A PRODUCTIVITY ANALYSIS OF 6 ERGONOMIC MOUSE DESIGNS

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MAIN MESSAGE
This study compared productivity measures of 6 popular ergonomic mouse designs in accordance with ISO 9241-400:2007. Quantitative measures of throughput, movement time, and error rate were used to assess productivity and qualitative self-report measures were used to assess comfort, fatigue, accuracy, perceived effort, and ease of use.

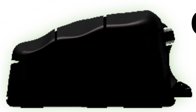
PROBLEM
The Canadian Centre for Occupational Health and Safety estimates that the duration a computer user spends performing mousing tasks is three times greater than the duration that they are using the keyboard. Often called “mouse arm”, prolonged and/or intensive mousing can lead to pain and musculoskeletal disorders of the upper extremity. While a traditional computer mouse design must be operated in a posture with a pronated forearm, alternative ergonomic mouse designs can be used with varying degrees of supination, for operation in a more neutral posture. Increasing the amount of forearm supination has been shown to yield many benefits to the mouse user when compared to a traditional mouse, including decreased pain (Aaras et al., 1999), lowered muscle activity (Houwink et al., 2009; Quemelo & Viera, 2014), and uncompromised productivity (Odell & Johnson, 2015; Hedge et al. 2010).

RESEARCH OBJECTIVE
The purpose of this study was to compare 6 popular, commercially-available ergonomic mouse designs with varying degrees of tilt, and to test their effect on user productivity and user comfort, through quantitative (Throughput, movement time, error rate) and qualitative (comfort, ease of use, fatigue, effort, accuracy) measures.

METHODOLOGY
Twenty participants (23.7 ± 2.3 years old, 10 Males, 10 Females) from the McMaster University population completed a multi-directional Fitts’ Law point-and-click mousing task using 6 popular, commercially available computer mouse designs with varying degrees of palmar tilt (Table 1). The angles of the ergonomic computer mice included in the study were: 1) 17º, 2) 25º, 3) 35-70º, 4) 66º, 5) 80º, and 6) 90º. For each mouse design, participants completed a familiarization task for at least 5 minutes before proceeding to the Fitts’ Law mousing task.

The task conditions completed were in accordance with the ISO standard for evaluating computer input devices (ISO 9241-400:2007) and were as follows: amplitude (A; distance between targets) varied between 200, 400, and 800 pixels, and target width (W) varied between 15, 30, 60, and 120 pixels. The Index of Difficulty (ID) of the tasks ranged from 1.42-5.76 bits. For each of the 12 combinations of A and W, participants completed 19 point-and-click trials. Experimental stimuli were presented and recorded using GoFitts software (MacKenzie, 2018) on a PC running Windows 10. Once all 12 conditions had been completed once, the task was then repeated. This occurred for each of the 6 tested mouse designs. Participants came in for two separate testing sessions that occurred at least 24 hours apart and completed three testing blocks during each 60-minute session. That is, 3 mouse designs were tested each day. The order in which the devices were tested was randomized and unique for each participant.

Table 1: Specifications and manufacturers of the 6 ergonomic mouse designs tested in this study. Note that the mouse designs will be referred to by their angle of tilt throughout this paper.

 17° **Contour Design, Inc.** Contour Mouse CMO-MR-WL	 25° **HIPPUS** Handshoe Mouse M2WB-LC
 35°-70° **Contour Design, Inc.** Unimouse UNIMOUSE-RH-WL	 66° **Goldtouch** Semi-Vertical Mouse KOV-GSV-RM
 80° **Evoluent** VerticalMouse 4 VM4RW	 90° **Posturite** Penguin Vertical Mouse 9820100

Upon completion of the pointing task with each mouse, participants completed a subjective questionnaire which asked 5 questions in the form of a Visual Analog Scale (VAS). For each question, the participant was presented with a 10 cm line and were instructed to indicate the point on the line that represented their response to the question. This allows for a continuous range of possible answers, rather than choosing a whole number between 1-10, for example. Responses were measured in cm from the leftward edge of the line, to the nearest 0.05 cm, with far-left edge of the line representing a response of 0 and the far-right edge representing a response of 10. The questions were as follows: 1) The physical effort for operation was [0=too low – 10=too high], 2) Accurate pointing was [0=easy – 10=difficult], 3) General comfort of the device was [0=uncomfortable – 10=comfortable], 4) Fatigue in the hand, wrist, and arm was [0=none – 10=very high], and 5) Overall, the device was [0=easy to use – 10=difficult to use].

To analyze performance variables, the GoFitts software was used to output participants' mean scores in each tested configuration. A one-way repeated measures ANOVA with independent factors of device (n=6), width (n=4), and amplitude (n=3) were conducted for each of the dependent variables. Since the purpose of the study was to compare the effect of the angle of each mouse design on mousing performance, main effects of device will be presented. The width and amplitude variations were included to ensure an adequate range of task difficulties were tested. The dependent variables of interest were: 1) Throughput, 2) Movement Time, 3) Error Rate, 4) Effort, 5) Accuracy, 6) Comfort, 7) Fatigue, 8) Ease of use. Tukey's post hoc analyses were used to test for significant differences between devices.

OUTCOMES

Throughput

Throughput accounts for the speed and accuracy of a task. It is calculated by dividing the level of difficulty of a movement sequence (ID) by the time that it takes to complete that sequence (movement time). It is measured in bits per second (bits/s), and a higher number is indicative of better performance. There was a significant effect of device on throughput $F(3.21, 60.96)=42.33$, $p<0.001$ (Table 2). The 17º, 25º, 35-70º, and 80º device designs resulted in better performance than the 66º and 90º devices. There were no statistically significant differences in performance between the 17º, 25º, 35-70º, and 80º devices. The 25º and 66º devices both performed better than the 90º device, but there was no statistically significant difference between the 25º and 66º devices.

Movement Time

Movement time is the duration elapsed between mouse clicks, as the participant changes their trajectory from the previous target to the new target. There was a significant main effect of device on MT, $F(2.92, 55.56)=54.92$, $p<0.001$ (Table 2). The 17º, 35-70º, and 80º device designs resulted in faster movements than the 25º, 66º, and 90º devices. There were no statistically significant differences between the MTs of the 17º, 35-70º, and 80º devices. The 25º and 66º devices both had faster movement times than the 90º device, however there was no statistically significant difference between the 25º and 66º devices.

Error Rate

Error rate gives an indication of the participants' accuracy while using a given device. Error rate reports the number of trials in which the cursor was not within the bounds of the target when the primary mouse button was clicked and is reported as a percentage of the total number of completed trials. There was a significant effect of device on error rate, $F(5, 95)=6.66$, $p<0.001$(Table 2). The 90º device led to more errors than the 25º, 66º, and 80º devices. The 25º device resulted in the lowest error rate, significantly lower than the 17º, 35-70º, and 90º devices, but not statistically different from the 66º or 80º devices. The 66º device resulted in a lower error rate than the 35-70º and 90º devices. There were no statistically significant differences between the 17º, 35-70º, or 90º devices.

Table 2: Average performance measures of each of the 6 tested mouse designs, including 1) Throughput, 2) Movement Time, and 3) Error Rate. Standard errors of each measure are shown in parentheses.

		Device					
		17º	25º	35-70º	66º	80º	90º
Performance Measure	Throughput (bits/s)	4.26 (0.09)	3.96 (0.11)	4.12 (0.08)	3.70 (0.10)	4.25 (0.08)	3.05 (0.10)
	Movement Time (ms)	782.96 (15.16)	909.26 (23.51)	789.09 (12.51)	901.65 (21.41)	812.06 (22.40)	1057.55 (26.57)
	Error Rate (% of trials)	8.00 (1.19)	4.62 (0.83)	9.04 (1.39)	5.95 (0.94)	6.45 (1.16)	9.53 (1.18)

Effort

Participants were asked about the amount of effort that they experienced when operating the mouse. There was a significant effect of device on perceived effort, $F(3.25, 61.72)=19.07$, p<0.001 (Table 3). Participants felt that the physical effort required for operation was significantly higher in the 25º and 90º devices than in the 17º, 35-70º, and 80º devices. There were no statistically significant differences in the effort required for use when using the 17º, 35-70º, or 80º devices. The 66º device was only statistically different from the 90º device, resulting in lower perceived effort when using the 66º device than when using the 90º device.

Accuracy
Participants were asked about their perceived ability to point accurately. There was a significant effect of device on perceived pointing accuracy, $F(5, 95)=12.43$, $p<0.001$ (Table 3). The 17º device resulted in the greatest perceived accuracy, however it was not statistically different from the 35-70º, 66º, or 80º devices. The 17º, 35-70º, and 80º devices were all rated to have higher perceived accuracy than both the 25º and 90º devices. The 66º device was only statistically different from the 90º device and resulted in a greater degree of perceived accuracy. Participants thought that the 90º and 25º devices were the most difficult to point accurately with.

Comfort
Participants were asked about their perceived comfort level while operating each of the 6 computer mice. There was a significant effect of device on comfort, $F=(5,95)=11.81$, $p<0.001$ (Table 3). The adjustable 35-70º device was rated as being the most comfortable, however there was no statistically significant difference between the adjustable mouse and the 17º, 66º, and 80º devices. The 90º device was rated as being the most uncomfortable and was significantly less comfortable than all of the tested mice except for the 25º device.

Table 3: Mean scores, as measured on a 10 cm visual analog scale, representing each of the 5 self-report measures including 1) the physical effort for operation, 2) perceived ability to point accurately, 3) general comfort of the device, 4) fatigue experienced in the hand, wrist, and arm, and 5) overall ease of use of the device. Standard errors of each measure are shown below the mean in parentheses.

		Question				
		1. Effort	2. Accuracy	3. Comfort	4. Fatigue	5. Ease of Use
Device	17º	3.57 (0.36)	3.16 (0.38)	6.28 (0.48)	3.48 (0.45)	3.18 (0.44)
	25º	6.36 (0.43)	5.88 (0.53)	3.93 (0.58)	5.78 (0.61)	5.90 (0.46)
	35-70º	3.04 (0.41)	3.29 (0.51)	7.40 (0.45)	2.83 (0.54)	2.10 (0.43)
	66º	4.77 (0.40)	4.99 (0.43)	6.25 (0.47)	4.30 (0.50)	4.42 (0.49)
	80º	4.18 (0.49)	3.93 (0.57)	5.91 (0.51)	3.75 (0.57)	3.62 (0.54)
	90º	7.25 (0.39)	7.4 (0.55)	3.04 (0.58)	6.42 (0.49)	7.61 (0.46)

Fatigue
Participants were asked about their perceived fatigue in the hand, wrist, and arm when operating each of the 6 computer mice. There was a significant effect of device on perceived

fatigue, $F(5, 95)=8.63$, $p<0.001$ (Table 3). The adjustable 35-70º device was rated as inducing the least amount of fatigue, however this value was not statistically different from the 17º, 66º, or 90º devices. The 90º device was rated as leading to the greatest degree of fatigue and was significantly more fatiguing than all of the tested mice except for the 25º device. The 25º mouse led to increased levels of perceived fatigue compared to the 17º, 35-70º, 66º and 80º devices, but not the 90º device.

Ease of Use

Participants were asked to give each of the 6 mice a rating about its overall ease of use. There was a significant effect of device on perceived fatigue, $F(5, 95)=8.63$, $p<0.001$ (Table 3). Overall, the adjustable 35-70º device was rated as being the easiest to use, however this was not statistically different from the 17º and 80º devices. The 90º device was rated as being the most difficult to use and was significantly more difficult to use than all other devices except for the 25º mouse. The 66º device was rated as more difficult to use than the 35-70º device, easier to use than the 90º device, and was not statistically different from the 17º, 25º, or 80º devices.

CONCLUSION

The 17º, 35-70º and 80º devices led to the most favourable performances in many of the tested domains. These three devices resulted in the highest throughput values, indicating better performance. They also resulted in the three fastest measured movement times. In terms of the self-report questionnaires that participants used to indicate their personal experiences with the devices, these three were ranked as requiring the lowest amount of effort to operate and as being the most comfortable, the least fatigue inducing, the easiest to point accurately with, and generally the easiest to use. Interestingly, the 35-70º mouse scored the most favourably in 4 out of the 5 questionnaire measures, when looking at the absolute score.

The 90º device performed the least favourably in the quantitative measures of performance, including the lowest throughput, the longest movement time, and the highest error rate. It also received the lowest rating in all 5 of the questionnaire measures. The 25º mouse was not statistically significantly different from the 90º mouse in any of the self-report measures, which also ranked it unfavourably in terms of performance. Interestingly, the 90º mouse reported the highest error rates while the 25º mouse reported the lowest error rates. These two designs also had the two longest absolute movement times, and the differences in error rate are reflected in the throughput values.

The 66º mouse resulted in mixed results in that it performed favourably in many of the questionnaire measures, however had a decreased measured throughput value and the 3rd highest absolute movement time, indicating decreased performance in the quantitative measures.

DISCLOSURE

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