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Get a Grip: Analysis of Muscle Activity and Perceived Comfort in Using Stylus Grips of Touchscreen Tablet Computer

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Abstract:

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 first dorsal interosseous, extensor digitorum, and flexor carpi radialis of three participants while they performed writing, drawing, and point-and-click tasks on a tablet using a standard stylus and three grip options. Participants were also timed and surveyed on comfort level for each trial. The preliminary subjective measures indicate that the use of grips is perceived as more comfortable than standard stylus use alone. We hypothesize that EMG results that are being analyzed, will correlate with user comfort and muscle activity will transfer from increased fine muscle activity to increased gross muscle activity with grip use. Results of the study should be applicable in improving the stylus grip design of tablet computers.

Keywords: Ergonomics, Stylus, Computer-based pen, Grip, muscle activity, comfort

1. Introduction

The ease of use and multitude of applications has triggered the incorporation of mobile computer devices in the workplace. The latest computer technologies in the hands of the many technology-savvy Y-Generation workers entering the workforce leads to the expectation of productivity increases.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 of a work environment. Mobile devices are ideal for the mobile worker (e.g. healthcare professionals, field service engineers, educators, etc.). 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).

The design of handwriting instruments has been based primarily on touch, feel, aesthetics and muscle exertion .Kao (1976) has investigated the effect on hand-writing quality of lead pencils, ball-point pens and fountain pens. In two other studies, Kao (1977, 1979) investigated the effects on writing time, writing pressure and writing efficiency of ball-point pens, pencils, felt pens, fountain pens and of pen point shape variations. These 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.

The 'dynamic-tripod' is one of the most common ways to hold a writing instrument (Wynn-Parry, 1966; Wu and Luo, 2006b). 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. He claimed that such a grip was superior as the muscles would be more relaxed.

Some researchers have shown that pen grip does not influence the speed of writing. Handwriting performance however, 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 and Otto, 1961) even though the amount of finger flexion and the pressure on the index finger when writing tends to reduce in children with increasing age (Ziviani, 1982). 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.

Even though hand grip strength variations with grip size have been extensively investigated, Wu and Luo (2006a) have mentioned that the diameter, length and shape of a stylus-pen affect handwriting performance and efficiency without further investigating the effect of grip size. 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 (Udo et al., 2000).

Most previous studies evaluating pens have had confounding effects and there are few studies that have considered these factors as they apply to stylus' specific for touchscreen devices. Hence, this study focuses primarily on evaluating grip size and style's impact on user comfort and muscle activity while using a stylus-pen. The precision grip involved in holding a stylus involves positioning the stylus where the hand and wrist are firmly held by the long flexor and extensor muscles, and the intrinsic muscles of the hand perform fine movements of the digits.

For a fair observation of muscle activity in this study we observed user activity of the interosseus of the 1st metatarsal, extensor digitorium, and flexor carpi radialis while writing, drawing, and point-and-clicking on a screen and surveyed user opinions of the tasks after operation on a screen. The tasks were observed using a combination of three kinds of pen grips with a standard stylus. The stetro grip is a standard grip with surface indentations which form a tripod grasp, the crosover grip contains wings that prevent the index finger and thumb from crossing over each other in tripod grasp, and the claw grip is made of three cups that the fingers fit into to stay in the tripod grasp. This study will evaluate if the use of either of these grips would be perceived as comfortable or produce lower muscle activity in comparison to the use of the standard stylus without a grip.

2. Methods

2.1 Participants

Phase one of this study involved six right-handed New Jersey Institute of Technology students (5 female, 1 male, aged 25.3 ± 1.6 years). The participants of this study were timed while randomly performing three tasks as they randomly used a stylus alone, with a stetro pencil grip, or with a claw pencil grip. During and after each task the participantss were surveyed on their perceived comfort.

Phase two of this study involved three female right-handed New Jersey Institute of Technology students (age 26.3 ± 2.89 years). The sEMG measures were taken approximate to the 1st metatarsal, extensor digitorium, and flexor carpi radialis of each participants as they randomly performed three tasks while randomly using a stylus alone, with a stetro pencil grip, claw pencil grip, or crossover pencil grip. Participants were also timed while performing each experiment using a stopwatch. During and after each task the participants were surveyed on their perceived comfort.

2.2 Workstation Set-up

The participants used the same tablet (Galaxy Note 10; Samsung). The tablet was set at a 45 degree angle to the center of an adjustable desk facing the user. For each user the table 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 Tasks

Each participants performed three tasks using four writing instrument options (three grip options and a standard stylus without a grip) on a 10.1 inch tablet The participants performed a writing task, drawing task, and pointing and clicking task (Figure 1) for each writing instrument option while being timed.

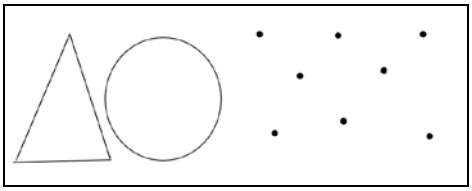

Figure 1: Tasks - drawing (left) and point-and-click (right)

For the writing task each participants wrote the sentence “The quick brown fox jumps over the lazy dog” because it is a pangram that incorporates all the letters of the English alphabet. Participants were provided with a blank page on the tablet and were shown the sentence to write while they performed the writing task. For the drawing task each participants traced a pre-drawn figure of a triangle and a circle. Participants were instructed to start this task from left to right; therefore everyone completed the triangle figure before moving onto the circle figure. For the pointing and clicking tasks 11 dots were pre-drawn on the screen. Participants were instructed to point to each dot moving left to right from the top to the bottom.

2.4 Writing Instruments

Every participants randomly performed the tasks and was randomly assigned the grip order for each task while using the stylus (Galaxy Note 10; Samsung). The stylus used in the study measures to 4.5 inches (11.43 cm) in length, .25 inches (0.635cm) in width and weighs 0.09 ounces .

The order in which the grips were used to perform the subsequent sets of tasks was randomized by using an online randomizer (researchrandomizer.com) for each participants. In phase one of our study the grip options used were a stetro grip and a claw grip (Figure 2). The phase two of our study added the crossover grip in addition to the previous options.

Figure 2: Writing Instruments- stetro (left), claw (center), crossover (right)

The stetro pencil grip (The Write Dudes) is often considered the classic pen and pencil grip. According to the manufacturer, this grip is used to promote proper finger positions when holding a writing device. It is a small piece of firm plastic slightly larger than a marble. Its surface has indentations which form the tripod grip when the users’ fingers are placed in the correct area. An arrow on the grip points up for a right handed student and down for a left handed users. There is a star shape on the indentation where the thumb rests. The pointer finger is opposite it, and the underside has a larger curve which the middle finger fits into. The grip is 0.3 ounces in weight and its dimensions 3.2 x 2.9 x 0.9 inches.

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 the 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 tipod 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 enourages large muscle use instead of use of the fingerss for moving the writing instrument. This grip was added in phase two because it prevents the thumb wrapping grip that the previous grip options do not address. Response from a phase one particpiant indicated that thumb wrapping occurred for them when performing tasks at the 45

degree screen angle used in our study. The additional flap on the crossover grip prevents from wrist position change that would occur when the fingers wrap around each other. This grip weighs 1.8 ounces and the dimensions are 4 x 6 inches.

2.5 Survey

Prior to starting the experiment, phase one and phase two participants reported their demographics (i.e. age, gender, and dominant hand) and history of touch screen usage (familiarity of touch screen devices and type of touch screen devices familiar with). During the experiment, after each phase one and phase two, participants completed a task and they were asked to rank their perceived comfort level on a quantitative scale of 1 (least comfortable) to 7 (most comfortable). After completing the experiment the participants was surveyed with a series of questions regarding their perceived comfort during the experimental task performance:

- Which is most comfortable for the drawing task, with or without a grip? Which grip was the most comfortable for the drawing task?
- Which is most comfortable for the point-and-click task, with or without a grip? Which grip was the most comfortable for the point-and-grip task?
- Which is most comfortable for the writng task, with or without a grip? Which grip was the most comfortable for the writing task?
- Which task was the most comfortable? Which task was the most uncomfortable?
- Was using a grip more or less comfortable than using the stylus alone?

2.6 EMG Measurement

Surface Electromyography (EMG) was used in phase two of this study to measure the muscle activity of each participants as they performed all of the trials. EMG data was collected and analyzed by DataLINK PC software Version 2.00 (Biometrics Ltd.) through DataLINK 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 interosseus of the 1st metatarsal, extensor digitorium, and flexor carpi radialis 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 1015 ohms. The amplified data passes through a high pass filter to reduce motion artifacts and a low pass filter to remove unwanted frequencies above 450Hz.

Prior to placement of the electrodes on the skin, the skin of dorsum of the hand and forearm was cleaned with an alcohol wipe and gel was rubbed on the electrode. The electrode for the interosseus was placed while the participants was holding the stylus to reduce the possibility of the electrode being accidently struck by the stylus. The extensor digitorium and flexor carpi radialis was determined by having the participants repeatedly squeeze their fingers and flex/extend their wrist while someone palpated the area 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 1 V and 1000 Hz. The maximum voluntary contraction (MVC) was determined by having the participants sqeeze a hand dynanometer 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. These values were then normalized to the MVC of the respective participants.

3. Results

3.1 Perceived Comfort

3.1.1 Drawing Task

In response to the question of the most comfortable writing tool option for drawing 4 participants chose the claw grip , 4 participants chose the stetro grip and 1 participant chose the crossover grip. Averaging the comfort scores taken from participants immediately following the drawing trials has also shown that all of the grips were considered equally more comfortable than the stylus alone by users (Figure 3). The claw grip was considerd the most comfort with an average comfort level (CL) of 5.86. However, the stetro grip (CL= 5.79) and crossover grip (CL=5.5) were rated closely behind.

3.1.2 Point-and-Click Task

In response to the question of the most comfortable writing tool option for pointing and clicking 4 participants choose the claw grip and 2 participants chose the stetro grip. However, the average of the comfort scores taken from participants immediately following the point and click trials shows that the stetro grip (CL=5.5) was considered more comfortable than the claw grip (CL=4.86), crossover grip (CL=4.5), and the stylus alone (CL=4.29) by users (Figure 3).

3.1.3 Writing Task

In response to the question of the most comfortable writing tool option for writing, 5 participants chose the claw grip,one participant chose the stetro grip, and one participant chose the crossover grip. The average of the comfort scores taken from participants immediately following the point and click trials supports that the claw grip (CL=5.57) was considered more comfortable than the stetro grip (CL=5.07) and the stylus only (CL=4.21) by users (Figure 3). The crossover grip was rated only slightly less comfortable than the claw grip with a comfort level of 5.5.

3.2 Task Timing

The average times for all of the times were arranged by grip type for calculation in each task type (Figure 4). The crossover grip provided the fastest average time of task completion for the drawing (6.1s) and writing tasks (21.65s). The stetro grip provided the fastest average time for completion of the point-and-click task (6.43s). Use of the stylus alone was the slowest in the drawing task (8.99s), but fell between the rate of the grips in other tasks. In the point-and-click task, the claw grip (7.51s) was the only grip slower than use of the stylus alone. For the writing task, the stylus alone had a short time than all other grips besides the crossover grip.

3.3 EMG Analysis

There was no considerable differences between the mean EMG measures for each grip for the drawing and point and click task. For the drawing task, the average EMG measures for the first dorsal interosseous (hand) , extensor digitorum (extensor), and flexor carpi radialis (flexor) were highest for the stetro grip and the lowest were for claw grip (figure 5; left).

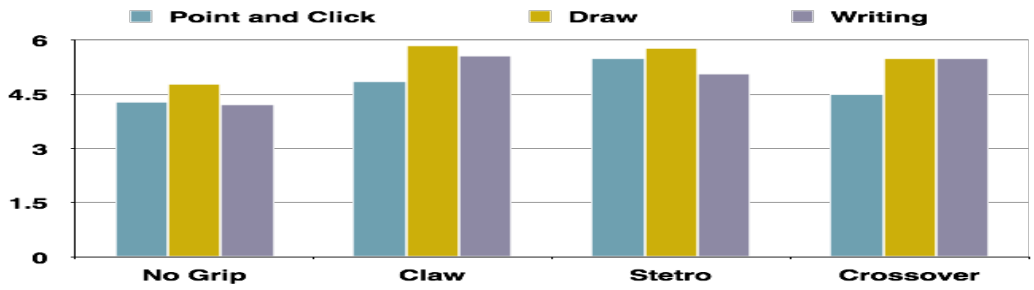

Figure 3: Average Perceived Comfort Rating

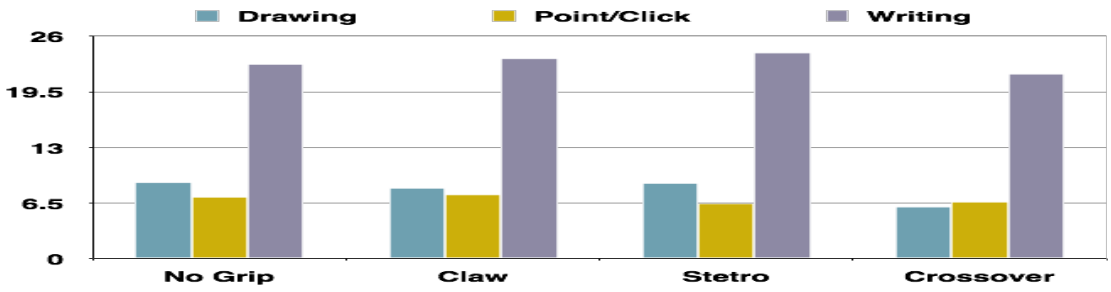

Figure 4: Average Time of Task Completion

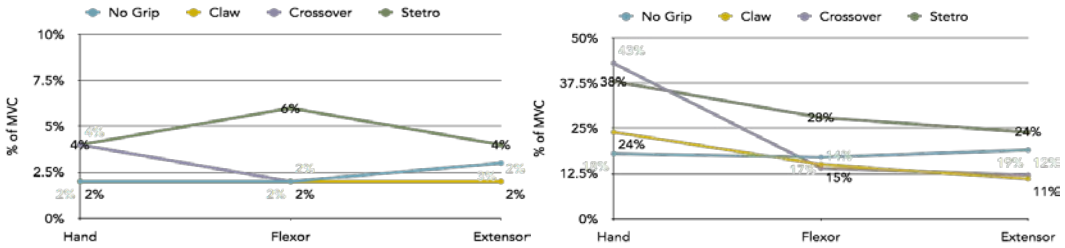

Figure 5: EMG means (left) and peaks (right) for Drawing Task

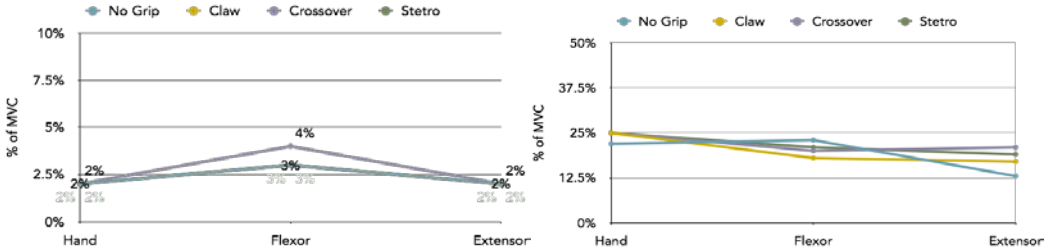

Figure 6: EMG means (left) and peaks (right) for Point-and-Click Task

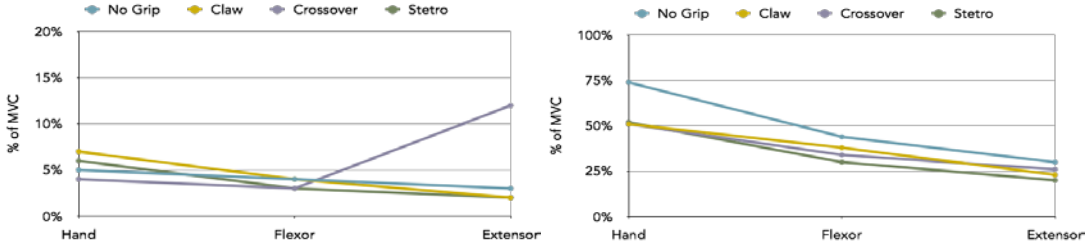

Figure 7: EMG means (left) and peaks for Writing Task

However, the peak values showed the stylus alone to have the least muscle activity of the hand (18% of MVC), the crossover grip had the least for the flexor (14% of MVC), and the claw grip was the least for the extensor (11% of MVC) for the draw task (Figure 5; right). For the point-and-click, the average EMG values were unanimous for all of the grip for each of the respective muscles except for the crossover grip having slightly higher muscle activity of the flexor (4% of MVC) (Figure 6; left) . In terms of the peak EMG values, all of the grips had higher muscle activity than the stylus alone for the hand and extensor while performing the point-and-click task (Figure 6; right). However, all of the grips produced lower EMG peak values in the flexor than the stylus alone for this same task, with the claw grip (18% of MVC) producing the lowest peak value. For the writing task, the crossover grip had the lowest average EMG measures for the hand (4% of MVC) and the flexor (3% of MVC) (Figure 7; left). Whereas, the claw grip had the lowest average EMG values for the extensor (2% of MVC) in the writing task. All of the grips had lower average EMG values than the use of the stylus alone, with the exception of the crossover grip having four times more muscle activity than the stylus alone. All of the EMG peak values of the grips were lower than the stylus alone for the writing task (Figure 7; right). The stretro grip had the lowest peak values for the flexor (30% of flexor) and the extensor (20% of MVC) int the writing task, while the claw grip and crossover grip (51% of MVC) shared the lowest peak muscle values for the hand during the writing task.

4. Conclusion

Results of this study indicate that participants overall felt using a grip was more comfortable than using a stylus alone. In regards to comfort, the stetro gave the best overall results (CL=5.45) with the stetro grip only being slightly less

comfortable (CL=5.43). All of the grip options were considered more comfortable overall in comparison to the use of a stylus alone (CL=4.43). In phase two, additional to the sample population being smaller, the third grip added to the study (crossover grip) was used improperly by the two participants that rated their comfort level. The comfort rating for the crossover grip (CL=5.19) may had been higher if the particpants were instructed on the proper way to fold the grip.The grip that produced the best results in regard to timing was the crossover grip. The time taken to complete a task with a grip was at the most one second longer than the use of a stylus alone. Therefore it could be predicted that the use of any of these grip options would not negeatively impact prodictivty The claw grip was the only grip to produced lower stylus in all tasks over all muscles. The grips unanimously feeling more comfortable than the stylus alone by all users, but producing no differnce in the mean EMG values is an indication that other factors may be involved in the comfort that the users are feeling. Further research on this topic may need to observe a longer task to see the decrease in musle activity that the grips could provide in compariosn to the stylus alone and involve other factors related to the grips in regard to comfort.

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