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Supervisory Control Information Management Research (SCIMR) Studies: Determination of Efficiency for a Variety of Input Control Equipment (DEVICE)

Aubrey C. Aldridge III
Meagan R. Newman
Thomas R. Carretta
Allen J. Rowe
Guy A. French
Warfighter Interface Division

James P. Whalen
InfoSciTex

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AIR FORCE RESEARCH LABORATORY
711 HUMAN PERFORMANCE WING,
HUMAN EFFECTIVENESS DIRECTORATE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

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//signed//
Allen J. Rowe, Work Unit Manager
Supervisory Control Interfaces Branch

//signed//
Gregory J. Barbato, Chief
Chief, Supervisory Control Interfaces Branch
Warfighter Interface Division

//signed//
Michael A. Stropki
Chief, Decision Making Division
Human Effectiveness Directorate

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Aubrey C. Aldridge III*, Meagan R. Newman*, Thomas R. Carretta*, Allen J. Rowe*, & James P. Whalen**

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InfoSiTex**
4027 Colonel Glenn Highway, Suite 210
Dayton OH 45431-1672

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14. ABSTRACT
This study investigated the effectiveness of several commercial, off-the-shelf input devices as alternatives to the standard mouse for simple computer screen movements and interactions. The devices were the standard mouse, the Belkin n52te, the Saitek Cyborg Command Unit, the Wacom Bamboo Fun with stylus, the Wacom Bamboo Fun with touch, and the Xbox 360 controller. Participants performed repetitions of 4 tasks with each device: neutral point movement, dragging, tracking, and zooming. Sixteen of the 20 comparisons between the standard mouse and the other five devices were statistically significant. In all instances where the difference was statistically significant, the standard mouse outperformed the other devices.

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GLOSSARY

RMS	Root Mean Square
RPA	Remotely Piloted Aircraft
SCIMR	Supervisory Control Information Management Research

PREFACE

This study was performed under work unit 71840919 in support of the Supervisory Control Information Management Research (SCIMR) program. The objective of this study was to investigate the impact and effectiveness of various commercial, off-the-shelf input devices as alternatives to the standard mouse for simple computer screen movements and interactions. This study will serve as the foundation for exploration into multi-modal input device efficacy for multi-remotely piloted aircraft (RPA) supervisory control.

1.0 INTRODUCTION

Military operations revolve around intelligence gathering, integration, and distribution to enable warfighters to successfully accomplish their missions. Key components in the reconnaissance, surveillance, and target acquisition effort are remotely piloted aircraft. Currently, RPAs require multiple personnel to directly pilot and monitor the sensor feeds of one aircraft. The Supervisory Control Interfaces Branch at the Air Force Research Laboratory is working to enable one operator to successfully manage and operate the payloads of multiple autonomous RPAs simultaneously. The SCIMR program is investigating information management aspects for a single operator supervising multiple RPAs. The program's objective is to investigate, develop, and evaluate novel information management tools (controls, displays, and decision aids) to support customer requirements while maintaining appropriate RPA operator situational awareness, workload, and performance. The current study is concerned with examination of the utility of a variety of input controllers for performing four common actions associated with foreseeable multiple-RPA control when using a desktop computer as a ground control station.

Methods for analysis of input methods fall into four categories: completion time, degree of error, training time, and ergonomics (Zhai, 2009). Fitts' law (Fitts, 1954) is a commonly-used model of human movement in ergonomics and human-computer interaction used to study input device performance. It predicts that the time required to quickly move to a target area is a function of the size and distance of the target. Fitts' law is used to model the act of pointing, either by physically touching an object with a finger or hand or virtually by pointing to an object on a display using a pointing device (e.g., mouse, light pen, control stick). However, it is of limited use for some complex tasks as it can be applied only to pointing tasks (Accot & Zhai, 1999). The current study augmented Fitts' law with the use of trajectory-based evaluations and those involving steering law. Steering tasks and trajectory-based tasks aim to analyze controller movement of a cursor around a display (Accot & Zhai, 1999). These analyses, however, will be altered to be more aligned with movements that might be encountered using a control station for multiple RPAs.

2.0 METHODS

2.1 Participants

The participants for this study consisted of 12 civilian and military personnel stationed at Wright-Patterson Air Force Base, OH. The sample consisted of 6 men and 6 women. Ten of the 12 participants were between 18-25 years of age and 2 were between 26-35 years. Participants were required to have normal visual acuity (20/20) or corrected-to-normal visual acuity in both eyes and normal color vision. Visual acuity and color vision were determined by self-report. Participation was voluntary; no compensation was offered for participation in this study.

2.2 Hardware

The test configuration consisted of a widescreen Dell LCD monitor with a resolution of 1920 x 1200 pixels. Six commercial devices were evaluated: 1) standard mouse, 2) Belkin n52te, 3) Saitek Cyborg Command Unit, 4) Wacom Bamboo Fun with stylus, 5) Wacom Bamboo Fun with touch, and 6) Xbox 360 controller. See Figure 1.

Figure 1. Control devices used in the study. Upper row (left to right): standard mouse, Belkin n52te, and Saitek Cyborg Command Unit; lower row (left to right): Wacom Bamboo Fun (with stylus or touch) and Xbox 360 controller.

2.3 Mapping

There were six functions mapped to each input device: cursor movement, “clicking”, “dragging”, zoom in, zoom out, and fast zoom. See Table 1 for a comparison of function mapping across all devices, and Figures 2 through 8 for graphic illustrations of the function mapping.

Table 1. Device Function Mapping.

Device	Cursor Movement	Clicking	Dragging	Zoom in	Zoom out	Fast Zoom
Mouse	Move mouse	Left button	Hold left button	Scroll forward on scroll wheel	Scroll backward on scroll wheel	Depress scroll wheel while scrolling
Belkin	Press d-pad	10 button	Hold 10 button	Scroll forward on scroll wheel	Scroll backward on scroll wheel	Depress scroll wheel while scrolling
Saitek	Analog stick	8 button	Hold 8 button	Hold 15 button	Hold 16 button	Hold 5 button while zooming
Touch	Slide finger across touchpad	Tap touchpad with finger	Double-tap touchpad with finger	Slide two fingers toward each other across touchpad ("squeezing" gesture)	Slide two fingers away from each other across touchpad ("stretching" gesture)	N/A
Stylus	Move stylus over tablet	Touch stylus to tablet	Touch stylus to tablet and hold	Press button on stylus, slide stylus down	Press button on stylus, slide stylus up	N/A
Xbox 360	Left analog stick	A-button	Hold A-button	Left bumper (LB)	Right bumper (RB)	Hold B-button while zooming

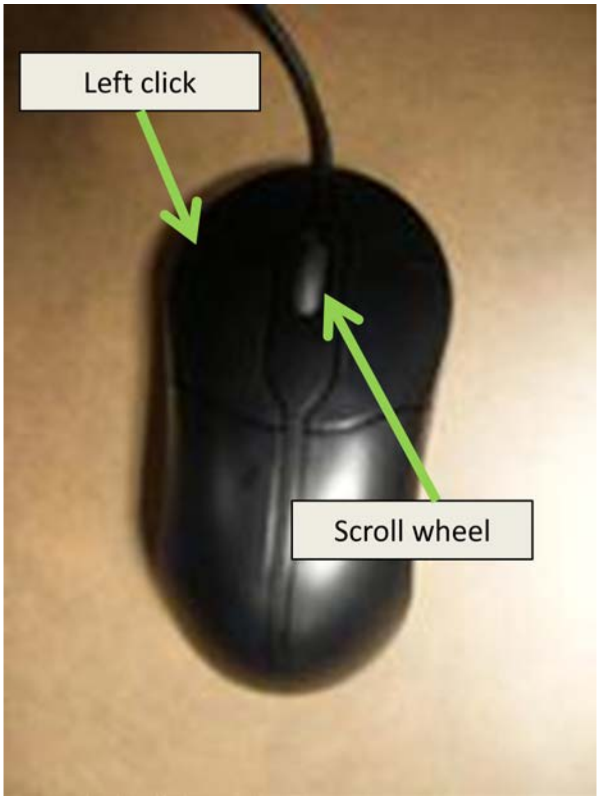

Figure 2. Mouse function mapping.

Figure 3. Belkin n52te function mapping.

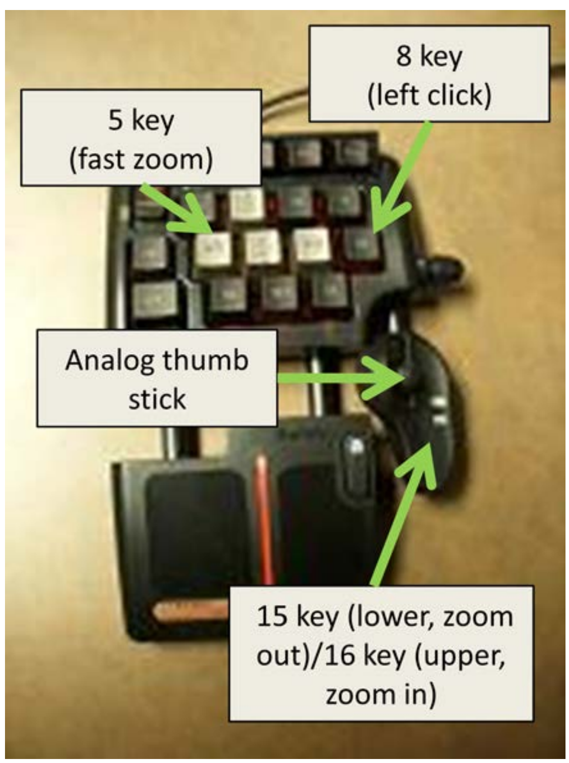

Figure 4. Saitek Cyborg Command Unit function mapping.

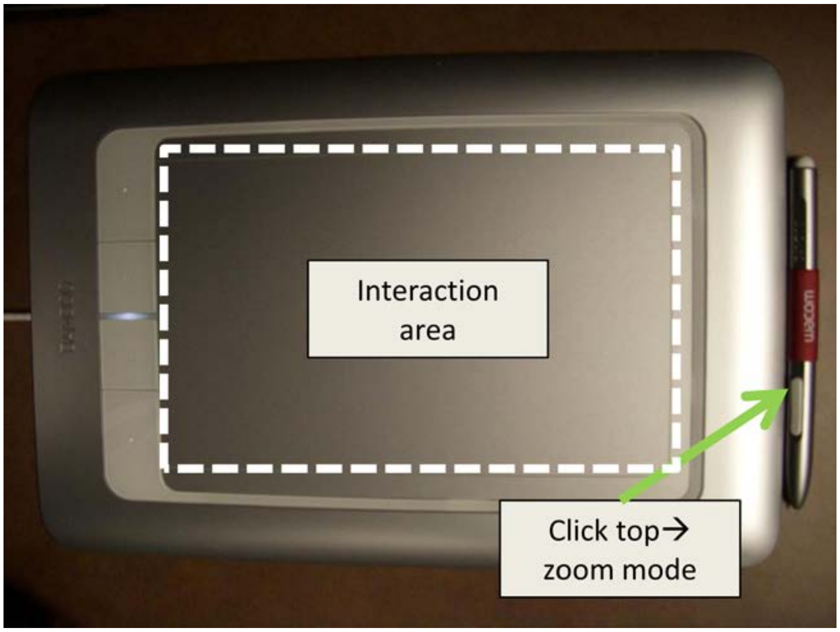

Figure 5. Wacom Bamboo Fun with stylus and touch function mapping. Operating the Wacom Bamboo Fun with the stylus involves touching the stylus to the interaction area. If touch is being used, the operator uses his or her fingers to perform gesture commands (as outlined in Table 1) on the interaction area.

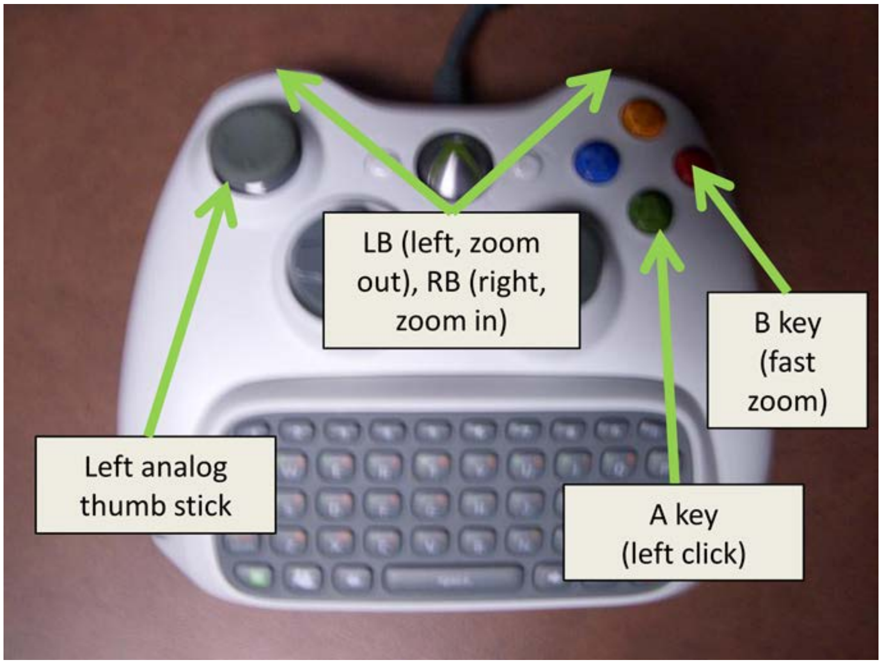

Figure 6. Xbox 360 controller function mapping.

2.4 Measures

Data collection included demographic data, objective task performance, and subjective ratings of the utility of the devices for performing the experimental tasks. Copies of the study questionnaires are provided in Appendix A.

Demographic data. This questionnaire elicited information about participants' age, vision (acuity, color vision), video game experience, and control device experience. Device experience level ratings used a 5-point scale: 1-very low, 2 - low, 3 - average, 4 - high, 5 - very high.

Task performance. Objective performance for the neutral point movement, dragging, and zooming tasks was average time to complete the task (measured in seconds). Objective performance for the tracking task was root mean square (RMS) error averaged over several replications.

Subjective ratings. Following completion of trials for each device, participants rated that device for its utility in performing each of 4 tasks: neutral point movement, tracking, dragging, and zooming. Ratings were on a 5-point scale that ranged from 1 "very poor" to 5 "very good." Participants also were asked to provide comments regarding the strengths and weaknesses of the device and suggestions for modifications. On completion of the experiment, participants rank-ordered the 6 devices from 1 "best" to 6 "worst" in regard to their performance on each of the experimental tasks: neutral point movement, tracking, dragging, and zooming. They also were asked to indicate their favorite/least favorite aspects of the devices and what they would change, combine, or remove from the devices to improve performance on the experimental tasks.

2.5 Procedures

The study began with a briefing regarding the study objectives and completion of the informed consent form and biographical data collection. During the course of the experiment, each participant performed 4 tasks (neutral point movement, tracking, dragging, and zooming) with each on the 6 devices. The order of the devices varied across participants. However, the order of the tasks was the same for each device. Participants were allowed to train with each device/task combination until they indicated they were comfortable with the task and input device. Following practice, participants completed several test trials for each task/device combination, then completed a post-device questionnaire regarding the utility of the device for performing each task and their comments regarding the strengths and weaknesses of that device. This procedure was followed until each of the devices had been evaluated. On completion of the test trials, participants completed the post-study questionnaire.

The tasks were neutral point movement, tracking, dragging, and zooming. In the *neutral point movement* task (see Figure 7), the cursor was moved from the center of a black background to a yellow circle that appeared at a varying distance from center (2” or 6”) and varying angle (0°, 60°, 120°, 180°, 240°, 300°). The measure of interest was time between clicking at the center of the screen to clicking on the target circle. Reaction time (time of appearance of the yellow circle to time of click on the center circle) was not included in the time measurement. There were 36 test trials.

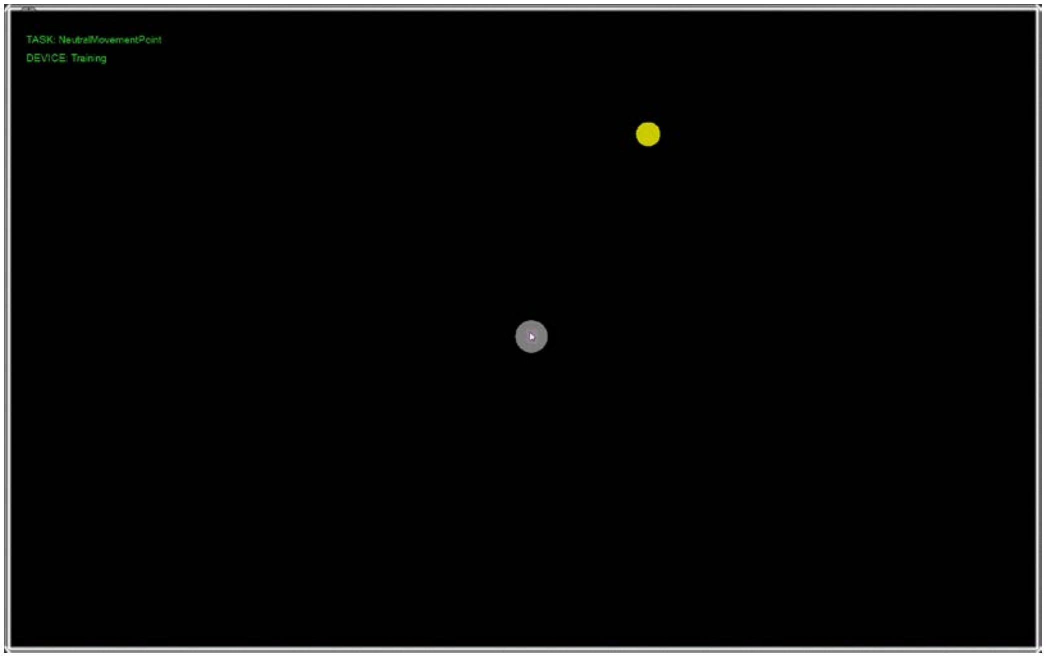

Figure 7. Neutral point movement task.

In the *tracking* task (see Figure 8), a yellow circle appeared on a black background and moved at varying speeds in a predetermined path. The path consisted of a string of shapes (square, spiral in, spiral out, circle, zigzag), but the sequence was not known by the participants. The task was to maintain the cursor over the yellow circle throughout the movement along the path. The measure of interest was RMS error, calculating distance of the cursor from the edge of the circle. There were 5 test trials.

Figure 8. Tracking task.

In the *dragging* task (see Figure 9), a white ring appeared at the center of a black background. Yellow circles with a radius of 0.3" appeared 6" from the center at angles of 0°, 60°, 120°, 180°, 240°, and 300°. Participants were required to click and drag the yellow circles to the white ring at the center of the screen and release the click. The measure of interest was of time between click depression and release of the input mechanism (i.e., hotkey, mouse click, etc.). There were 18 test trials.

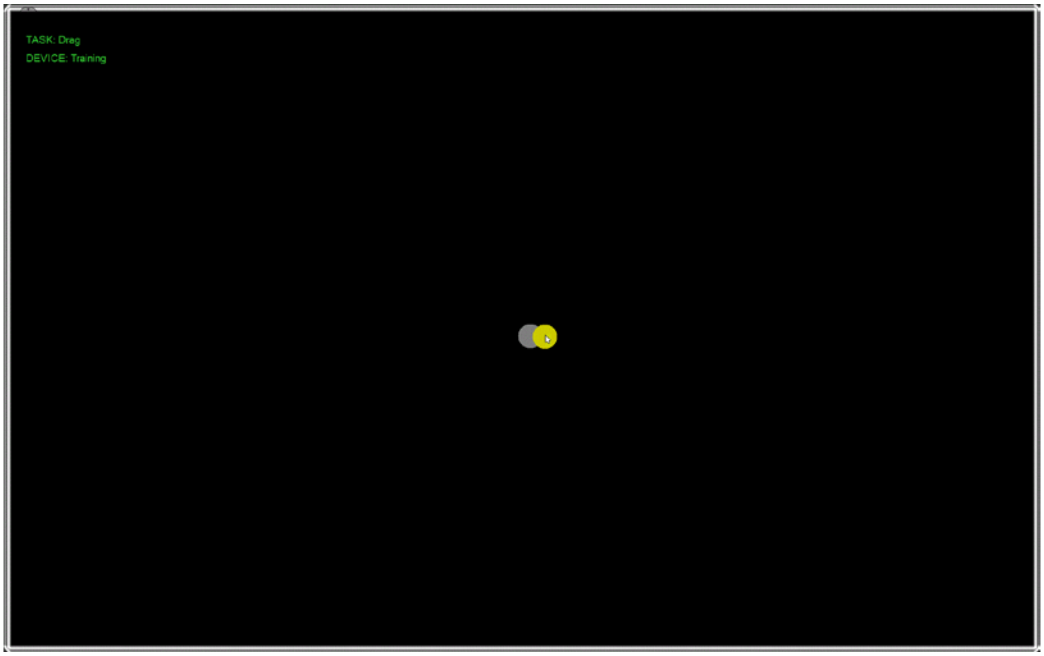

Figure 9. Dragging task.

In the *zooming* task (see Figure 10), two circles (one translucent grey, one yellow) appeared centered on a black screen. Participants used the zooming mechanism to adjust the size of the yellow circle to match that of the target grey circle. The measure of interest was the time elapsed from the beginning of zoom until the participants matched the circle sizes and clicked to indicate completion. There were 18 test trials.

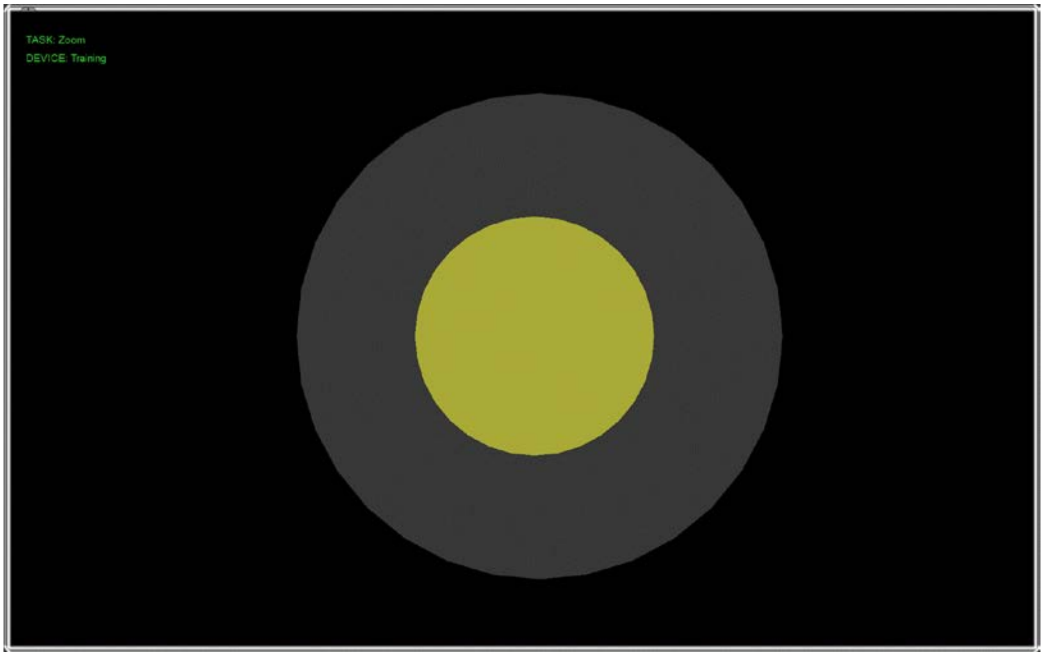

Figure 10. Zooming task.

2.6 Analyses

In all analyses, the standard mouse was treated as a baseline condition against which the effectiveness of the other control devices was evaluated. Related samples t-tests were used to examine all of the objective measures of performance and subjective measures that used interval-level scales. The Wilcoxin signed ranks test (Wilcoxin, 1945) was used to examine participants' subjective rankings of the devices collected in the post-study questionnaire. The Wilcoxin signed ranks test is the nonparametric analogue of the ordinary 2-related samples t-test. It is used when the distributional assumptions that underlie the t-test cannot be met. We had no clear expectation of how performance would be affected by control device. As a result, non-directional (2-tailed) tests were used. All statistical tests used a 0.05 Type I error rate.

3.0 RESULTS

Participants' self-reported level of experience varied among the devices. Paired samples t-tests indicated that they were more familiar with the standard mouse and keyboard (office setting; mean = 4.00) than with any of the other devices. With one exception, all comparisons with the standard mouse and keyboard (office setting) were statistically significant: standard mouse and keyboard (computer gaming) (mean = 2.25, $t_{(11)} = 4.98$, $p < .01$), touchpad with fingers (mean = 3.00, $t_{(11)} = 3.63$, $p < .01$), and touchpad with stylus (mean = 2.17, $t_{(11)} = 6.16$, $p < .01$). The difference with video game controllers (mean = 3.33, $t_{(11)} = 1.87$, $p < .10$) was not significant.

3.1 Task Performance

Tables 2 through 5 summarize the task performance comparisons between the standard mouse and other control devices for each task. Task performance was measured by average response time across trials for the neutral point movement, dragging, and zooming tasks. Task performance for the tracking task was measured by average root mean square error across trials.

Sixteen of the 20 comparisons between the standard mouse and the other five devices were statistically significant. In all instances where the difference was statistically significant, the standard mouse outperformed the other devices (i.e., lower response time, smaller RMS error). The standard mouse outperformed all other devices on the neutral point movement and dragging tasks. It outperformed the Belkin n52te, Saitek Cyborg Command Unit, and Xbox 360 controller on the tracking task and the Saitek Cyborg Command Unit, Wacom Bamboo Fun with stylus, and Wacom Bamboo Fun with touch on the zooming task.

Table 2. Neutral Point Movement Task Average Response Time: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	1.17	0.123				
Belkin n52te	3.71	0.563	0.148	-17.167	11	.000
Saitek Cyborg Command Unit	2.88	0.885	0.227	-7.521	11	.000
Wacom Bamboo Fun with Stylus	1.76	0.229	0.056	-10.487	11	.000
Wacom Bamboo Fun with Touch	2.42	0.293	0.057	-21.465	11	.000
Xbox 360 Controller	2.68	1.368	0.373	-4.038	11	.002

Table 3. Tracking Task Average Root Mean Square Error: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	0.0612	0.0173				
Belkin n52te	0.2948	0.1236	*****	-6.649	11	.000
Saitek Cyborg Command Unit	0.4468	0.1741	*****	-7.679	11	.000
Wacom Bamboo Fun with Stylus	0.0924	0.0839	*****	-1.344	11	.206
Wacom Bamboo Fun with Touch	0.2274	0.2867	*****	-2.029	11	.067
Xbox 360 Controller	0.3564	0.1976	*****	-5.221	11	.000

Table 4. Dragging Task Average Response Time: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	1.64	0.256				
Belkin n52te	5.04	1.178	0.312	-10.905	11	.000
Saitek Cyborg Command Unit	4.54	1.367	0.356	-8.135	11	.000
Wacom Bamboo Fun with Stylus	2.18	0.450	0.186	-2.904	11	.016
Wacom Bamboo Fun with Touch	4.08	0.992	0.288	-8.472	11	.000
Xbox 360 Controller	4.75	3.053	0.857	-3.626	11	.005

Table 5. Zooming Task Average Response Time: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	4.30	0.660				
Belkin n52te	4.42	0.645	0.166	-0.713	11	.491
Saitek Cyborg Command Unit	4.870	1.088	0.194	-2.928	11	.014
Wacom Bamboo Fun with Stylus	5.15	1.121	0.222	-3.840	11	.003
Wacom Bamboo Fun with Touch	10.65	1.584	0.445	-14.275	11	.000
Xbox 360 Controller	4.02	1.131	0.255	1.089	11	.299

3.2 Subjective Ratings

Tables 6 through 9 summarize the subjective ratings comparisons between the standard mouse and other control devices for each task. Ratings were on 5-point scale: 1 - very poor, 2 - poor, 3 - neutral, 4 – good, 5 - very good. Participants rated the performance of the standard mouse equal to or better than that of the other devices on all 4 tasks. The mouse was rated higher than all other devices for the neutral point movement task and higher than 4 of 5 alternative devices for the tracking and dragging tasks (the exception was the stylus which was not significantly different from the mouse). The mouse performance was not significantly different from the other devices on the zooming task.

Table 6. Subjective Ratings of the Neutral Point Movement Task: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	4.58	0.669				
Belkin n52te	3.25	1.289	0.355	3.752	11	.003
Saitek Cyborg Command Unit	3.67	0.651	0.260	3.527	11	.005
Wacom Bamboo Fun with Stylus	3.92	0.669	0.188	3.546	11	.005
Wacom Bamboo Fun with Touch	3.67	0.778	0.260	3.527	11	.005
Xbox 360 Controller	3.75	0.965	0.366	2.278	11	.044

Table 7. Subjective Ratings of the Tracking Task: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	4.33	0.888				
Belkin n52te	1.50	0.674	0.297	9.530	11	.000
Saitek Cyborg Command Unit	1.58	0.996	0.329	8.370	11	.000
Wacom Bamboo Fun with Stylus	3.83	1.403	0.435	1.149	11	.275
Wacom Bamboo Fun with Touch	3.00	0.953	0.376	3.546	11	.005
Xbox 360 Controller	2.17	1.115	0.458	4.733	11	.001

Table 8. Subjective Ratings of the Dragging Task: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	4.58	0.515				
Belkin n52te	3.17	1.030	0.288	4.926	11	.000
Saitek Cyborg Command Unit	3.25	1.055	0.310	4.304	11	.001
Wacom Bamboo Fun with Stylus	4.08	0.900	0.230	2.171	11	.053
Wacom Bamboo Fun with Touch	3.42	1.165	0.241	4.841	11	.001
Xbox 360 Controller	3.33	0.888	0.305	4.103	11	.002

Table 9. Subjective Ratings of the Zooming Task: Means, Standard Deviations, and t-tests.

Device	Mean	SD	Paired Differences (Mouse vs. Other Device)			
			SE	t	df	2-tailed Prob.
Standard Mouse	3.83	0.718				
Belkin n52te	3.67	0.888	0.271	0.616	11	.551
Saitek Cyborg Command Unit	3.67	0.985	0.322	0.518	11	.615
Wacom Bamboo Fun with Stylus	3.17	1.193	0.449	1.483	11	.166
Wacom Bamboo Fun with Touch	3.50	1.087	0.414	0.804	11	.438
Xbox 360 Controller	4.08	0.793	0.279	-0.897	11	.389

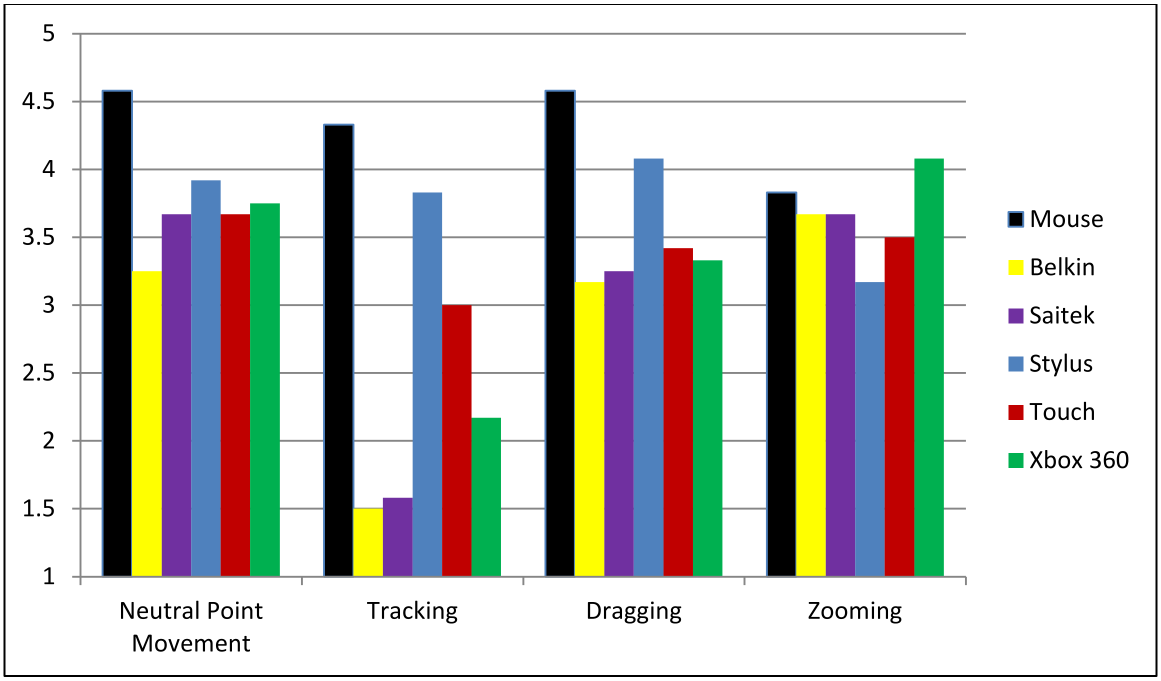

Figure 11. Subjective ratings of performance for each task by device.

Similar results were observed for participants' post-study rankings of the standard mouse versus the alternative devices for the 4 tasks. The standard mouse was ranked higher than the other devices on 12 of 20 comparisons. The mouse performance was not ranked significantly different from the other devices on the zooming task. A summary of the Wilcoxin comparisons is provided in Tables B-1 through B-4 and Figures B-1 through B-5.

4.0 DISCUSSION

As one would expect, participants performed the standard move-and-click and dragging tasks best with the mouse. Participants indicated a high level of experience and comfort with the mouse. They also required little to no training with the mouse, as they had performed similar tasks in day-to-day home and office use. The mouse, however, did not provide for significantly better performance on the zooming and tracking tasks in comparison with some of the evaluated devices. For zooming, the Xbox 360 controller and Belkin n52te (which featured a scroll wheel similar to that of the mouse) were not significantly different from the standard mouse in performance. The Wacom Bamboo Fun, in both the stylus and touch conditions, did not perform significantly differently than the mouse on the tracking task. The lack of significant difference in performance between the mouse and Xbox 360 controller on the zooming task, and the mouse and Wacom Bamboo Fun (utilizing touch or stylus) on the tracking task, is of interest due to the lack of experience and minimal training with each device.

This study was intended to relate specific attributes of each device to the individual tasks at which they excelled. By assessing the devices' performance levels at specific tasks, the origins of their performance scores can be assessed and the features most successfully implemented can be identified. Participants largely identified their familiarity with the mouse and its ergonomic design (comfort) as its strengths. For simple, repetitive tasks, such as the neutral point movement and dragging tasks (in which the mouse excelled), it is important to use a device that is comfortable and feels natural in order to avoid fatigue. Also identified as a strength of the mouse was the ability to easily control the cursor at whatever speed was desired with minimal movement and concentration required by the user.

Ergonomically, the Xbox 360 controller was rated well by participants. They enjoyed the ability to utilize both hands and relax their posture with the controller in their laps. What is of interest is that the zooming task required the use of 3 buttons (zoom in, zoom out, accelerated zoom) and that the button layout and design on this device provided for excellent performance. The "bumper" buttons ("RB" and "LB") seemed advantageous for the zooming task because they allowed the participants the ability to comfortably coordinate use of their index fingers while allowing full thumb movement. This arrangement allowed for excellent bimanual coordination to manipulate zoom in and zoom out with accelerated zoom for quick and accurate inputs. While the Belkin n52te also performed well, it utilized the same feature (a scroll wheel) for the zooming task as was present on the standard mouse. Therefore, the lack of a significant difference in the performance between the two devices on the zooming task is expected.

In the tracking task, the Wacom Bamboo Fun with touch operated similarly to the mouse using relative positioning—that is, one can pick up the mouse and reposition it without affecting the cursor on the screen. By contrast, the Wacom Bamboo Fun with stylus operated with absolute positioning. Absolute positioning is implemented on the Wacom Bamboo Fun with a rectangular tablet/touchpad that serves as a representation of the screen. As such, placing the stylus anywhere on the touch pad would snap the cursor to the corresponding position on the screen. Comments from the participants indicated that using either touch or stylus felt natural and familiar for use in the tracking task, with complaints centering on a limited input area (the Wacom Bamboo Fun tablet/touchpad). It is likely that the main difference between the three top performers (the standard mouse, the Wacom Bamboo Fun with touch, and the Wacom Bamboo Fun with stylus) and the bottom three performers (the Xbox 360 controller, the Belkin n52te, and the Saitek Cyborg Command Unit) in the tracking task is related to the amount of control that participants had over the input device. The lower group of devices utilized analog sticks or a d-pad for movement of the cursor. The upper group more closely emulated direct control by allowing participants to easily manipulate the speed of the cursor movement and its position.

Participants' comments for the standard mouse noted its strengths revolved around its familiarity and ease of use. When weaknesses were indicated, they focused on the need to reposition the mouse when it reached the limits of the mouse pad and the difficulty in performing the zooming task.

For the Belkin n52te, 11 of 12 participants commented that it was difficult to perform diagonal movements and/or tracking. Comments for the Saitek Cyborg Command Unit focused on ergonomic issues including awkwardness in using a left-handed device, its size for people with small hands, and difficulty in performing tracking with the thumb-driven joystick. For the alternate devices, the most positive comments were for the Wacom Bamboo Fun either with the stylus or with touch. Participants indicated that the stylus was easy to use and effective for tracking and dragging tasks. Negative comments regarding the stylus indicated that it was too sensitive and was not suitable for the zooming task. Participants indicated that the touch mode was easy to use, but as with the stylus, weaknesses were indentified concerning sensitivity and calibration. Finally, participants indicated that the Xbox 360 controller was easy to use and that the two-handed configuration was desirable. However, there were some concerns with using the analog stick to control the cursor. Right-handed participants found it uncomfortable to use their left thumbs to operate the analog stick for cursor movement and thought that the analog stick was too sensitive for the tracking task.

While the researchers sought to limit confounds and provide an even field for testing the devices and their implemented features in the prescribed tasks, some issues still arose that must be mentioned. Mapping functions to the various devices was a difficult task for this study. It was impossible to enable all devices to perform to their fullest capabilities in terms of movement. The most salient example of this was the Belkin n52te. Due to interaction problems between the inner workings of the timing algorithms used in the evaluation software and the internal timers that the Belkin n52te uses to operate, cursor movement with the device was a difficult task. While vertical and horizontal movement worked fairly well, diagonal movement was severely hindered. Any movement not on the x- or y-axes was extremely slow. Participants typically opted for a path involving “up and over” movement rather than attempting to move the cursor diagonally, as they would have done with a more capable device.

The analog sticks for the Saitek Cyborg Command Unit and the Xbox 360 controller were difficult to implement effectively. In the case of the Saitek device, the movement of the cursor could not be finely calibrated. Cursor movement was slow and highly sensitive, rendering any attempt at fine movement adjustments an arduous task. Our implementation of the Xbox 360 controller required that the cursor be moved at a fixed speed throughout all tasks. In most video games that utilize this controller, the acceleration is set so that fine movements are enabled. This meant that the analog stick could move the cursor very quickly, but that participants could not make fine movements easily. The Xbox 360 controller also had complications with cursor registration. Rather than registering the point of a click at the tip of the cursor image (an arrow), the Xbox 360 controller registered it at the bottom of the image. As a consequence, upon clicking the circle to be moved in the dragging task, the circle would often “drop” at the bottom of the cursor image instead of the tip. This made it very difficult to control where the dragged circle was placed.

It would seem that one of the strengths of the Wacom Bamboo Fun with touch in the zooming task would be the ability to directly influence speed of the zooming movement with no need for a button or toggle for acceleration. However, the Wacom Bamboo Fun with touch did not perform as expected and could not interpret two-finger touch movements at the speed at which they were performed. Thus, no matter how quickly one attempted to zoom in or zoom out, the on-screen circle would enlarge or shrink at a set speed, which was sluggish. Furthermore, it would keep any movement commands in a queue. If participants attempted to have it zoom very quickly, with rapid gesture commands, it would continue the zooming motion even after they ceased providing input. This lead to participants “overshooting” the target size and was a large source of frustration for participants.

This study limited the implementation of the gaming keyboards. The Belkin n52te and Saitek Cyborg Command Unit were intended to augment the performance of the standard mouse, rather than replace it and control the cursor. As a result, these devices were designed to be operated using the left hand for occasional input control. Using the left-handed gaming keyboards as the primary input devices for the tasks studied proved difficult for a majority of our participants, as 10 of 12 indicated that they were right-handed. This means that device efficiency was not maximized because participants were forced to use their non-dominant hands.

As training progressed at a pace controlled by the participants, there was no metric in place to determine that participants were comfortable enough with a device to perform the study’s tasks adequately. Thus, participants found themselves inadequately prepared in some cases due to rushing through the training tasks. Participants would forget which inputs were required to perform the task at hand and would ask the test administrator for confirmation of the controls to be used. In future research, training to a baseline will be the desired method.

Not much research has been published for input device evaluation. Most research is proprietary to manufacturers and not available in the public domain. For that reason, this study was designed incorporating simple devices and tasks. Future research must be conducted for more complex devices in a task-saturated environment. One area of research that is of interest would be evaluating performance in bimanual coordination tasks that offer more complex stimuli and responses. In this way, one could more closely assess the full range of human manual input potential. This could involve the use of touch displays that offer greater freedom of movement and direct input, rather than exclusively evaluating indirect input devices as was done in this study.

The gaming keyboards likely have uninvestigated potential when used in concert with the mouse, as designed. Due to the limited evaluation of the gaming keyboard devices in this study, further research into their use would be required to adequately assess their full capabilities. The configuration of a left-handed gaming keyboard paired with a mouse could also be of interest in a bimanual coordination study.

New technologies arise every day. These devices provide unforeseen capabilities and potential applications. For this reason, input device evaluations must take an iterative approach which constantly implements and assesses new devices and compares them to existing technologies. Input devices are currently introduced to the market with a variety of feature combinations. The consumer must make assumptions as to what performance these devices provide in different contexts. Input device assessments allow the customers to not only better select the device required for their specific needs, but also enable them to have more robust requirements so that devices can be created that would explicitly support their unique task environments. In this case, devices that aid an operator in supervisory control of multi-RPAs may be developed that provide new capabilities and enhance performance.

5.0 REFERENCES

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Appendix A
Study Questionnaires

Demographic Questionnaire

Is your vision 20/20 or correctable to 20/20?		Yes	No	
What is your handedness?	Right	Left	Ambidextrous	
In what age group are you?	18-25	26-35	36-45	46+

Please rate your expertise with video games (circle one):

None	I never, or rarely, play video games
Novice	I occasionally play video games
Average	I have my own video game system that I use once or twice a week
Experienced	I enjoy playing video games often and can learn new games easily
Expert	I am very skilled with my favorite types of games and play them a lot

Rate computer/video game experience with the following systems *(1=Very Low, 2=Low, 3=Average, 4=High, 5=Very High)*:

Standard mouse and keyboard (office setting)	1	2	3	4	5
Standard mouse and keyboard (computer gaming)	1	2	3	4	5
Touch screens (used with fingers)	1	2	3	4	5
Touch screens (used with stylus)	1	2	3	4	5
Video game controllers	1	2	3	4	5

Post-Trial Questionnaire

For questions 1-4, please rate the device's performance on a scale of 1-5 for each of the given tasks (1 being 'very poor', 3 being 'neutral', 5 being 'very good') and add any comments you may have.

Circle the device you are evaluating:

1) Mouse

2) Belkin n52te

3) Sartek Cyborg Command Unit

4) Wacom Bamboo Fun with Stylus

5) Wacom Bamboo Fun with Touch

6) Xbox 360 Controller

1. How well do you feel this device helped you perform the neutral point movement task?

   1 2 3 4 5

2. How well do you feel this device enabled you to perform the tracking task?

   1 2 3 4 5

3. How well do you feel this device enabled you to perform the dragging task?

   1 2 3 4 5

4. How well do you feel this device enabled you to perform the zooming task?

   1 2 3 4 5

5. What were the weaknesses of this device for performance in all of the tasks?

6. What were the strengths of this device for performance in all of the tasks?

7. What modifications would you make to this device (configuration, design, button functions, etc.)? Provide illustrations if necessary.

Post-Session Questionnaire

1. Rank the following controllers in order of performance for the neutral point movement task (1-6, 1 being best performance):

Mouse	
Belkin n52te	
Saitek Cyborg Command Unit	
Bamboo Fun tablet (stylus)	
Bamboo Fun tablet (touch)	
Xbox 360 Controller	

2. Rank the following controllers in order of performance for the dragging task (1-6, 1 being best performance):

Mouse	
Belkin n52te	
Saitek Cyborg Command Unit	
Bamboo Fun tablet (stylus)	
Bamboo Fun tablet (touch)	
Xbox 360 Controller	

3. Rank the following controllers in order of performance for the tracking task (1-6, 1 being best performance):

Mouse	
Belkin n52te	
Saitek Cyborg Command Unit	
Bamboo Fun tablet (stylus)	
Bamboo Fun tablet (touch)	
Xbox 360 Controller	

4. Rank the following controllers in order of performance for the zooming task (1-6, 1 being best performance):

Mouse	
Belkin n52te	
Saitek Cyborg Command Unit	
Bamboo Fun tablet (stylus)	
Bamboo Fun tablet (touch)	
Xbox 360 Controller	

5. What were your favorite aspects of any of the controllers?

6. What were your least favorite aspects of any of the controllers?

7. What would you change, combine, or take away from any of the controllers to aid performance in the prescribed tasks?

8. Are there any other considerations you wish to bring up to the test administrator?

Appendix B
Summary of Wilcoxin Signed Ranks Tests

Table B-1. Subjective Rankings on the Neutral Point Movement Task: Standard Mouse vs. Alternative Devices – Wilcoxin Signed Ranks Test

Comparison	N Ranks		Z	2-Tailed Probability
Standard Mouse vs. Belkin n52te	Positive Ranks	11	-2.957	.003
	Negative Ranks	1		
Standard Mouse vs. Saitek Cyborg Command Unit	Positive Ranks	11	-2.721	.007
	Negative Ranks	1		
Standard Mouse vs. Wacom Bamboo Fun with Stylus	Positive ranks	8	-0.996	.319
	Negative Ranks	4		
Standard Mouse vs. Wacom Bamboo Fun with Touch	Positive Ranks	10	-1.764	.078
	Negative Ranks	2		
Standard Mouse vs. Xbox 360 Controller	Positive Ranks	9	-2.082	.039
	Negative Ranks	3		

Table B-2. Subjective Rankings on the Tracking Task: Standard Mouse vs. Alternative Devices – Wilcoxin Signed Ranks Test

Comparison	N Ranks		Z	2-Tailed Probability
Standard Mouse vs. Belkin n52te	Positive Ranks	12	-3.105	.002
	Negative Ranks	0		
Standard Mouse vs. Saitek Cyborg Command Unit	Positive Ranks	12	-3.078	.002
	Negative Ranks	0		
Standard Mouse vs. Wacom Bamboo Fun with Stylus	Positive ranks	7	-0.855	.392
	Negative Ranks	5		
Standard Mouse vs. Wacom Bamboo Fun with Touch	Positive Ranks	10	-2.496	.013
	Negative Ranks	2		
Standard Mouse vs. Xbox 360 Controller	Positive Ranks	12	-3.104	.002
	Negative Ranks	0		

Table B-3. Subjective Rankings on the Dragging Task: Standard Mouse vs. Alternative Devices – Wilcoxin Signed Ranks Test

Comparison	N Ranks	Z	2-Tailed Probability
Standard Mouse vs. Belkin n52te	Positive Ranks 12 Negative Ranks 0	-3.090	.002
Standard Mouse vs. Saitek Cyborg Command Unit	Positive Ranks 11 Negative Ranks 1	-2.999	.003
Standard Mouse vs. Wacom Bamboo Fun with Stylus	Positive ranks 9 Negative Ranks 3	-2.174	.030
Standard Mouse vs. Wacom Bamboo Fun with Touch	Positive Ranks 11 Negative Ranks 1	-2.338	.019
Standard Mouse vs. Xbox 360 Controller	Positive Ranks 10 Negative Ranks 2	-2.285	.022

Table B-4. Subjective Rankings on the Zooming Task: Standard Mouse vs. Alternative Devices – Wilcoxin Signed Ranks Test

Comparison	N Ranks	Z	2-Tailed Probability
Standard Mouse vs. Belkin n52te	Positive Ranks 9 Negative Ranks 3	-1.303	.192
Standard Mouse vs. Saitek Cyborg Command Unit	Positive Ranks 9 Negative Ranks 3	-1.711	.087
Standard Mouse vs. Wacom Bamboo Fun with Stylus	Positive ranks 6 Negative Ranks 6	-0.831	.406
Standard Mouse vs. Wacom Bamboo Fun with Touch	Positive Ranks 4 Negative Ranks 8	-0.079	.937
Standard Mouse vs. Xbox 360 Controller	Positive Ranks 6 Negative Ranks 6	-0.158	.874

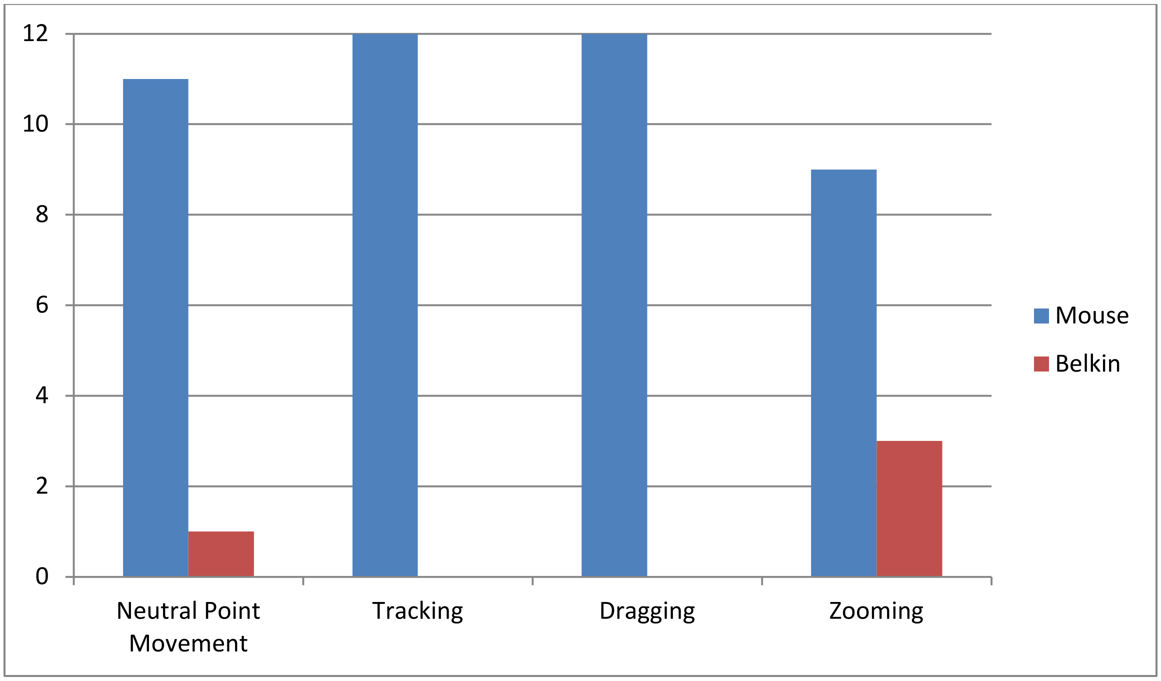

Figure B-1. Participants' preferences for standard mouse versus Belkin n52te by task.

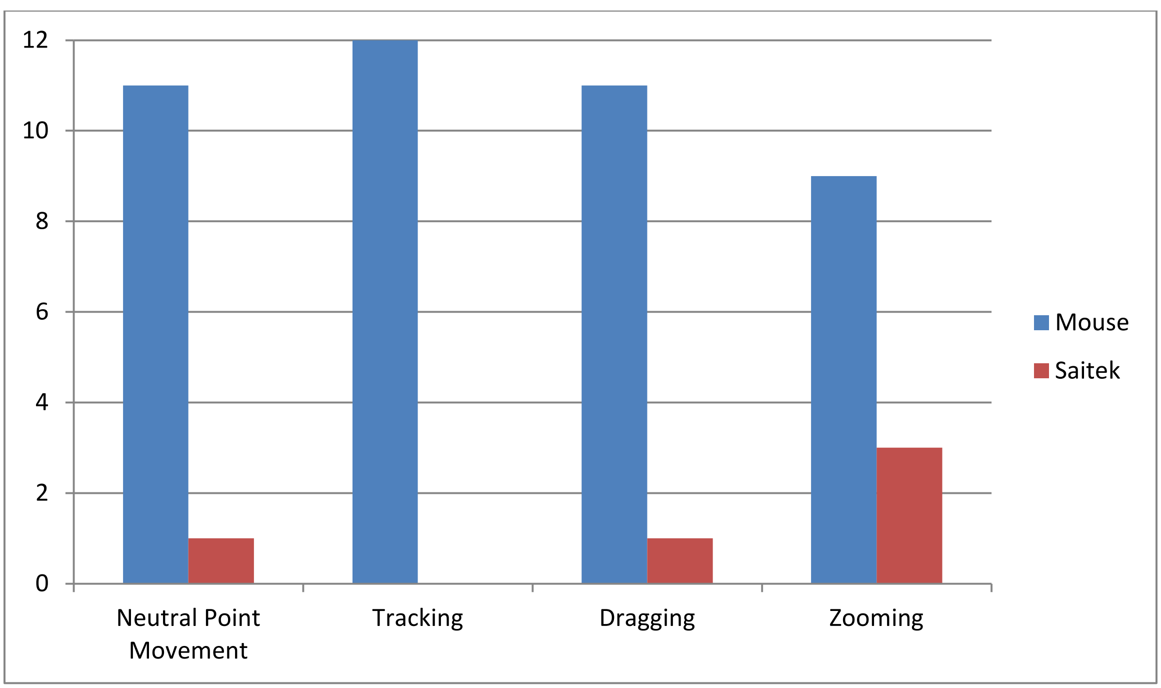

Figure B-2. Participants' preferences for standard mouse versus Saitek Cyborg Command Unit by task.

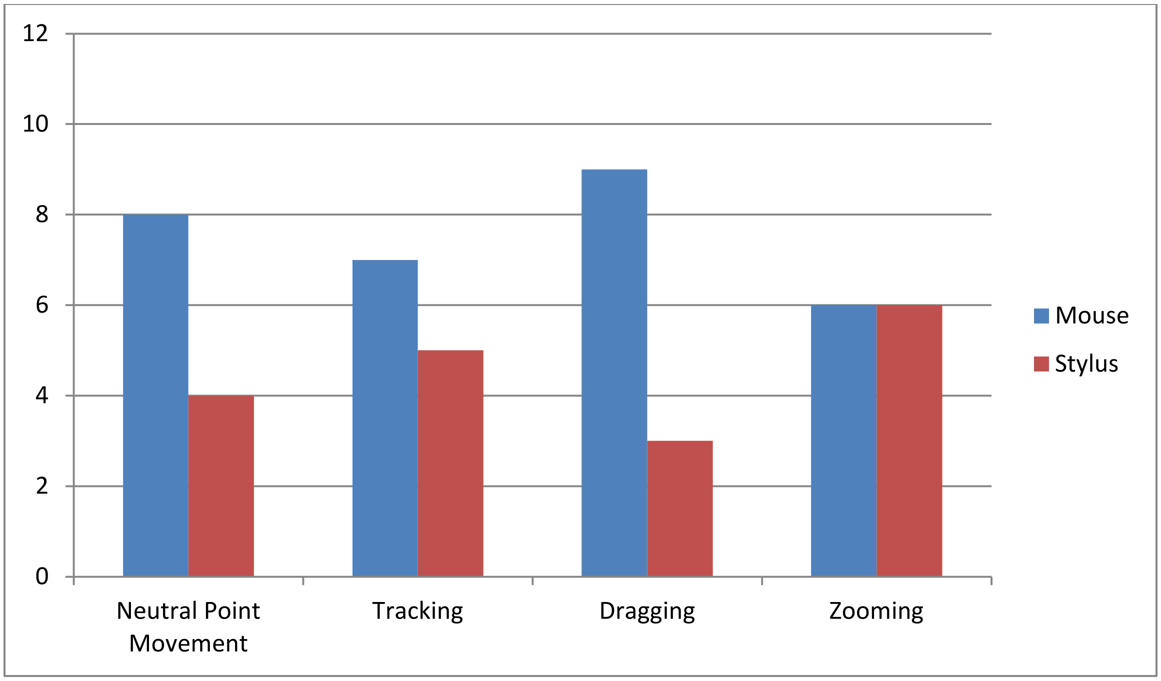

Figure B-3. Participants' preferences for standard mouse versus Wacom Bamboo Fun with stylus by task.

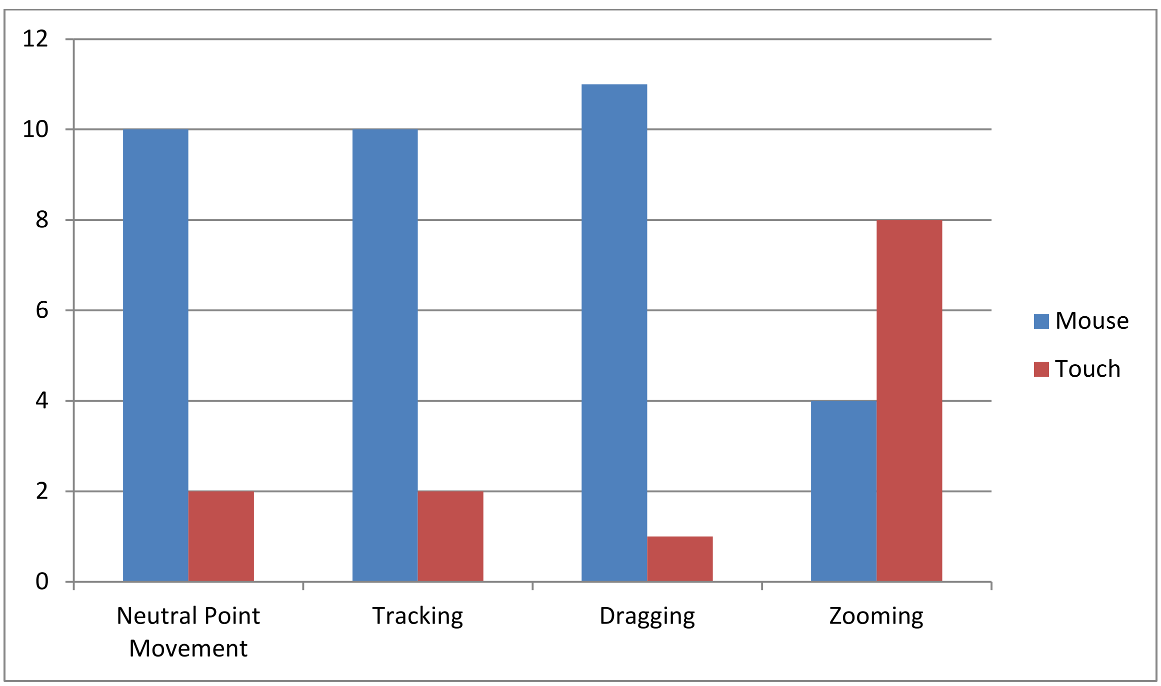

Figure B-4. Participants' preferences for standard mouse versus Wacom Bamboo Fun with touch by task.

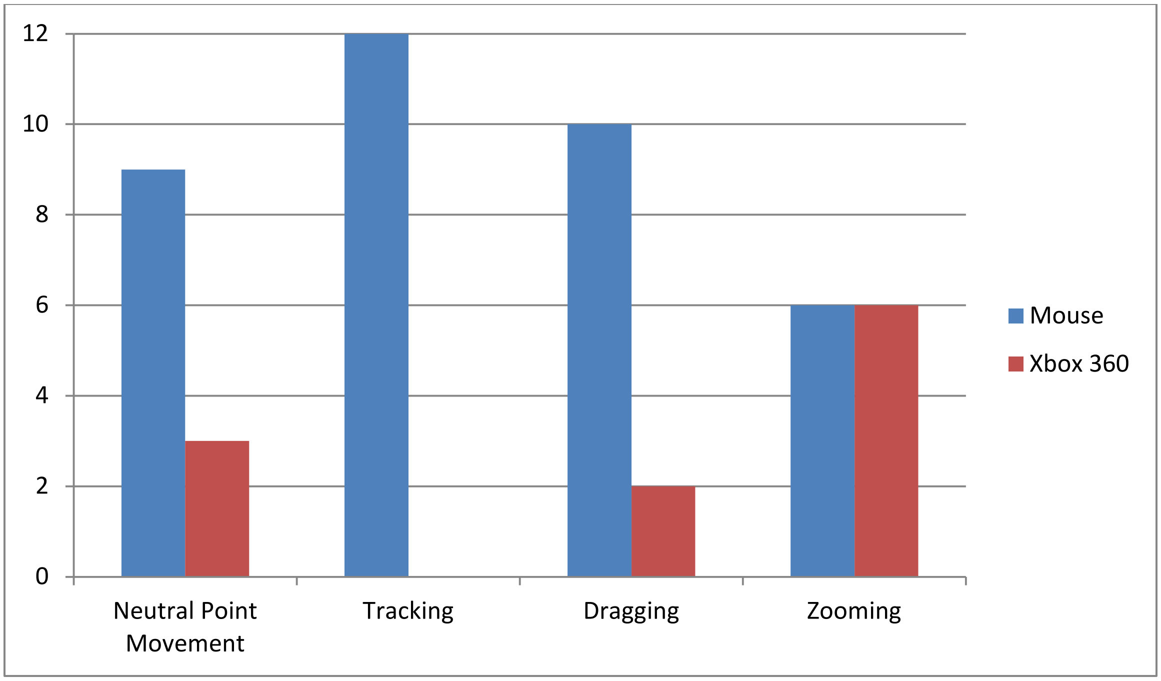

Figure B-5. Participants' preferences for standard mouse versus Xbox 360 controller by task.