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"Least Gain or Wrist Pain": A comparative study about performance and usability of mouse, trackball, and touchpad

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Abstract

The mouse as an input device has undoubtedly brought convenience to users due to its intuitiveness and simplicity, but it also brought unprecedented issues such as carpal tunnel syndrome (CTS). As a result, the necessity of alternative input devices that put less strain on the wrist, while still providing the convenience of a conventional mouse, has emerged. Unfortunately, there have been several research about alternative devices to replace a mouse, however, they showed inconsistent results. This study suggests that those inconsistent results may stem from the type and the difficulty of tasks used in previous studies. Therefore, we designed this study to compare the performance and perceived workload of three input devices (Mouse/Trackball/Touchpad) in each condition in terms of task type (Targeting/Tracking) and difficulty level (Easy/Hard). The results indicated that there were significant performance differences and no significant workload differences among the three devices, and the interactions were observed in some conditions. These results can provide users with practical guidelines to choose the optimal input device according to their needs or purpose.

Keywords: *HCI, Ergonomics, Workload, Input Device*

1. INTRODUCTION

Mouse is a kind of input device which is usually used to control a computer. Although there are many variations of its shape, it includes two buttons (Left/Right) and a wheel in the middle, and users move it across a flat surface to control the cursor on the computer screen. Since its invention in 1964, the mouse has occupied the highest usage rate among computer input devices due to its intuitiveness and simplicity. With the development of computer performance and Graphical User Interface (GUI), the mouse has allowed users to perform more tasks quickly and conveniently. For these reasons, the mouse became one of the most popular input devices until today.

However, the increased use of mice also caused unprecedented issues such as carpal tunnel syndrome (CTS). Carpal tunnel syndrome is a condition that causes wrist pain as the median nerve in the wrist gets pinched [1], and it is often regarded to be caused by increased pressure on the wrist [2]. It is also called 'Mouse Syndrome', and there has been much empirical evidence for the relationship between mice and this symptom [3-6].

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On the other hand, A lot of research for alternative input devices to reduce muscle load and fatigue has been conducted, and various input devices such as 'trackball (or trackball mouse)' and 'touchpad' have emerged recently. Trackball is an input device which usually consists of a ball to move the cursor, buttons to click, and a wheel to scroll. Early trackballs had various form factors but gradually converged into shapes like traditional mice. On the contrary, the form of touchpads has not changed much from the early flat surface design to the present. A flat surface of touchpads can be used to move the cursor and to click, but sometimes they consist of separate buttons for clicking. It has been revealed through various studies that the trackball and touchpad have similar operating methods to the existing mouse, while also having their advantages. According to the study by Karlqvist *et al.* [7], when using a trackball, less shoulder elevation and less shoulder muscle activity were shown compared to when using a mouse. Although the performance was better with the mouse in a comparison study with a touchpad, using a mouse caused more finger fatigue [8, 9].

Despite these advantages, however, trackballs and touchpads still cannot fully replace mice, and there is a need to study the reasons for these shortcomings. It is also important to note that the ergonomic factors of these input devices have been greatly improved from when the previous research was conducted, but the results of many comparative studies are still somewhat inconsistent. For example, researchers found that the trackball caused more wrist fatigue than the mouse, but the shape of the trackball used in the study was significantly different from that of current products, making it difficult to apply this result to the present circumstance [7]. In addition, while some studies have shown that the mouse performs generally better than the trackball [10, 11], other studies have found that the performance of the two devices varies depending on the task or environment [12, 13].

Nevertheless, it is still clear that users prefer a mouse over a trackball or touchpad. According to Kotin’s study [8], users showed a significant preference for the mouse when using the Windows 8 operating system, and Malečkar and his colleagues [14] found that users still prefer to use a mouse even though they may perform worse than a touchpad in some tasks. Therefore, this study aims to verify whether the performance and workload of input devices vary depending on the type and difficulty of the task.

The followings are the hypotheses of this study:

H1: There will be differences in targeting performance depending on the three input devices.
H2: There will be differences in tracking performance depending on the three input devices.
H3: There will be differences in perceived workload depending on the three input devices.

2. METHOD

2.1 Experiment Design

The experiment was designed in a 3 × 2 × 2 mixed factorial design with one between-subjects factor and two within-subjects factors. One independent variable was the input device (Mouse/Trackball/Touchpad), and it was the between-subjects factor. The other two within-subjects factors were the difficulty level (Easy/Hard) and the type (Targeting/Tracking) of the task. All participants were randomly assigned to each of the three input device conditions, and they performed all task types and difficulty levels.

2.2 Participants

90 undergraduate students from Yonsei University who are taking a psychology course were recruited as participants. Participants received course credits as compensation for participating in the experiment. All participants' first language was Korean, had normal vision, and had no physical constraints in moving their upper body. Each participant was randomly allocated to each condition, and their personal information was not collected excluding experiment data and survey responses for the experiment.

2.3 Materials

For input devices, we used Logitech's 'Logitech M120' mouse, 'Logitech ERGO M575 Wireless Trackball' trackball, and the touchpad attached to 'Logitech K400+'. The targeting task required participants to move the cursor toward a stimulus which appeared at an arbitrary location on the computer screen. In the tracking task, participants had to move the cursor continuously to keep it in the stimulus which was moving at constant speed on the computer screen.

To distinguish the difficulty level of the task, we adjusted the stimulus size for the targeting task and the stimulus speed for the tracking task. A white circle with a diameter of 30px was used for the 'easy-targeting' tasks, and a white circle with a diameter of 10px was used for the 'hard-targeting' tasks. Meanwhile, a circle with a diameter of 50px moved at a speed of 3px/frame up and down, 4px/frame left and right, and 5px/frame diagonally in ‘easy-tracking’ tasks, and a circle with a diameter of 50px moved at a speed of 6px/frame up and down, 8px/frame left and right, and 10px/frame diagonally in the ‘hard-tracking’ tasks.

In addition, we measured the reaction times (in seconds) of participants’ responses in the targeting task and measured the accuracy rate calculated with the number of frames in which the Euclidean distance between the stimulus and the cursor was smaller than the radius of the stimulus in the tracking task.

All experiment programs were made using 'PsychoPy' and presented on a 22-inch LED monitor with a resolution of 1920 * 1080. The survey measured the perceived workload of the input device which the participant used for each task by NASA-TLX [15] questionnaire items.

2.4 Experiment Procedure

Before starting the experiment, all participants completed a consent form and received instructions about the experiment procedure from the researcher. Participants then experimented in the order of ‘Easy-Targeting’, ‘Hard-Targeting’, ‘Easy-Tracking’, and ‘Hard-Tracking’ tasks. Before starting the task, they were able to practice the basic operation of the input device. The targeting task consisted of 10 practice trials and 180 main trials, and the tracking task consisted of 12 practice trials and 120 main trials. Participants responded to the NASA-TLX questionnaire after the experiment ended.

2.5 Data Analysis

A Mixed ANOVA was conducted for the analysis of experimental data and questionnaire data. In case the differences among the three input devices were statistically significant, Bonferroni post-hoc tests were conducted. The partial eta-squared or Cohen's d was reported as the effect size for each result. All statistical analyses were performed using the JASP software.

3. RESULTS

3.1 Performance

A mixed ANOVA was conducted to examine whether the difficulty level and device type affected the reaction times (RTs) in the targeting task and accuracies in the tracking task. The result demonstrated that the targeting RT in the easy level (M = 1.32, SD = 0.38) was significantly faster than in the hard level (M = 1.64, SD = 0.41), $F(1, 87) = 496.78$, $p < .001$, $\eta_p^2 = .85$, and the tracking accuracy in easy level (M = 0.54, SD = 0.17) was significantly higher than in the hard level (M = 0.28, SD = 0.12), $F(1, 87) = 1685.29$, $p < .001$, $\eta_p^2 = .95$. Among three device types, in addition, there were also significant differences in targeting RT, $F(2, 87) = 165.77$, $p < .001$, $\eta_p^2 = .79$, and tracking accuracy, $F(1, 87) = 1685.29$, $p < .001$, $\eta_p^2 = .95$. Therefore, H1 and H2 were supported.

We conducted a Bonferroni post-hoc test to explore the specific differences between device types, and it revealed that all the performance differences among the three devices were statistically significant (see Figure 1). The targeting RT of the mouse (M = 1.00, SD = 0.19) was significantly faster than trackball (M =

1.63, *SD* = 0.27), $t(87) = -13.48$, $p < .001$, $d = -3.26$, and touchpad (*M* = 1.81, *SD* = 0.28), $t(87) = -17.34$, $p < .001$, $d = -4.20$, and the targeting RT of trackball was also significantly faster than the touchpad, $t(87) = -3.86$, $p < .001$, $d = -0.93$. Similarly, the tracking accuracy of the mouse (*M* = 0.57, *SD* = 0.17) was higher than trackball (*M* = 0.36, *SD* = 0.16), $t(87) = 9.93$, $p < .001$, $d = 2.42$, and touchpad (*M* = 0.30, *SD* = 0.14), $t(87) = 12.92$, $p < .001$, $d = 3.14$, and the tracking accuracy of trackball was also significantly higher than the touchpad, $t(87) = 2.99$, $p = .011$, $d = 0.73$.

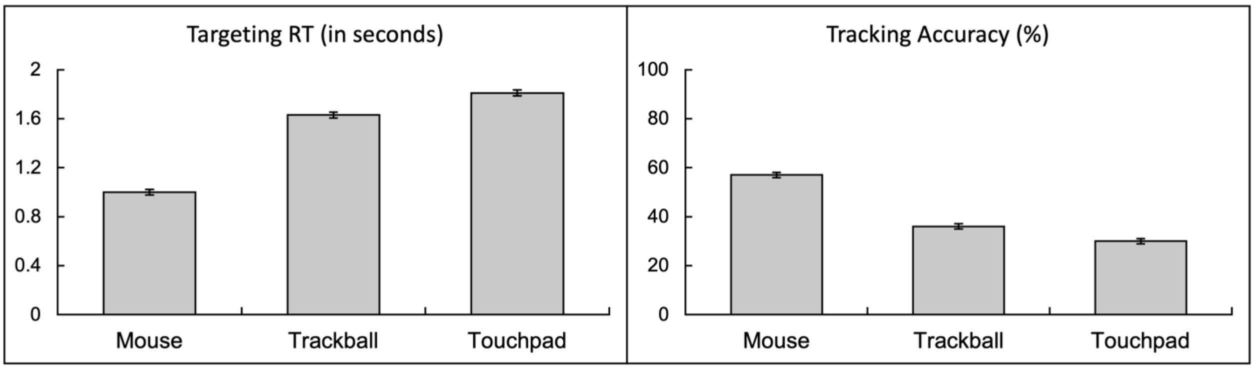

Figure 1. Targeting RTs and tracking accuracies by each input device of the experiment

Moreover, the interaction between the difficulty level and device type in the tracking task was statistically significant, $F(2, 87) = 18.48$, $p < .001$, $\eta_p^2 = .30$, whereas the interaction in the targeting task was not, $F(2, 87) = 0.95$, $p = .393$, $\eta_p^2 = .02$. We conducted a Bonferroni post-hoc test to explore the simple main effect in this interaction (see Figure 2). In the easy tracking task, the accuracy of the mouse (*M* = 0.72, *SD* = 0.01) was significantly higher than trackball (*M* = 0.49, *SD* = 0.12), $t(87) = 10.40$, $p < .001$, $d = 2.69$, and touchpad (*M* = 0.40, *SD* = 0.11), $t(87) = 14.21$, $p < .001$, $d = 3.67$, and the accuracy of trackball was also significantly higher than the touchpad, $t(87) = 3.81$, $p = .003$, $d = 0.98$. In the hard tracking task, however, the accuracy of the mouse (*M* = 0.42, *SD* = 0.08) was still significantly higher than trackball (*M* = 0.23, *SD* = 0.08), $t(87) = 8.31$, $p < .001$, $d = 2.15$, and touchpad (*M* = 0.19, *SD* = 0.05), $t(87) = 10.12$, $p < .001$, $d = 2.61$, but the difference of accuracy between trackball and touchpad was not statistically significant, $t(87) = 1.81$, $p = 1.000$, $d = 0.47$.

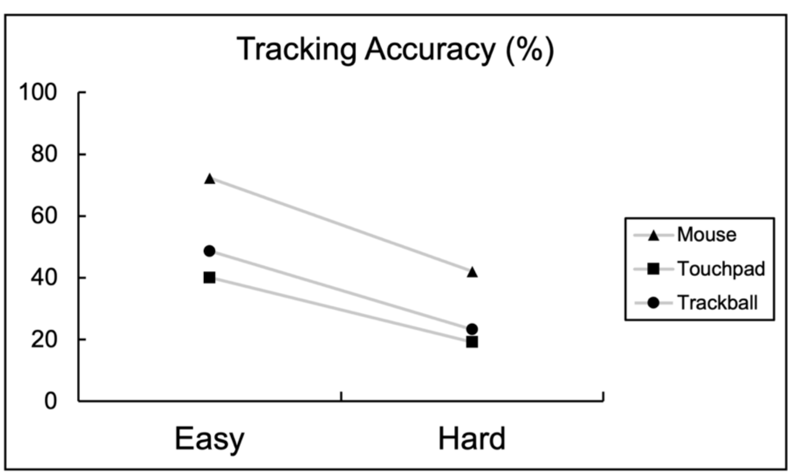

Figure 2. Tracking accuracies by each input device and difficulty level

3.2 Workload

A series of mixed ANOVA was conducted to examine whether the task type, difficulty level, and device type affected the perceived workload (see Appendix A). Table 1 displays the descriptive statistics of each dimension of NASA-TLX, and Table 2 shows the result of Mixed ANOVA. Firstly, the targeting task shows low mental demand, $F(1, 87) = 82.32$, $p < .001$, $\eta_p^2 = .49$, low physical demand, $F(1, 87) = 64.75$, $p < .001$, $\eta_p^2 = .43$, low temporal demand, $F(1, 87) = 9.66$, $p = .003$, $\eta_p^2 = .10$, high overall performance, $F(1, 87) = 114.60$, $p < .001$, $\eta_p^2 = .57$, and low frustration, $F(1, 87) = 68.44$, $p < .001$, $\eta_p^2 = .44$, than the tracking task. However, there was no significant difference in effort between the targeting task and the tracking task, $F(1, 87) = 0.01$, $p = .932$, $\eta_p^2 < .001$.

Secondly, the easy level shows low mental demand, $F(1, 87) = 107.51$, $p < .001$, $\eta_p^2 = .55$, low physical demand, $F(1, 87) = 62.42$, $p < .001$, $\eta_p^2 = .42$, low temporal demand, $F(1, 87) = 20.80$, $p < .001$, $\eta_p^2 = .19$, high overall performance, $F(1, 87) = 84.42$, $p < .001$, $\eta_p^2 = .49$, and low frustration, $F(1, 87) = 55.63$, $p < .001$, $\eta_p^2 = .39$, than the hard level. However, there was also no significant difference in effort between the easy level and the hard level, $F(1, 87) = 2.46$, $p = .120$, $\eta_p^2 = .03$.

Thirdly, there were no statistically significant differences among device types in mental demand, $F(2, 87) = 0.46$, $p = .630$, $\eta_p^2 = .01$, physical demand, $F(2, 87) = 0.04$, $p = .960$, $\eta_p^2 < .001$, temporal demand, $F(2, 87) = 0.07$, $p = .935$, $\eta_p^2 = .002$, overall performance, $F(2, 87) = 1.77$, $p = .18$, $\eta_p^2 = .04$, effort, $F(2, 87) = 2.21$, $p = .116$, $\eta_p^2 = .05$, and frustration, $F(2, 87) = 0.95$, $p = .392$, $\eta_p^2 = .02$. Therefore, H3 was rejected.

Lastly, there were significant two-way interactions between the task type and the device type in temporal demand, $F(2, 87) = 3.41$, $p = .037$, $\eta_p^2 = .07$, and overall performance, $F(2, 87) = 5.36$, $p = .006$, $\eta_p^2 = .110$ (see Figure 3). The two-way interactions between the task type and the difficulty level were statistically significant in mental demand, $F(2, 87) = 12.02$, $p < .001$, $\eta_p^2 = .12$, physical demand, $F(2, 87) = 8.76$, $p = .004$, $\eta_p^2 = .09$, temporal demand, $F(2, 87) = 11.76$, $p < .001$, $\eta_p^2 = .12$, and frustration, $F(2, 87) = 14.39$, $p < .001$, $\eta_p^2 = .14$. However, there was no two-way interaction between difficulty and the device. There was a three-way interaction among task type, difficulty level, and device type in overall performance, $F(2, 87) = 3.85$, $p = .025$, $\eta_p^2 = .08$ (see Figure 4).

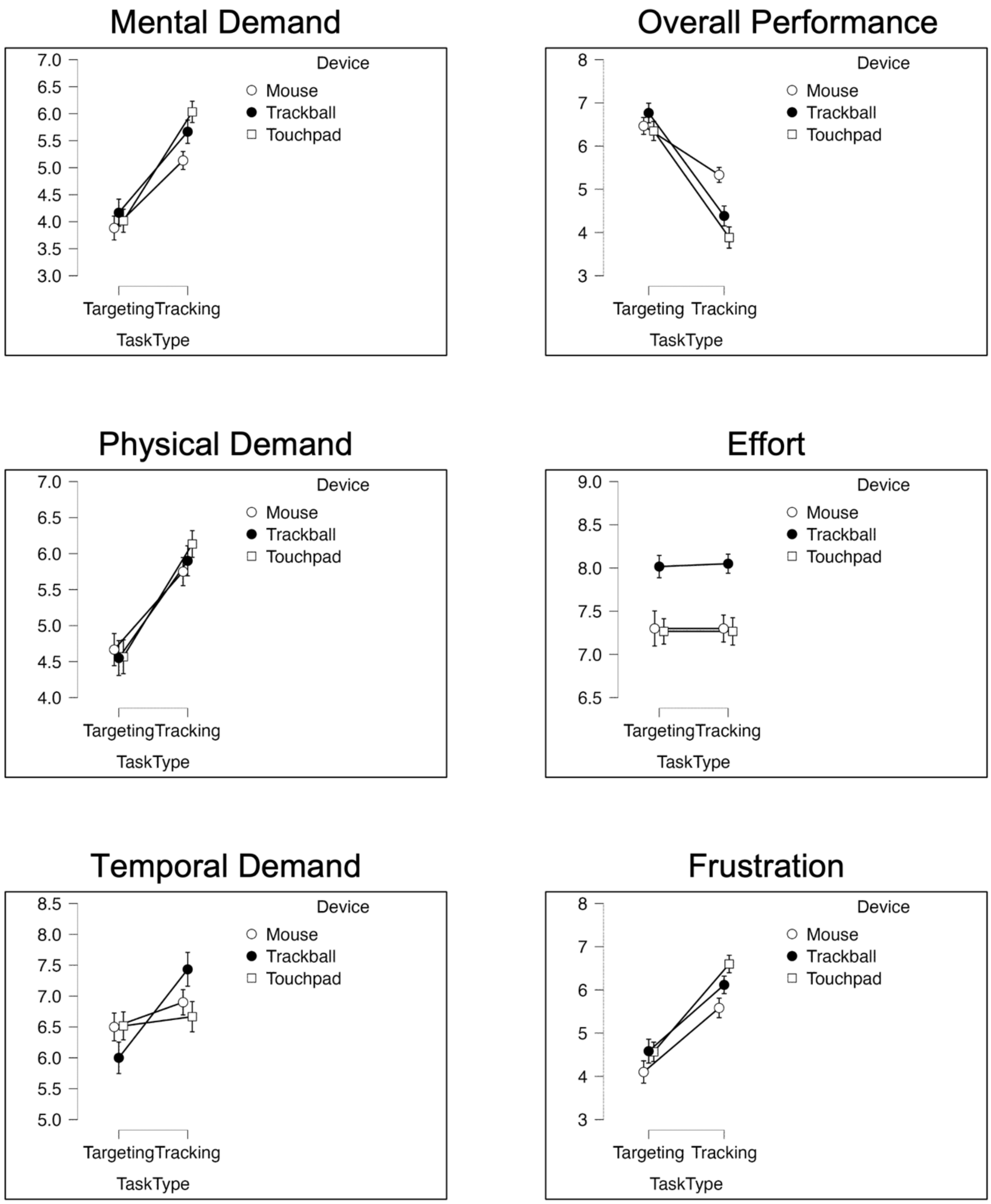

Figure 3. Perceived workload by each input device and task type

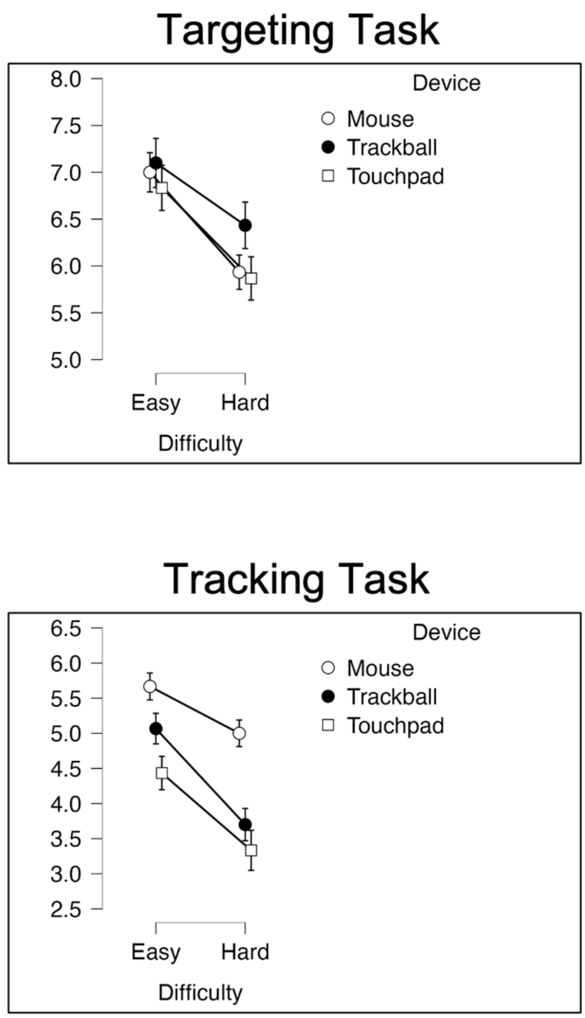

Figure 4. Three-way interaction in perceived overall performance

4. DISCUSSION

This study suggests several findings about the performance and workload of input devices. Researchers found that the differences among the three input devices were statistically significant in both targeting and tracking tasks. In general, the performance of the mouse was the best, and the performance of the touchpad was the worst. The interaction between the input device and the difficulty level, however, was statistically significant only in the tracking task. The performance of trackball showed a steep decline of performance when the tracking task became hard. On the contrary, there was no statistically significant difference in perceived workload among input devices, despite the actual performance differences. Furthermore, there were interactions between task type and input device in two dimensions of perceived workload (*i.e.*, temporal demand and overall performance). Specifically, the temporal demand score of trackballs was the lowest when the task was about targeting, but it was the highest when the task was about tracking. The overall performance score of each input device showed larger gaps in the tracking task than in the targeting task, and there was also three-way interaction among task type, difficulty level, and input device.

Although this study found several interesting findings, it has some limitations. Firstly, there were differences in participants' proficiency with input devices. Since the trackball is not as common as the mouse or touchpad, most participants might not have prior experience using a trackball. In other words, participants are already proficient in using a mouse and touchpad through sufficient experience. We suggest a follow-up study to include participants who are proficient in using each device to solve this problem.

Secondly, the tasks used in the experiment differed somewhat from real-world situations where input devices are used. In the experiment, tasks were presented in simplified forms such as targeting tasks and tracking tasks, but tasks which are required in real-world situations consist of more integrated and complicated control. Thus, we strongly recommend including various tasks for the follow-up study.

Finally, it should be noted that all participants performed tasks in the order of 'Easy-Targeting', 'Hard-Targeting', 'Easy-Tracking', and 'Hard-Tracking'. Even though it was virtually impossible to apply counterbalancing for this study, it could not exclude the order effect from the fixed order.

5. CONCLUSION

This study was designed to explore whether the type of input devices affects performance and workload and whether it would be different by the type and difficulty of the task. Researchers used two task types (i.e., Targeting and Tracking) which are critical functions of input devices and found that there are some significant performance and workload differences among the three device types (*i.e.*, mouse, trackball, and touchpad), and this effect varies by the task characteristics. Furthermore, this study demonstrated how to input device performance and its perceived workload show different patterns depending on task types and difficulty levels. To our best knowledge, this study was the first study that compared three devices within the dimension of performance and usability. These findings can provide not only academic insights about input devices but also practical implications for users. With these results, users will be able to choose more conveniently the optimal input device according to their needs or usage scenarios.

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APPENDIX

Table 1. Descriptive Statistics of each dimension of NASA-TLX

Workload	Task	Difficulty	Device	N	Mean	SD	SE
Mental Demand	Targeting	Easy	Mouse	30	3.17	2.10	0.38
			Touchpad	30	3.40	2.14	0.39
			Trackball	30	3.50	2.45	0.45
		Hard	Mouse	30	4.60	2.43	0.44
			Touchpad	30	4.63	2.39	0.44
			Trackball	30	4.83	2.83	0.52
	Tracking	Easy	Mouse	30	4.77	2.29	0.42
			Touchpad	30	5.63	2.09	0.38
			Trackball	30	5.27	2.48	0.45
		Hard	Mouse	30	5.50	2.74	0.50
			Touchpad	30	6.43	2.29	0.42
			Trackball	30	6.07	2.70	0.49
Physical Demand	Targeting	Easy	Mouse	30	4.03	2.36	0.43
			Touchpad	30	3.93	2.07	0.38
			Trackball	30	3.97	2.58	0.47
		Hard	Mouse	30	5.30	2.26	0.41
			Touchpad	30	5.20	2.16	0.39
			Trackball	30	5.13	2.64	0.48
	Tracking	Easy	Mouse	30	5.50	2.30	0.42
			Touchpad	30	5.77	2.13	0.39
			Trackball	30	5.60	2.43	0.44
		Hard	Mouse	30	6.00	2.56	0.47
			Touchpad	30	6.50	2.21	0.40
			Trackball	30	6.20	2.55	0.47
Temporal Demand	Targeting	Easy	Mouse	30	6.43	1.79	0.33

			Touchpad	30	6.47	1.94	0.36
			Trackball	30	5.77	1.79	0.33
		Hard	Mouse	30	6.57	1.76	0.32
			Touchpad	30	6.57	1.76	0.32
			Trackball	30	6.23	2.13	0.39
	Tracking	Easy	Mouse	30	6.37	2.04	0.37
			Touchpad	30	6.30	2.04	0.37
			Trackball	30	6.93	1.70	0.31
		Hard	Mouse	30	7.43	2.18	0.40
			Touchpad	30	7.03	1.99	0.36
			Trackball	30	7.93	1.84	0.34
Overall Performance	Targeting	Easy	Mouse	30	7.00	1.62	0.30
			Touchpad	30	6.83	1.78	0.33
			Trackball	30	7.10	2.34	0.43
		Hard	Mouse	30	5.93	1.68	0.31
			Touchpad	30	5.87	1.87	0.34
			Trackball	30	6.43	2.25	0.41
	Tracking	Easy	Mouse	30	5.67	1.83	0.33
			Touchpad	30	4.43	1.79	0.33
			Trackball	30	5.07	2.02	0.37
		Hard	Mouse	30	5.00	2.03	0.37
			Touchpad	30	3.33	2.17	0.40
			Trackball	30	3.70	1.86	0.34
Effort	Targeting	Easy	Mouse	30	7.00	2.20	0.40
			Touchpad	30	7.30	1.58	0.29
			Trackball	30	7.93	1.91	0.35
		Hard	Mouse	30	7.60	1.63	0.30
			Touchpad	30	7.23	1.57	0.29
			Trackball	30	8.10	1.61	0.29
	Tracking	Easy	Mouse	30	7.33	1.94	0.35
			Touchpad	30	7.17	1.58	0.29
			Trackball	30	8.03	1.65	0.30
		Hard	Mouse	30	7.27	2.38	0.43
			Touchpad	30	7.37	1.73	0.32
			Trackball	30	8.07	1.64	0.30
Frustration	Targeting	Easy	Mouse	30	3.57	2.42	0.44
			Touchpad	30	4.03	2.40	0.44
			Trackball	30	3.83	2.63	0.48
		Hard	Mouse	30	4.63	2.67	0.49
			Touchpad	30	5.10	2.51	0.46

		Trackball	30	5.33	2.59	0.47
Tracking	Easy	Mouse	30	5.50	2.64	0.48
		Touchpad	30	6.20	2.01	0.37
		Trackball	30	5.80	2.19	0.40
	Hard	Mouse	30	5.67	2.85	0.52
		Touchpad	30	7.00	2.18	0.40
		Trackball	30	6.43	2.11	0.39

Table 2. The result of Mixed ANOVA

Workload	Case	Sum of Squares	df	F	p	η_p^2
Mental Demand	Device	17.82	2	0.46	.630	.01
	Residuals	1668.58	87			
	TaskType	227.21	1	82.32	< .001	.49
	TaskType ✻ Device	9.17	2	1.66	.196	.04
	Residuals	240.12	87			
	Difficulty	100.28	1	107.51	< .001	.55
	Difficulty ✻ Device	0.07	2	0.04	.962	.00
	Residuals	81.15	87			
	TaskType ✻ Difficulty	6.94	1	12.02	< .001	.12
	TaskType ✻ Difficulty ✻ Device	0.27	2	0.24	.791	.01
	Residuals	50.28	87			
Physical Demand	Device	1.44	2	0.04	.960	.00
	Residuals	1530.52	87			
	TaskType	160.00	1	64.75	< .001	.43
	TaskType ✻ Device	3.52	2	0.71	.494	.02
	Residuals	214.98	87			
	Difficulty	76.54	1	62.42	< .001	.42
	Difficulty ✻ Device	0.27	2	0.11	.895	.00
	Residuals	106.68	87			
	TaskType ✻ Difficulty	8.71	1	8.76	.004	.09
	TaskType ✻ Difficulty ✻ Device	0.24	2	0.12	.887	.00
	Residuals	86.55	87			
Temporal Demand	Device	1.11	2	0.07	.935	.00
	Residuals	717.81	87			
	TaskType	39.34	1	9.66	.003	.10
	TaskType ✻ Device	27.77	2	3.41	.037	.07
	Residuals	354.14	87			
	Difficulty	30.63	1	20.80	< .001	.19
	Difficulty ✻ Device	1.52	2	0.52	.599	.01
	Residuals	128.11	87			

	TaskType ✻ Difficulty	11.03	1	11.76	< .001	.12
	TaskType ✻ Difficulty ✻ Device	0.65	2	0.35	.708	.01
	Residuals	81.58	87			
Overall Performance	Device	37.17	2	1.77	.176	.04
	Residuals	911.74	87			
	TaskType	358.00	1	114.60	< .001	.57
	TaskType ✻ Device	33.47	2	5.36	.006	.11
	Residuals	271.78	87			
	Difficulty	85.07	1	84.42	< .001	.49
	Difficulty ✻ Device	0.51	2	0.25	.779	.01
	Residuals	87.68	87			
	TaskType ✻ Difficulty	0.47	1	0.80	.374	.01
	TaskType ✻ Difficulty ✻ Device	4.54	2	3.85	.025	.08
	Residuals	51.24	87			
Effort	Device	45.07	2	2.21	.116	.05
	Residuals	886.53	87			
	TaskType	0.01	1	0.01	.932	.00
	TaskType ✻ Device	0.02	2	0.01	.993	.00
	Residuals	130.97	87			
	Difficulty	1.88	1	2.46	.120	.03
	Difficulty ✻ Device	0.69	2	0.45	.638	.01
	Residuals	66.43	87			
	TaskType ✻ Difficulty	0.71	1	1.35	.249	.02
	TaskType ✻ Difficulty ✻ Device	3.29	2	3.11	.050	.07
	Residuals	46.00	87			
Frustration	Device	34.52	2	0.95	.392	.02
	Residuals	1586.21	87			
	TaskType	255.03	1	68.44	< .001	.44
	TaskType ✻ Device	5.55	2	0.75	.478	.02
	Residuals	324.18	87			
	Difficulty	68.47	1	55.63	< .001	.39
	Difficulty ✻ Device	3.21	2	1.30	.277	.03
	Residuals	107.08	87			
	TaskType ✻ Difficulty	10.34	1	14.39	< .001	.14
	TaskType ✻ Difficulty ✻ Device	1.91	2	1.33	.271	.03
	Residuals	62.51	87			