisted of three phases: observation, design, and evaluation.

During the first phase (Wu & Luo, 2006a), various lengths and diameters of styli were compared by the preference of subjects performing writing, drawing, and point-and-click tasks. The goal of this study was to provide a reference of the ideal dimensions for touch-pens for each task in order to help minimize discomfort and enhance efficiency and safety for users. The study population was university students, aged 25 to 31(mean age of 26.69 years) that used computers for at least 4 hours each day and had an average of 7.56 years (SD=1.86 years) of experience. This was a relevant population to study that coincides with reports that 50 percent of the mobile smartphone market is under 35 and over 60 percent of the under-35 demographic is touch-screen users (comScore, Inc., 2009). However, a strong demographic of 18-24 was left out of the study. This demographic is the fastest growing and largest user group of touch-screen devices. In particular, 86 percent of undergraduate students owned a smartphone in 2014 and 47 percent owned a tablet (Chen, Seilhamer, Bennett, & Bauer, 2015). A recent survey also shows that 50 percent of students report using smartphones or tablets to do daily schoolwork (Wright, 2013). This population could potentially be the age for early remediation of stylus use.

The experimental design of the Wu and Luo study (2006a) followed three fixed factors: touch-pen length, touch-pen diameter and gender. The gender was fixed by having a balanced number of males and females in the study. However, gender had no significant effect on the different lengths and diameters for all the performance measurements in the three screen tasks. The touch-pen lengths included three lengths (80, 110, and 140 mm) and the diameters included four diameters (5.5, 8, 11 and 15 mm). Numerous styli were purchased with the minimum length approximately 80 mm. This finding indicates that most styli are shorter than traditional pens. The performance times and number of errors found in the study for the stylus length of 80mm was found to be significantly inferior to the other lengths for all three tasks. To further explore the reason for the poor performance at this length, the hand breadth of the participants were analyzed to be an average of 81.77mm; which is close to the length of the 80 mm length stylus. The grips observed in the study were either one where the pen head was pushed up against the cleft of a user's thumb to counter act the torque of the stylus or the stylus was held in the palm with no contact with cleft of the thumb. In regards to biomechanics, when a short handle does not span the breadth of the palm the tool is difficult to hold (Stanton, 1998) and creates high forces at the center of the palm (Lewis & Narayan, 1993). Furthermore, the handle digs into the user's palm and obstructs the blood flow through the palm (Sanders & McCormick, 1993). The touch-pens with lengths 110 and 140 mm were suitable for use during the three tasks. Subject performance improved with increasing diameters for the drawing tasks, but had the opposite effect for the point-and-click task. The writing task was best performed with a mid-sized diameter. This indicates that the grip position of the digits on the pen handle differs specific to the task requirements.

The experimental results of this study showed that stylus length had a significant influence on performance during the three screen tasks. They also demonstrated that different size requirement were preferred depending on the task type. People can choose a suitable pen diameter based on the main activity of the task. For example, when using a PDA, a mobile phone, or a pen-based product, the main activity is pointing-and-clicking and writing. In this case, the ideal diameter size for combined tasks is 8 mm. However, if a person considers time and accuracy as the principal requirements for the pointing-and-clicking activities, then the recommended diameter is 5.5 mm. If one considers gripping comfort for writing, then the recommended diameter is 8 mm. It is also necessary to compromise in accordance with the various tasks being performed. The ideal diameter for combined tasks of pointing-and-clicking, writing and drawing is 8 mm. Additionally, for the drawing tablet device, the recommended diameter is between 8 and 15 mm.

In the second touch-pen study by Wu and Luo (2006b), the performance of a five-point grip pen (FPGP; Figure 1.2) was compared with the common touch pen for the same three tasks. The dimensions for the common stylus were 140 mm long with a diameter of 9 mm based on recommendations from the first phase of the study. The most common gripping method is a tripod grip, which uses four contact points: thumb, index finger, middle finger, and thumb cleft. The FPGP added a fifth contact on the normal pen below the thumb cleft to minimize unnatural gestures and slipping. The position of the fifth point is on the tough tissues of the thumb between the flexor pollicis brevis and adductor pollicis, and stretches across the thumb cleft.

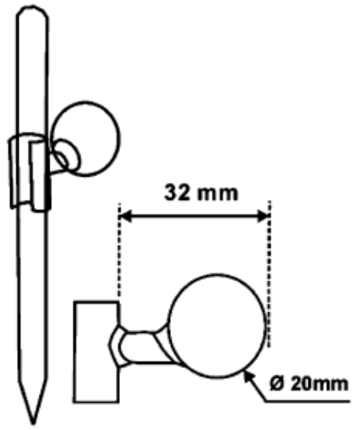

Figure 1.2 Illustration of the five-point grip pen.

Source: Wu, F.-G., & Luo, S. (2006). Design and evaluation approach for increasing stability and performance of touch pens in screen handwriting tasks. Applied Ergonomics , 37, 319-327..

It was observed that the subjects held the common stylus using unnatural gestures, such as lack of elbow and wrist support, and little finger support for each of the screen tasks. These behaviors were theorized in the study as a result of usage experience, variety of writing media (such as paper vs. screen), or the desire of users to avoid scratching or staining the screen during on-screen tasks. It was also observed that while holding the FPGP, the upper limb of users was more stable. Resultantly, the performance times were shortened for the drawing task. This result may be applicable to tasks needing higher accuracy or continuous freehand movements. Although the performance times were not shortened for the point-and-click and writing tasks with the FPGP, their error rates were reduced with the use of the tool. Correction posed for this tool from subject interviews was to provide smaller and larger sizes for the brace.

The third grip study by Wu and Luo (2006c)examined how the user handbreadth, brace shape and brace size of the FPGP affected the performance for the on-screen tasks.

It was expanded to include new braces in addition to the original to accommodate smaller and larger hand sizes. Three handle shapes were created for each size (ball-shape, ball-and-brick shape, and natural shape) (Figure 1.3). The purpose of this study was to answer three questions:

- Are the effects of user handbreadth, brace shape and size significant when using an FPGP?
- What brace sizes are suited to different handbreadths?
- Do different screen tasks require different brace sizes and shapes?

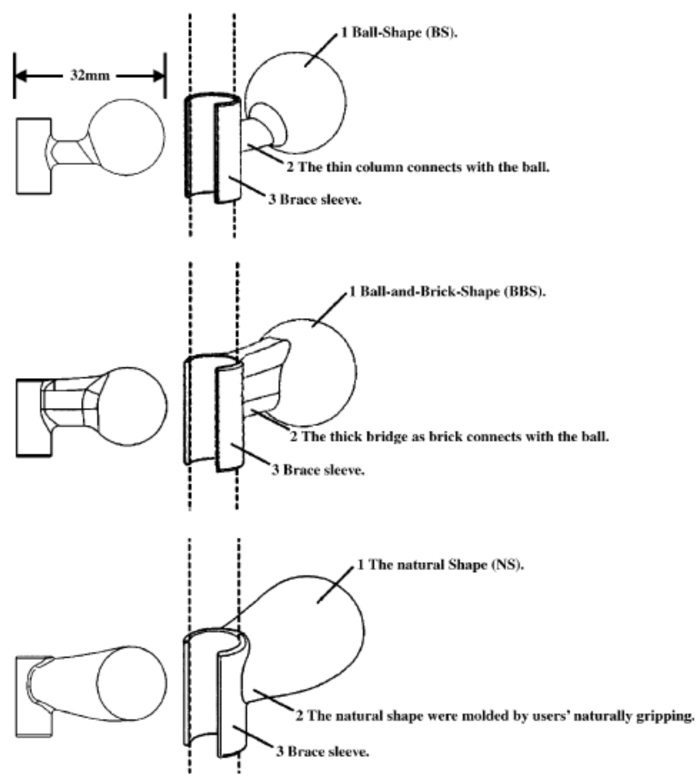

Figure 1.3 Illustration of the five-point grip pen. The three braces shapes used in the Wu and Luo experiment (ball-shape, ball and brick shape and natural-shape).

Source: Wu, F.-G., & Luo, S. (2006c). Performance of the five-point grip pen in three screen-based tasks. Applied Ergonomics , 37, 629-639.

The main effects of shape in each variable were significant for all three tasks. This was verification of a previous study (Stanton, 1998) that posed that handle shape of tools has the greatest effect on user performances. The examination of brace shape for all three tasks showed that the natural shaped braces were significantly superior to the other two shapes. The ball shape brace was inferior to the other shapes. It was concluded that the brace shape should be designed to aid gripping and the contour of the brace should match the shape of a user's hand. Their recommendation was for manufacturers to offer consumers a grip type of natural shape. The ball shape and the ball-and-brick shape were the worst, presumably because both shapes did not completely fit between the thumb and the index finger of a palm for entire support.

There was significant interaction between handbreadth and brace size in the performance time of writing and drawing a square, but not for other variables or tasks. For the writing task, the small brace was suitable for all four handbreadth groups; the medium brace was suitable only for the handbreadth group of above seventy-five percentile and the large brace was not suitable for any of them. For task of drawing, the large-and-medium brace were suitable for all groups while the small brace was not suitable for the handbreadth group of above seventy-five percentile. This outcome suggests that manufacturers should provide guidelines for those with smaller than normal or large than normal hands.

Test results also showed that the preferences of different brace sizes depended on the tasks and the handbreadth groups. This finding suggested that the small braces were preferred for performing tasks that required detailed operation in various directions and that the large braces were appropriate for tasks that required prompt or accurate position-based movements and stable tracing movements.

Through this series of studies it was concluded that the addition of a brace for support can reduce the error rates and performance times especially during the required prompt aiming or accurate position-based movements and stable tracing movements that require higher stability. However, these studies did not use or offer a commercial solution to address the need for improving task performance. This still leaves an unanswered gap of what tools are available to meet the task demands.

Even though handgrip variations have been extensively investigated for handwriting tools, few studies have considered these factors in the productivity, comfort, and muscle activity as they apply to the stylus. Wu and Luo (2006a) have mentioned that the diameter, length and shape of a stylus affect handwriting performance and efficiency without further investigating the effect of the style of grip. Other parameters that have been shown to have an effect on performance and comfort are the taper on the shank and the friction coefficient of the material used in the shank to reduce grip force (Wu & Luo, 2006a; Udo K. O., 2000).

1.2 Objective

In the studies that have been reviewed, there was little consideration of how the user intended to hold the stylus, which influences its effectiveness. Commercially available grips provide variations of grip features that alter the gripping style of the stylus. This study focuses on evaluating the impact of the grip feature on user comfort, productivity and muscle activity while using a stylus. Varied pencil grip styles act as a support brace while using a stylus for on-screen tasks. The objective of the work is to evaluate the perceived comfort, productivity and muscle activity for various commercially available pencil grips associated with common tasks performed with a stylus on a touchscreen device.

CHAPTER 2

METHODS

This study was designed to evaluate the perceived comfort, productivity, and muscle activity for various grips associated with common tasks performed on a touchscreen device. Participants of the study performed a writing, drawing, and point-and-click task for two grips with a common stylus to accomplish this. For a fair observation of muscle activity in this study we observed user activity of the adductor pollicis, flexor digitorum, and extensor indicis while writing, drawing, and point-and-clicking on a screen. These muscles were chosen based on gross motion and compressive forces involved in precision handling. Muscle activity is collected through each trial for three lower arm and hand muscles involved in digit manipulation while each participant is timed for each trial. Following each trial, participants are also immediately surveyed on comfort and usability.

2.1 Participants

This study involved eight right-handed New Jersey Institute of Technology students (5 female, 3 male, aged mean 25.3 years). All participants had no history of visual impairment or musculoskeletal disorder for the upper extremities. The participants ranged in age of 21-31 years and had an average time frame of 9 years of experience using mobile devices and less than one year of experience using a stylus on a touch screen device. The average amount of time daily that participants spend on their mobile device is 5.75 hours, with on average no time involving a stylus.

Prior to their workstation set-up, participants were informed that they will be performing in a study to perform three tasks on a touchscreen tablet and will be asked questions on their comfort performing each task. They were also informed of the placement of the electrodes for the study and the expected duration of their participation for consent to participate.

Prior to beginning the trials, the workstation was set for the individual and a maximum voluntary contraction (MVC) data were collected by the participant squeezing a pinch meter. The order of tasks performed was randomized. For the first trial for each task, the participants used a stylus without a grip to provide a baseline comfort level for each task. All of the following trials for each task were randomized.

2.2 Workstation Set-Up

Participants used either a tablet (iPad; Apple) with 9.56 in. by 7.47 in. display or smartphone (Galaxy 5; Samsung) with 5.59 in. by 2.85 in display for the study. The selection of either option was rotated between participants to maintain an even number of participants in each group. The tasks were performed at a desk, since typically handwriting instruments are used on a table with a sitting posture when not held for mobile use. Postures while standing or sitting without a table were not addressed. The tablet was placed flat on the desk to reduce additional strains on the wrist and hands. For each user the table surface height was adjusted to elbow height and their chair was adjusted to have their feet resting on the floor while their knees were at a 90-degree angle.

2.3 Writing Instruments

Based on the findings from the Wu & Luo studies (Wu & Luo, 2006a), a length of 110mm-140mm and diameter of 8 mm were recommended for the dimensions for a stylus for all three touchscreen tasks, point and click, writing and drawing. A commercially available pen-stylus (StylusPen; Zebra) was selected for this study. It was designed for dual use as a pen as well as a stylus. The grip was attached to fit facing the stylus side of the pen. The stylus used in the study measures to 13.716 cm in length, 8 mm in diameter and weighs 0.64 oz. Three identical styluses were used, each having a different grip attached to it (Figure 2.1). Each participant randomly performed the tasks and was randomly assigned the grip order for each task while using the stylus.

Figure 2.1 Photo of the styli used in the study.

The order in which the grips were used to perform the subsequent sets of tasks was randomized, by using an online randomizer (www.researchrandomizer.com) for each participant. The grip options used were a claw grip and crossover grip (Figure 2.2).

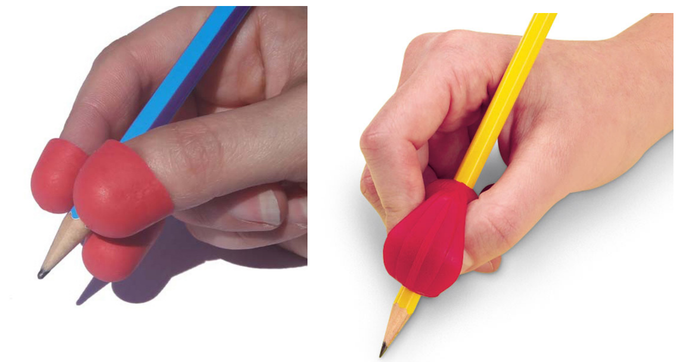

Figure 2.2 Photos of the pencil grips used in the study. The claw grip on the left and the crossover grip on the right.

Source: Bernell. (2016). CLAW. Retrieved October 12, 2016, from Bernell: http://www.bernell.com/product/CLAW/Home-VT; Nasco. (2016). The Pencil Grip Crossover Grip. Retrieved October 12, 2016, from eNasco: https://www.enasco.com/product/SN02859CQ/

The claw pencil grip (Classic) is made of three small, flexible cups that the fingers fit into. In the middle is a space to place the stylus. The cups ensure that the fingers stay in the tripod grasp the entire time the instrument is held. The markings on the underside of the "finger cups" were shown to the participants to ensure proper placement. Based on the manufacturer description of the Writing Claw, the grip builds a positive habit and produces improved handwriting and control. The grip weighs 0.8 ounces and the dimensions are 1.5 x 0.9 x 1.5 inches.

The crossover pencil grip (The Pencil Grip) is a tripod pencil grip with an additional flap on the top to prevent fingers from crossing over the top. The shape of the body of this grip supports the first knuckle of the pointer finger while promoting a proper thumb position that encourages large muscle use instead of use of the fingers for moving the writing instrument. This grip was added because it prevents the thumb-wrapping grip that the previous grip options do not address. Response from a phase one participant indicated that thumb wrapping occurred for them when performing tasks at the 45 degree screen angle used in that study. The additional flap on the crossover grip prevents wrist position change that would occur when the fingers wrap around each other. This grip weighs 1.6 oz. and the dimensions are 1.27 cm x 1.27 cm x 5 cm.

2.4 Tasks

Writing, pointing-and-clicking, and drawing are typical screen handwriting tasks. Each participant performed these three tasks using three writing instrument options (two grip options and a standard stylus without a grip) on a touch screen device. These tasks were adopted from the Wu and Luo (2006) studies. For each task, three dependent variables were recorded: (1) the total time taken to complete the task, (2) the EMG measurement, and (3) the surveyed response of participant's perceived comfort. Recording of the timing and EMG were started when the recorder verbally cued the participant to place the stylus on the screen.

2.4.1 Drawing Task

Three common geometric figures (a circle, square, and triangle) were pre-drawn onto the tablet screen to serve as a tracing route for the drawing tasks (Figure 2.3). The participants followed the lines from left to right to draw the figures. The timing and EMG measures were collected until all three figures were completed.

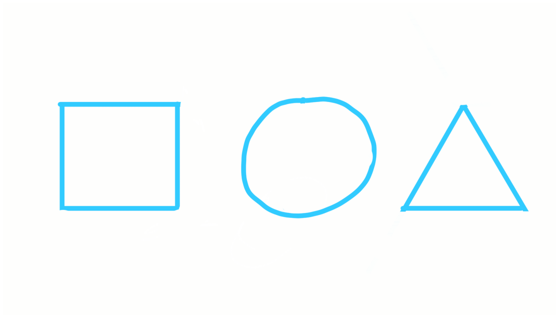

Figure 2.3 Screenshot of the geometric figures traced for the drawing task.

2.4.2 Point-and-Click Task

Eight round targets were arranged in their fixed positions in an area of 9.7 inches on a tablet with 1536 x 2048 pixel resolution or cell phone with 1080 x 1920 pixel resolution (Figure 2.4). To reduce subject familiarity with the target positions, targets were made wide enough for multiple points. The target positions covered all the possible positions on the screen. Before starting the trials, participants were asked to start pointing from the target at upper left corner of the screen. The researcher cued the participant to start while starting the biometrics program. The participants pointed into the target traveling from left to right down the screen. Each participant had to hit all 8 targets completely for each trial. Thus, the total moving distance and target area can be seen as constants.

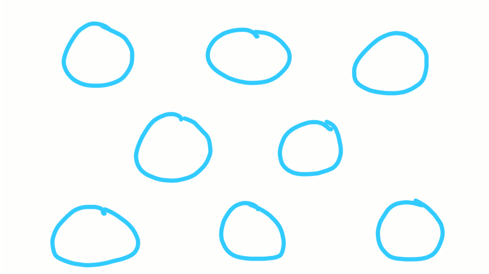

Figure 2.4 Screenshot of the point-and click arrangement.

2.4.3 Writing Task

In performing the writing task each participant wrote the sentence "The quick brown fox jumps over the lazy dog" because it is a sentence that incorporates all the letters of the English alphabet. A sheet with the sentence was placed in front of the participant to read before the task and refer to during the task. Participants were provided with a blank page on the tablet to write the sentence in front of him/her. The researcher cued the participant to start writing while starting the EMG data collection. The participant verbally and visually indicated he/her finished the sentence by saying done and placing the stylus down.

2.5 Survey

Prior to starting the experiment, participants reported their demographics, age, gender, dominant hand, and history of touch screen usage. For measuring the perceived comfort of the participants a Likert-type scale was used. Likert-type scales use fixed choice response formats designed to measure attitudes or opinions. The Likert Scale was used in this study because it is one of the most common rating scales for measuring attitudes directly. In order to measure attitude, it is assumed in this type of scale that the strength of comfort is linear; on a continuum from strongly agree to strongly disagree.

Respondents in the experiment were offered a choice of five pre-coded responses with the neutral point being neither comfortable nor uncomfortable (Figure 2.5). After each participant completed a trial they were asked to score their perceived comfort level on a Likert-type scale of one (very uncomfortable) to five (very comfortable). After completing the experiment the participants were asked to select their most comfortable grip option for each task.

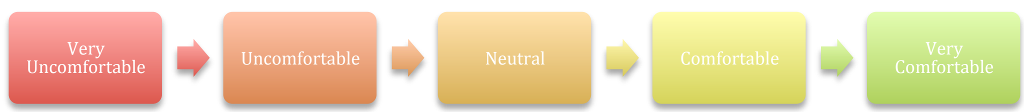

Figure 2.5 Likert scale of perceived comfort.

2.6 EMG Measurement

The electromyography data for this study was collected using biometric data logging EMG system by Biometrics Limited. Bipolar surface electrodes were placed on the adductor pollicis, flexor digitorum, and extensor indicis for each of the participants (Figure 2.6). The precision grip for holding a stylus involves positioning the stylus where the hand, wrist, and arm are controlled by the long flexor and extensor muscles, and the intrinsic muscles of the hand perform fine movements of the digits.

Figure 2.6 Photo of electrode placement.

The tripod grip we use when we hold a pen is formed by distinct positioning of parts of the hand: (1) the thumb is brought into opposition with an index and a middle finger that are flexed at the metacarpophalangeal joint, slightly flexed at the proximal interphalangeal joint, and extended at the distal interphalangeal joint. (2) The ring finger and little finger are also flexed at the same joints, and lie against the writing surface when the hand is writing to provide support and a foundation for the movements of the middle and index fingers (KenHub, 2016).

During the execution of a functional task, the adductor pollicis pulls on the base of the proximal phalanx in an ulnar and ventral direction to draw the 1st metacarpal laterally to oppose the thumb toward the center of the palm and rotate it laterally. As the pinching on the stylus increases, the adductor pollicis muscle activation increases. The surface electrode was placed over the trigger point along the length of the muscle to capture the central location for muscle activation (Figure 2.7)

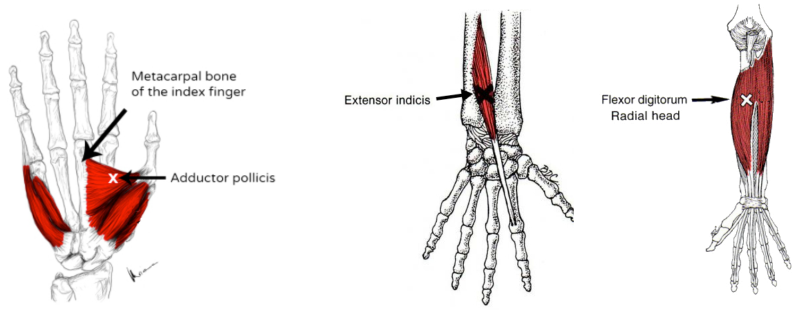

Figure 2.7 Trigger points for the adductor pollicis, extensor indicis, and flexor digitorum.

Source: www.paintopia.com. (2013). Opponens and Adductor Pollicis Pain and Trigger Points. Retrieved October 23, 2016, from Paintopia: http://www.painotopia.com/adductor-pollicis.html; MyoRehab. (2014). Extensor Indicis. Retrieved October 23, 2016, from The Trigger Point & Referred Pain Guide: http://www.triggerpoints.net/muscle/extensor-indicis; MyoRehab. (2014). Flexor Digitorum Superficialis. Retrieved October 23, 2016, from The Trigger Point & Referred Pain Guide: http://www.triggerpoints.net/muscle/flexor-digitorum-superficialis

The extensor indicis (Figure 2.7) is a long, thin muscle in the forearm that stems from the back of the ulna. The key role of the extensor indicis is to enable the extension of the index finger (Kerkar, 2015). The flexor digitorum (Figure 2.7) is a muscle within the forearm that allows the four medial fingers of the hand (index, middle, ring, and pinkie) to flex. This muscle has two distinct heads: (1) the humeroulnar head and (2) the radial head (Healthline Medical Team, 2015). The electrode was placed over the belly of the radial head to capture EMG distinct for the index and middle fingers. The secondary role of this muscle is to flex the metacarpophalangeal joints (MCP). The MCP flexes to adapt to the shape of the object in the grasp. Increased flexion of this muscle indicates locking of the collateral ligaments to reduce abduction and rotation (Bain, Polites, Higgs, & Heptinstall, 2015).

The extensor indicis and flexor digitorum were determined by having the participant move their index finger for their dominant hand while the area was palpated for contraction. The electrodes were placed lengthwise to the located contraction. The ground was placed on the wrist of the same arm being measured. The analog output was set to 100 mVolt at a sample rate of 1000 per second and an excitation output of 4950 mV.

Surface Electromyography (EMG) was used in this study to measure the muscle activity of each participant as they performed all of the trials. EMG data was collected and analyzed by DataLog PC software Version 2.00 (Biometrics Ltd.) through DataLog Base Unit connected to an active EMG electrode with sampling rate of 1000 data/second and sensitivity of 300mV. Bipolar surface electrodes (Biometrics type SX230) were placed approximate to the adductor pollicis, extensor indicis, and flexor digitorum for each of the participants. The sensor circuitry employs a differential amplifier with common mode rejection ratio of greater than 96 dB and very high input impedance of the order of 10^{15} ohms. The amplified data passes through a high pass filter to reduce motion artifacts and a low pass filter to remove unwanted frequencies above 450 Hz.

Prior to placement of the electrodes on the skin, the skin of the hand (palmar side) and forearm was cleaned with an alcohol wipe and electrolyte gel was applied on the electrode to reduce the electric resistance at the electrode-skin interface. The electrodes were placed lengthwise to the located contraction. The ground was placed on the wrist of the same arm being measured. The analog output was set to 1 V and 1000 Hz. The maximum voluntary contraction (MVC) was determined by having the participants squeeze a hand dynamometer for 30s. Individual recordings were taken for each trial in sync with timing of the trial.

The raw EMG data were corrected for zero shift and rectified. The 1-3s of the recording for each drawing and point-and-click task was used for calculating the average EMG and for determining the peak value for each drawing and point-and-click trial. The 7-10s of each writing task was used for calculating the average values and determining the peak value for each writing trial.

2.7 Statistical Analysis

The information collected was coded into a spreadsheet (Microsoft; Excel) and then analyzed by the Minitab statistical software. Descriptive statistics (i.e. mean and standard deviation, percent) were utilized to delineate the perceived comfort, performance time and EMG measurement between the grip options and the stylus alone.

The measurements from grip styles were compared to determine any differences. The EMG data were normalized for each participant with respect to his or her EMG data for stylus only measurements. The normalized EMG measurements and surveys were analyzed with paired sample t-tests. The change in performance time from the stylus alone to the grip options was also analyzed to determine if any changes were significant.

CHAPTER 3

RESULTS

The experimental data for the individual participants are attached to the Appendix. The average perceived comfort scores, in a scale of 1-5 for drawing, point and click, and writing tasks using the tree tool options are presented in Figure 3.1. The averages of the time taken in seconds, to complete the three tasks are presented in Figure 3.2. The normalized percent EMG scores for the two grips with respect to no grip for the three muscle groups are presented in Figure 3.3, 3.4 and 3.5 for these three tasks. None of the grip options produced a statistically significant ($p < 0.05$) difference. The following sections discuss the experimental results and analyses for drawing task, point and click task, and writing task.

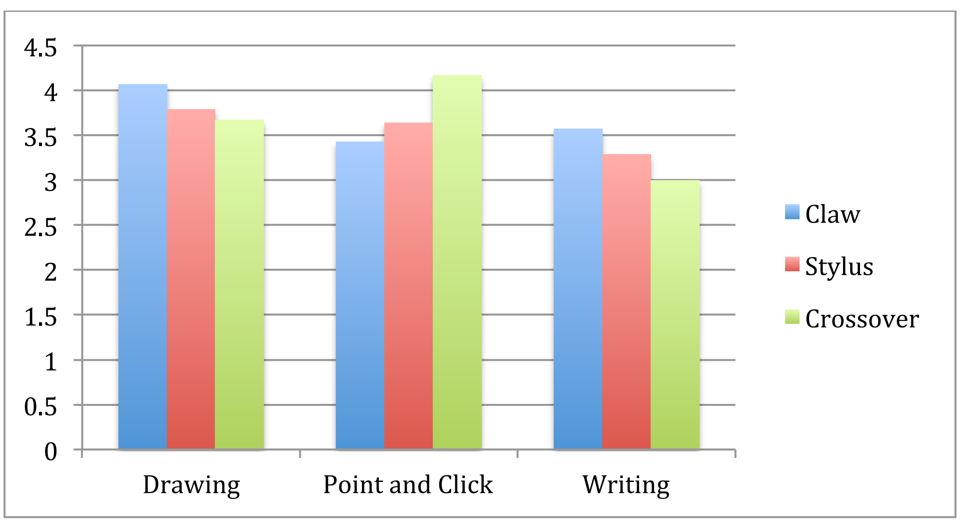

Figure 3.1 Average perceived comfort score for touchscreen tasks using tool options.

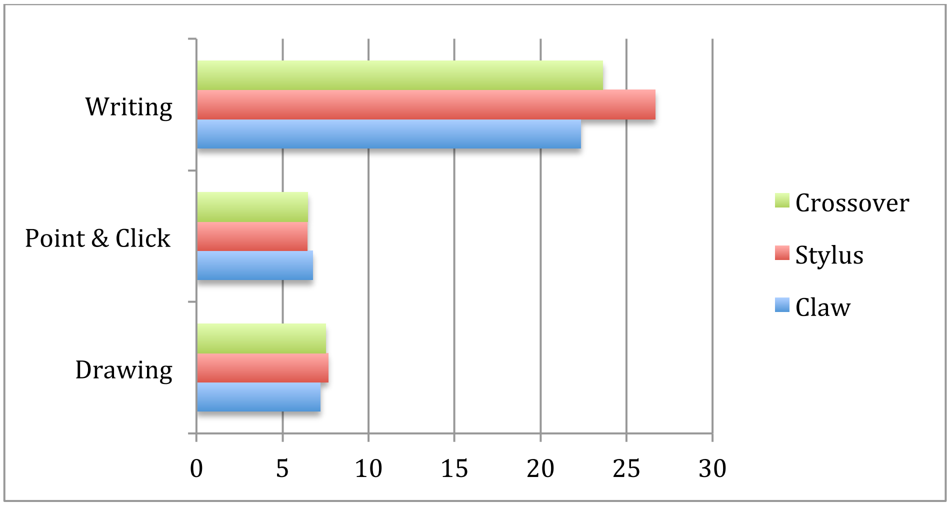

Figure 3.2 Average time span for touchscreen tasks using tool options.

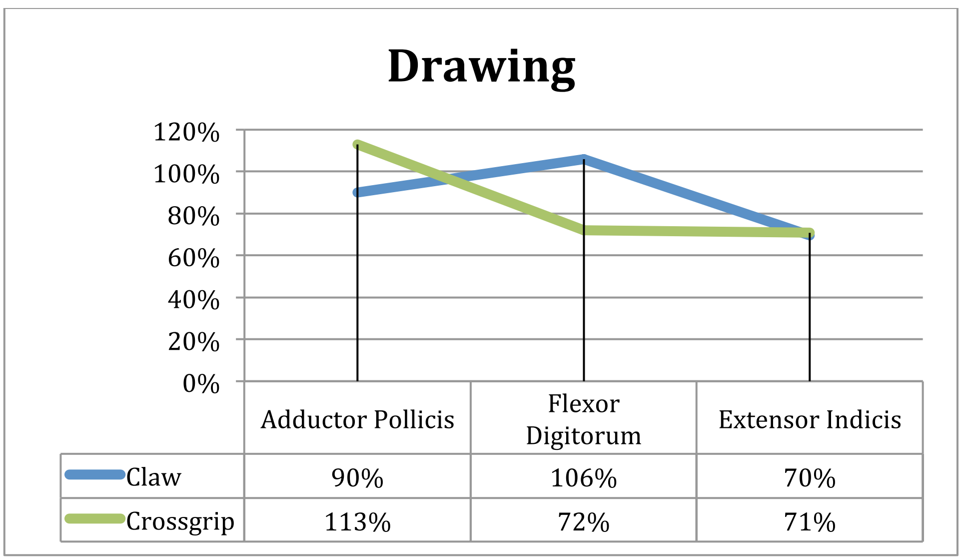

Figure 3.3 Muscle activity of grips for drawing relative to the average EMG for stylus.

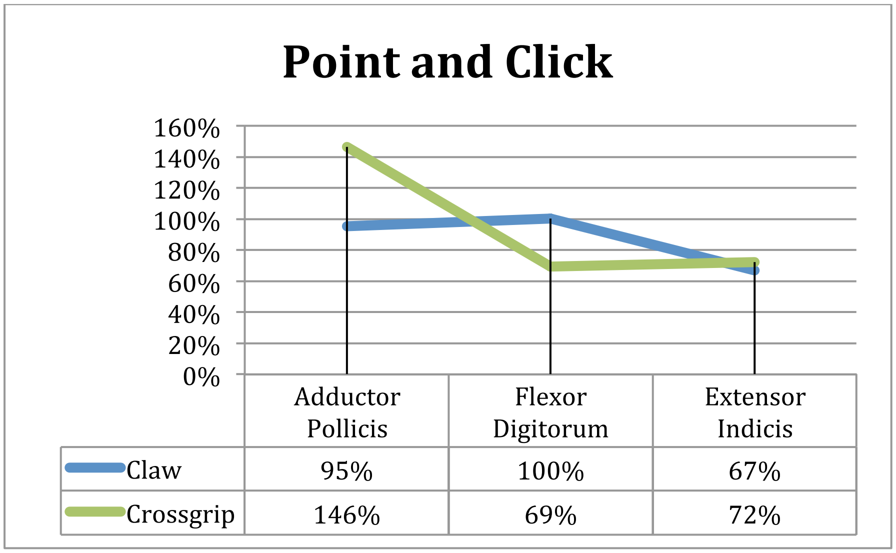

Figure 3.4 Muscle activity of grips for pointing and clicking relative to the average EMG for stylus.

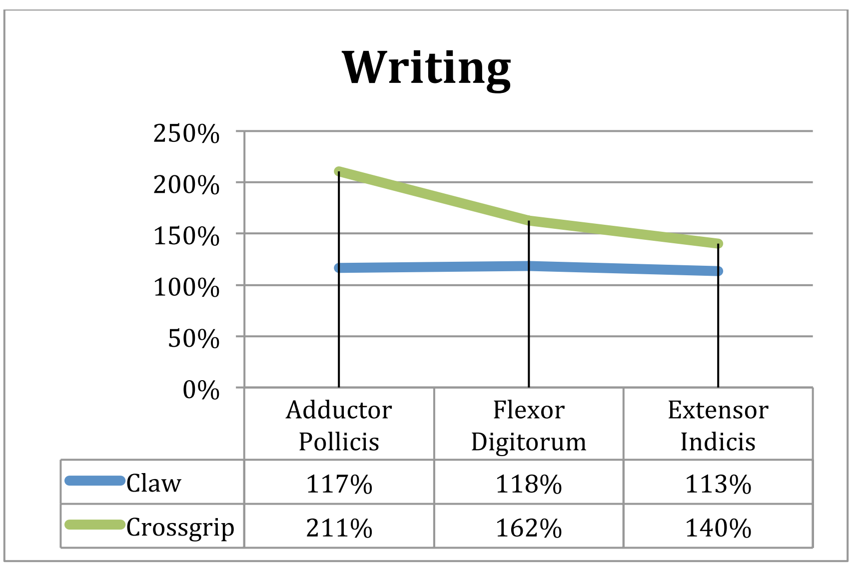

Figure 3.5 Muscle activity of grips for writing relative to the average EMG for stylus.

3.1 Drawing Task

In response to the question of the most comfortable tool for drawing 5 participants chose the claw grip and 2 participants chose the crossover grip. The claw grip was the fastest and most comfortable option for drawing. The average comfort score (CS) for using the stylus alone was above neutral at 3.79. Of the two grip options, only the claw grip averaged to be scored more comfortable than the stylus with an average score of 4.07 (Figure 3.3). Although the crossover grip scored less than the stylus, it was still considered more comfortable than neutral with an average score of 3.67 (Figure 3.1).

Both the claw and crossover grips were able to perform at a faster speed than the stylus alone (Figure 3.2). Either grip option was faster than the stylus by at least 14 milliseconds. The difference between the grips was greater, with the claw grip being 30 milliseconds faster than the crossover grip.

The muscle activity of the grips use has shown lower muscle activity compared to the stylus alone for the extensor indicis (Figure 3.3). The claw grip produced lower signals of the adductor pollicis by 10% and of the extensor indicis by 30%. However, the claw grip showed increased muscle activity of the flexor digitorum by 6%. The use of the crossover grip produced 28% lower EMG signal for the flexor digitorum and 29% lower for the extensor indicis. The muscle activity of the adductor pollicis was increased 13% with the crossover grip.

3.2 Point-and-Click Task

In response to the question of the most comfortable tool for tapping the touchscreen 6 participants chose the claw grip and 1 participant thought all the options had the same level of comfort. The crossover grip was the most comfortable option for pointing and clicking and the faster grip between the two provided. The average comfort score (CS) for using the stylus alone was above neutral at 3.64. Of the two grip options, only the crossover grip averaged to be scored more comfortable than the stylus with an average score of 4.17. Although the crossover grip scored less than the stylus, it was still considered more comfortable than neutral with an average score of 3.43 (Figure 3.1).

Neither grip options were able to outperform the speed of the stylus alone (Figure 3.2). However, the crossover grip was only slower than the stylus by 1 millisecond. The difference between the grips was greater, with the crossover grip being 29 milliseconds faster than the claw grip.

The muscle activity of the grips use has shown lower muscle activity compared to the stylus alone for the extensor indicis (Figure 3.4). The claw grip produced lower signals of the adductor pollicis by 5% and of the extensor indicis by 33%. The use of the crossover grip produced 31% lower EMG signal for the flexor digitorum and 28% lower for the extensor indicis. The muscle activity of the adductor pollicis was increased 46% with the crossover grip.

3.3 Writing Task

In response to the question of the most comfortable tool for writing 6 participants chose the claw grip, 1 participant chose the crossover grip, and 2 participants chose the stylus alone. The claw grip most comfortable option and the crossover grip was the fastest for writing. The average comfort score (CS) for using the stylus alone was slightly above neutral at 3.29. Of the two grip options, only the claw grip averaged to be scored more comfortable than the stylus with an average score of 3.57. The crossover grip scored less than the stylus and was neutral in comfort with an average score of 3.00 (Figure 3.1).

Both the claw and crossover grips were able to perform at a faster speed than the stylus alone (Figure 3.2). The crossover grip was faster than the stylus by 3 seconds. The difference between the grips was small, with the claw grip being 26 milliseconds faster than the crossover grip.

The grips showed increased activity for all muscles for writing tasks compared to the stylus alone. The highest activity increase was observed with the cross over grip, which had a 40% increase of activity in the extensor indicis, 62% increase in activity in the flexor digitorum, and 111% increase of activity in the adductor pollicis. The muscle activity using the claw grip was much lower for all, but still had an increase in the muscle compared to the stylus alone. With the claw grip the muscle activity increased 13% for the extensor indicis, 17% for the adductor pollicis, and 18% for the flexor digitorum.

3.4. Discussion

Results of this study indicate that participants overall felt using a grip was more comfortable than using a stylus alone. Each grip was perceived to be either better or worse than the stylus alone depending on the task being performed. The claw grip was the preferred choice for writing and drawing. On the other hand, the crossover grip was preferred for pointing and clicking. Despite the preference, the difference between the perceived comforts between the grips were minimal with less than a half point difference between the grip options and stylus for each tasks. Future analysis with a larger Likert scale, 10 points or higher, may increase the variance and precision between the rating of each grip to obtain a more significant outcome. The results with the 5- point Likert scale may not have pointed to a major improvement of comfort using a grip option. The small difference does suggest that the use of a grip may not feel uncomfortable when considered as an option.

The Goonetilleke (2009) study found for short-term tasks, uncomfortable pens did not negatively slow writing performance. The findings of this study concur with those results, as the average time of task completion was nearly the same for most stylus options. The difference in the time span was merely the difference of milliseconds for the drawing and point-and-click tasks between all of the options. Due to the lack of statistical significance, this is more suggestive that a grip option would not be a hindrance in productivity than an indicator of improvement in productivity. A longer duration of use may be needed in further study to capture the possibility of either grip option being more productive than a stylus alone for either task. For the writing task, more of a difference in time span was observed. Use of a grip was able to reduce the time span by at least a 10% of the total time for the task. The claw was also able to complete the task 1% faster than the crossover grip. The writing task had a three times longer time span than any other type of task. This shortened time span with the grips may also be due to the fact that these grips were designed for handwriting, which is most similar to the writing task than any other task. Grip design more specific for the finger placement for the other two tasks could be helpful in a greater reduction in the time span with the use of a grip.

For pointing-and-clicking and drawing, both grip options reduced the muscle activity for the extensor indicis. Each grip additionally reduced a muscle opposite each other. The claw grip was able to reduce the muscle activity of the adductor pollicis by at least 5% in drawing and pointing-and-clicking. Whereas, the crossover grip was able to reduce muscle activity of the flexor digitorum by at least 28% for either task.

For the writing task, both grip options produced greater muscle activity than the stylus alone. The increase in activity was much greater using the crossover grip than the claw grip. The claw grip increased muscle activity between 13%-18% more than the stylus alone. On the other hand, the crossover grip increased muscle activity by 40%-111% more than the stylus alone. With this outcome with the crossover grip, as well as a lower perceived comfort score than the stylus alone, the crossover grip could be removed as a contender for a comfort grip for writing on a touchscreen device. However, I would not rule out the claw grip. Keen and colleagues (1994) reported on average a 20% reduction in force fluctuation during low-level contractions of index-finger abduction after strength training with muscle contractions of the same type. More similarly, Ranganthan and colleagues (2000) reported a 27% reduction of pinch force when this same training approach was applied to skilled finger movements in the elderly. With training it could be possible that the muscle activity of the claw grip for writing could reduce to less than with just the stylus.

The p-values of the statistical tests were more than 10% for all outcomes. This is likely due to the small sample population for the study. Increasing the sample size could produce significant differences for at least some of the responses. The response measures that can reach a level of significance are EMG measures of the adductor pollicis for all tasks and the timing for the drawing task. Due to problems with the electrode, the EMG measures for the adductor pollicis was readable for only four of the participants. Despite the smaller population the p-value was 0.1301 over all tasks for this muscle group. If the entire sample were able to be used, the statistical significance could be below a p-value of 0.05. The average time taken for the drawing task was skewed by the results of one participant and missing data from a participant. The time taken by subject #6 appeared to be an outlier. If these two observations were excluded from the statistical test, the p-value would be less than 0.03.

CHAPTER 4

CONCLUSION

The writing grip offers an option for comfort based on the task being performed. The potential for reduced muscle activity and the perceived comfort of participants shows the claw grip to be a viable option for improving comfort for writing or drawing on a touchscreen device. The crossover grip also produced higher comfort and lower muscle activity for pointing-and-clicking. I would recommend modifications for further study. I would increase the study population based on effect size to measure statistical significance. I would also modify the drawing and pointing-and-clicking tasks to range within the same time span as the writing task. I would also incorporate training prior to grip use to more accurately capture the reduction of muscle activity with continuous use.

APPENDIX

		Drawing				
		Timing (Seconds)	Comfort Level	Hand EMG	Flexor EMG	Extensor EMG
	Claw	5.479	5	0.0202	0.0405	0.057
	Crossover	5.619	3	0.0195	0.0397	0.06
1	None	6.159	3	0.027	0.0675	0.1642
	Claw	7.299	3	0.1365	0.0292	0.0322
	Crossover	9.219	3	0.1582	0.0262	0.0382
2	None	6.599	5	0.1275	0.0217	0.0232
	Claw	7.479	4	0.0915	0.0225	0.042
	Crossover	8.739	5	0.201	0.024	0.0405
3	None	9.399	4	0.129	0.0255	0.0382
	Claw	5.129	4		0.0055	0.0097
	Crossover	6.849	4		0.0057	0.0097
4	None	5.499	4		0.0072	0.009
	Claw	9.499	5	0.2145	0.1117	0.0562
	Crossover	10.619	3	0.2017	0.024	0.0412
5	None	13.419	4	0.2302	0.0742	0.0525
	Claw	7.599	3		0.0115	0.0055
	Crossover	3.742	4		0.0272	0.0157
6	None	4.779	4		0.0122	0.0145
	Claw	7.999			0.008	0.018
	Crossover	7.769			0.0087	0.0195
7	None	7.679			0.008	0.0155
	Claw				0.1175	0.00525
	Crossover				0.0135	0.006
8	None				0.01975	0.00625

Table A.1 Data collected for drawing task.

		Point-and-Click				
		Timing (Seconds)	Comfort Level	Hand EMG	Flexor EMG	Extensor EMG
	Claw	5.059	2	0.0165	0.0315	0.045
	Crossover	5.679	5	0.0195	0.0307	0.0495
1	None	7.439	4	0.033	0.0722	0.1485
	Claw	5.399	4	0.0675	0.0285	0.021
	Crossover	5.619	5	0.0375	0.0247	0.0217
2	None	5.459	5	0.0975	0.03	0.0195
	Claw	7.339	4	0.0577	0.0195	0.0375
	Crossover	7.099	5	0.1425	0.018	0.0382
3	None	7.62	5	0.0705	0.0195	0.036
	Claw	5.849	4		0.008	0.0137
	Crossover	5.759	4		0.0137	0.0135
4	None	5.006	4		0.009	0.0127
	Claw	7.319	5	0.1672	0.048	0.0465
	Crossover	5.959	3	0.276	0.0427	0.0517
5	None	6.259	5	0.1237	0.0637	0.0397
	Claw	6.859	1		0.0785	0.0057
	Crossover	7.139	3		0.0177	0.006
6	None	5.859	3		0.017	0.006
	Claw	9.429			0.0102	0.0195
	Crossover	7.999			0.0077	0.0235
7	None	7.509			0.0125	0.0202
	Claw				0.01475	0.0055
	Crossover				0.01775	0.00625
8	None				0.0167	0.00725

Table A.2 Data collected for point-and-click task.

		Writing				
		Timing (Seconds)	Comfort Level	Hand EMG	Flexor EMG	Extensor EMG
	Claw	19.779	2	0.0232	0.0352	0.0622
	Crossover	21.339	4	0.4005	0.111	0.1102
1	None	19.679	4	0.012	0.0255	0.0607
	Claw	23.339	4	0.288	0.0345	0.066
	Crossover	22.559	1	0.2505	0.0345	0.0765
2	None	24.759	5	0.219	0.03	0.0555
	Claw	28.319	2	0.0817	0.0142	0.039
	Crossover	26.359	4	0.1732	0.018	0.0397
3	None	26.219	3	0.1387	0.0142	0.0337
	Claw	18.179	4		0.012	0.0202
	Crossover	19.539	3		0.0142	0.0215
4	None	15.219	4		0.0177	0.0295
	Claw	22.819	5	0.285	0.1132	0.0975
	Crossover	27.94	1	0.4005	0.1102	0.111
5	None	27.839	4	0.2115	0.087	0.0712
	Claw	21.679			0.0092	0.027
	Crossover	23.909			0.0117	0.0272
6	None	23.879			0.01	0.0247
	Claw				0.01725	0.00725
	Crossover				0.0175	0.007
7	None				0.022	0.0065

Table A.3 Data collected for writing task.

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