# USABILITY OF VARIOUS INPUT DEVICES ON A STEERING TASK

by

IAN FUND

A thesis submitted in partial fulfillment of the requirements
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Thesis Chair: Daniel McConnell, Ph.D.

# Abstract

In this study we examined the differences of performance of various input devices on a steering task. Two paths were created, one easy and one hard, with the harder path having more turning points to navigate with one of three different input devices: mouse and keyboard, Xbox 360 controller, and a joystick. Participants were also exposed to low or high stress conditions. High stress was caused by playing loud short bursts of music over headphones worn by participants during testing. Results indicated the mouse and keyboard performed better in all cases. There was no significant difference between the Xbox controller and joystick. No differences were found in the low and high stress conditions. Differences in sex were found, even when controlling for video game experience. These findings indicate that the mouse and keyboard is the best device to use on a steering task.

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# Introduction

As technology advances humans find additional ways to interact with technology.  The U.S. Army has been using complex telecommunications devices (e.g., joysticks) to steer and pilot UGVs (unmanned ground vehicles) and UAVs (unmanned aerial vehicles). Navigators of these unmanned vehicles (UVs) piloted the vehicles via joystick and laptop they carried into the field (Axe & Olexa, 2008). There are instances of the pilots disconnecting the joysticks and hooking up Xbox 360 controllers to pilot the vehicles. These actions have sparked research investigating which input device has the best usability (i.e. accuracy, comfort, response time, etc.). Most previous research focuses on performance of input devices on tracking tasks or tasks with minimal movement (Billings & Durlach, 2010; Pettitt, Carstens, & Redden, 2012).

The earliest evaluation of input devices compared a mouse, joystick and text keys and found that the mouse resulted in faster text selection (Card, English, & Burr, 1980). MacKenzie, Sellen, and Buxton (1991; see also MacKenzie, Kauppinen, & Silfverberg, 2001) compared a mouse, trackball, and stylus with tablet on pointing and dragging tasks. The stylus outperformed the other devices on the pointing task; while the mouse outperformed on the dragging task. The trackball was the lowest device in each task.

More appropriate to performance with UGVs and UAVs are various studies that evaluated input devices on tracking tasks. Isokoski and Martin (2007) used a first person shooter (FPS) to find which input device was preferred by participants and which device had higher accuracy. Participants were to track and shoot targets in an open world. Participants preferred the mouse to keyboards and Xbox 360 controllers. Aiming on the mouse was better than the Xbox controller. Another FPS game was used to compare a mouse, PlayStation 2 controller, and a joystick on target accuracy (Lenz, Chaparro, & Chaparro, 2008). No differences were found between the devices; however, those who used the mouse took significantly fewer shots to kill the target. Finally, Klocheck and MacKenzie (2006) created a tracking task that emulated aspects of FPS games, and compared a mouse to the Xbox360 controller. They found that the mouse resulted in faster and more accurate target tracking than the gamepad. On the whole, these results suggest that a mouse is more efficient in target tracking, at least in FPS contexts.

In contrast to these findings, Rupp, Oppold, and McConnell (2015) used a simple and complex tracking task to compare performance of an Xbox 360 controller and a joystick paired with a keyboard (for the complex condition). The results indicated that even after training, performance on the Xbox controller was superior to that of the joystick and keyboard. They interpreted their findings in terms of the reduced workload associated with the game controller in the difficult version of the task. Importantly, they did not include a mouse in their design.

While this previous research slightly favors the mouse as the device of choice on tracking tasks, such tasks do not accurately emulate the task of the pilot of a UV, especially an unmanned ground vehicle (UGV). The pilot must control the movement of the vehicle while staying on course. Therefore, a steering task would be more appropriate for application to operators of UGVs. No research on similar steering tasks has been reported in the literature. The input devices selected for this task are: mouse, due to previous findings of success, joystick, for its use in the military as the standard input device, and Xbox 360 controller, because of its familiarity and use in the field.

Stress is a factor while pilots control UVs in the field. The usability of certain input devices may be affected by levels of stress. Stress is known to impair cognitive functioning

(Boals & Banks, 2012), and further, research has shown that use of gamepad controllers is associated with reduced mental workload (Rupp, Oppold, & McConnell, 2015). Therefore, examining the interaction between stress and device is necessary for an accurate examination of which input device performs the best. Van Gemmert and Van Galen (1997) demonstrated that audio stressors can have two effects on a task. If the task is simple, the noise can provide stimulation during the task and facilitates performance. The contrary is true if the task is complex; noise can consume cognitive resources and decrease performance on the task. On a test of graphical aiming, using a pen, reaction times were faster when a tone was scheduled to play (Van Gemmert & Van Galen, 1998). An audio stressor was included in the present experiment, which also included an easy and difficult version of the task, for the purpose of examining the dual effects of stress as a function of input device

The goal of this study is to evaluate the usability of three input devices (mouse and keyboard, joystick, and Xbox360 controller) in easy and difficult steering tasks under stressful or stress free (audio stressor or no audio stressor) conditions using a steering task. Stress and performance are related in a bell-shaped manner. Up to a point stressors can improve performance; however after that point has been reached performance suffers. (Yerkes & Dodson, 2007). UGVs are used in dangerous and stressful environments. Therefore, to have a better understanding of how each device would perform in the field a stressor was included as a condition to, somewhat, simulate a stressful environment. If it is the case the game controllers are associated with reduced mental workload, then we predict that steering performance with this device will be better than the joystick or mouse, at least in those conditions associated with increased workload, namely the difficulty steering course in the presence of the auditory stressor.

Participants should also report lower mental workload and better usability for this device compared to the others.

# Method

## Participants

Participants were 69 students from University of Central Florida, recruited using the UCF Sona system. There were 35 females and 16 males in this study (Appendix F, Table 1). No ages were recorded in data collection. Participants received partial or extra course credit for completing the study.

## Materials

A 3D path was created using the FPS game engine Garry's Mod. The map used for this study was a large, open, and grassy field. Next we used a rail create the path participants would traverse. Two long winding paths were made for participants to navigate over, one easy and one hard. The easy and hard tracks were different in their complexity and number of turns; with the easy course having 23 turns and the hard course having 80 turns. The total length of each rail was equated as well as possible, although the software did not provide a mechanism to specify the exact total length. The width of the rail was set to be as narrow as the software would allow. The height of the rail was shallow enough to allow participants to be able to jump back on if they were to fall off.  The in game physics engine is what determined when user fell off of the path. There was no visible avatar in the game; rather participants controlled a moving first-person point of view through the environment. See Appendix I for images of each course and the starting position.

The testing environment was run on Dell computers running Windows 7 with Pinnacle as the software that we used to map the Xbox controller and the joystick to have mouse and keyboard functions. Participants sat approximately 26” from the monitor. The monitors used were14” displays with resolution of 1280×1024 and 60Hz refresh rate.

The stress for the high stress condition was created by playing loud short bursts (2-3 seconds) of different songs played a continuous fashion. The stressor was played on over-ear headphones worn by the participants are wearing.

The following scales were used during the study. The NASA-TLX was used to assess perceived workload associated with the controller. The Dundee Stress State Questionnaire (DSSQ) was used to assess perceived stress levels associated with each task. Finally, the Software Usability Survey (SUS) was used to measure the perceived usability of the device.

## Design

For this study a 3×2×2 mixed factorial design was used, and the variables were controller type, stress level, and task difficulty. Controller type had three levels: mouse and keyboard, Xbox controller, and joystick; controller type was a between subjects’ variable. Two levels of stress were used, high stress and low stress, and was a between subjects’ variable. Task difficulty had two levels: easy and hard. Difficulty was a repeated measures variable.

There were seven dependent variables used to measure both subjective and objective aspects of performance with the devices. First, the objective measures included the number of times the participant stopped; a stop was defined as no movement for at least one frame. Stops may indicate difficulties in navigating and staying on the path, in which the participant had to stop and perform a correction in their movement direction. Next was the number of falls from the path, which were determined by using coordinates of the avatar, and if they dropped below the elevation of the path. The last objective measures were the total time taken to complete the path, and the proportion of that total time spent off the path. The subjective measures were the SUS rating, DSSQ scores, and NASA TLX scores.

## Procedure

Participants were randomly assigned to a controller and stress condition (high or low) upon arrival. A tutorial (printed powerpoint) for the assigned condition was given to participants. Each tutorial explained the task (navigating the path) and condition (controller type and stressor) for each participant. Participants were given five minutes to acclimate themselves with the controller they would be using. This was done by giving them time to use the controller on a very simple path. Next, participants donned the over-ear headphones. Those in the stress condition listened to the loud music, while those in the no-stress condition experienced only silence via the headphones. Participants completed both easy and difficult courses the order of which was counterbalanced across participants. Immediately following the completion of one of the courses, participants completed NASA TLX, SUS, and DSSQ questionnaires administered via Qualtrics. Errors were recorded by tracking when the vertical coordinates of the avatar fell to the ground level. A demographic survey was administered as the last survey to be completed. Each participant was then thanked for their time, debriefed and released from the study.

## Results

The data of eighteen participants' were not useable due to errors in data collection. Therefore, we analyzed the remaining 51 participants' data for our research.

We used a 3×2×2 mixed design ANOVA to compare the variables, number of stops, number of falls, total time, proportion of time off path and total time, SUS rating, DSSQ scores, and NASA TLX scores to each input device and arousal level. Despite the Yerkes-Dodson law stating the relationship between arousal and task performance, arousal levels did not seem to have an effect on performance for the steering task. The demographics for sex, computer use days per week, gamepad use days per week, mouse use days per week, and video game use days per week were all considered as covariates. Sex was the only covariate that had any significant differences, and those differences were found on the variables falls, stops, and total time.

### Input Device

Comparisons made between input devices revealed a significant effect on the number of falls indicated fewer falls in the easy condition $F(1,45)=12.33$, $p < .001$ partial $\eta^2=.354$, see figures 9 and 10 for means and standard deviations. Participants stopped fewer times on the easy course, $F(1,45) =3.95$, $p = .026$ partial $\eta^2=.149$, see figures 11 and 12 for means and standard deviations, And when sex was included as a covariate, a significant effect was found. Participants had a higher proportion of time off the path on the difficult course, $F(2,45) =3.54$, $p = .037$ partial $\eta^2=.136$, see figures 13 and 14 for means and standard deviations.

### Task Difficulty

In terms of easy vs. difficult steering tasks, when sex was included as a covariate, this manipulation resulted in a significant influence on falls, with the difficult course having more stops, *F*(1,44) =7.716, p = .008 partial $\eta^2$=.149. The number of stops on the difficult course was greater than the easy course, *F*(1,44) = 9.161, p = .004 partial $\eta^2$=.172.Participants took longer to complete the difficult course, *F*(1,44) = 6.88, p = .012 partial $\eta^2$=.135. The proportion of time off path was higher in the difficult course, *F*(1,45) =3.54, p = .014 partial $\eta^2$=.127. Without sex as a covariate, the SUS showed a significant influence *F*(1,45) =4.83, p = .033 partial $\eta^2$=.097. The effect of task difficulty on reported workload was significant when sex was included as a covariate in the MANCOVA, Wilks' Lambda *F*(6,39) = 4.05, *p* = .003, partial $\eta^2$ = .38. Subsequent univariate analyses revealed that the affected subscales of the NASA-TLX included physical workload, *F*(1,44) = 5.99, *p* = .018, partial $\eta^2$ = 0.12, temporal workload, *F*(1,44) = 4.73, *p* = .035, partial $\eta^2$ = .10, and frustration, *F*(1,44) = 6.93, *p* = .012, partial $\eta^2$ = 0.14.

### Arousal

There were no significant influences of arousal on any of the dependent measures.

### Sex

When used as a covariate in the analyses of variance, sex significantly influenced number of stops *F*(1,44) = 9.161, p = .004 partial $\eta^2$=.172, total time *F*(1,44) = 6.88, p = .012 partial $\eta^2$=.135, NASA-TLX *F*(6,39) = 4.05, *p* = .003, partial $\eta^2$ = .38, and number of falls *F*(1,44) =7.716, p = .008 partial $\eta^2$=.149.

### Interactions

None of the interactions between the variables resulted in a significant effect on any of the performance measures, except the two-way interaction between Task Difficulty and Sex on falls *F*(1, 44) = 7.716, *p* =.008, partial $\eta^2$ = 1.50), stops *F*(1, 44) = 4.309, *p* =.044, partial $\eta^2$ = .089, total time *F*(1,44) = 5.02, *p* =.030, partial $\eta^2$ = .102, and NASA-TLX Wilks' Lambda

*F*(5,45) = 3.64, *p* = .006, partial $\eta^2$ = .359. Subsequent univariate analyses revealed that the affected subscales of the NASA-TLX included physical workload, *F*(1,44) = 4.141, *p* = .048, partial $\eta^2$ = 0.86, temporal workload, *F*(1,44) = 5.575, *p* = .023, partial $\eta^2$ = .112, and frustration, *F*(1,44) = 8.529, *p* = .005, partial $\eta^2$ = 0.162.

# Discussion

Contrary to our expectation that the game controller would result in better steering performance, especially in the demanding conditions involving the complex path and high stress, the mouse tended to result in better performance, as indicated by fewer falls and stops during the steering task. Rupp, Oppold, and McConnell (2015) reported that the game controller resulted in better tracking when workload demands were high, and attributed the effect to lower workloads associated with the device. In our study, there were no significant differences in reported mental workload, though there were differences in physical and temporal effort as well as frustration levels. Importantly, the game controller was associated with higher effort and frustration. It seems probable that the steering task in the current study was not as cognitively demanding as the tracking and executive function tasks used by Rupp, et al. (2015). Thus, for a single steering task without additional demands from secondary cognitive tasks, the mouse results in better performance and less frustration.

The task difficulty only had one significant influence, the system usability scale. However, there were several influences once sex was added to analysis as a covariant. The number of falls, number of stops, total time, and proportion of time off path were all significant after the covariant was added. This difference was not explained by comparing video gaming experience either. Future research could possibly explore these differences by examining spatial direction of both sexs. The NASA-TLX scale also became significant when using sex as a covariant; specifically, the areas of physical workload, temporal workload, and frustration.

We expected to find differences in performance and errors based on arousal. Surprisingly, arousal did not affect performance in any significant way.  This could be a possible limitation to the study because the form of arousal we used did not cause stress. If we did not effectively induce stress, then we might not have achieved a fair test of the hypothesis. This is especially true since there was no effect on the DSSQ measures.

Future studies could explore other stressors and also incorporate secondary tasks that are cognitively demanding (ala Rupp. Et. al., 2015) to see if the current results still hold true. The current difficulty level of the task is physically and spatially demanding but doesn’t necessarily place a load on working memory or executive control/attention. Also, future studies could explore the difference in sex effects.  We believed that differences in the sex effects would disappear after adjusting for video game experience. This did not hold and leaves the sex differences unexplained.

There were several issues with data collection that could be tuned for future research. One issue was video lag. Several participants encountered video lag during certain parts of the course. This could possibly be due to a high density of textures in the area that the computer could not process. A course that is simpler in ground textures could alleviate the problem. It is also possible that the computers used were a bit outdated and could not properly handle the graphics settings; despite all of the settings being as low as possible. Having sufficient hardware would help.

Another consideration is having the task on a different platform. The sandbox open world of Garry’s Mod gave people too much freedom. Sometimes participants would stray from the path or accidently turn themselves around. The ideal program would be one that holds their hand through the task; like pointing them in the right direction and giving them no other way to go (no roaming around). Also, a program that would automatically fix the user’s error would improve data collection. During this experiment participants were instructed to jump back on the path if they were to fall off. That leaves a lot of variance in the time participants were off the path; with some falling off and never jumping back on. A solution to this would be a platform that automatically corrects errors. For this task it would put the user back on the path exactly where they fell off.

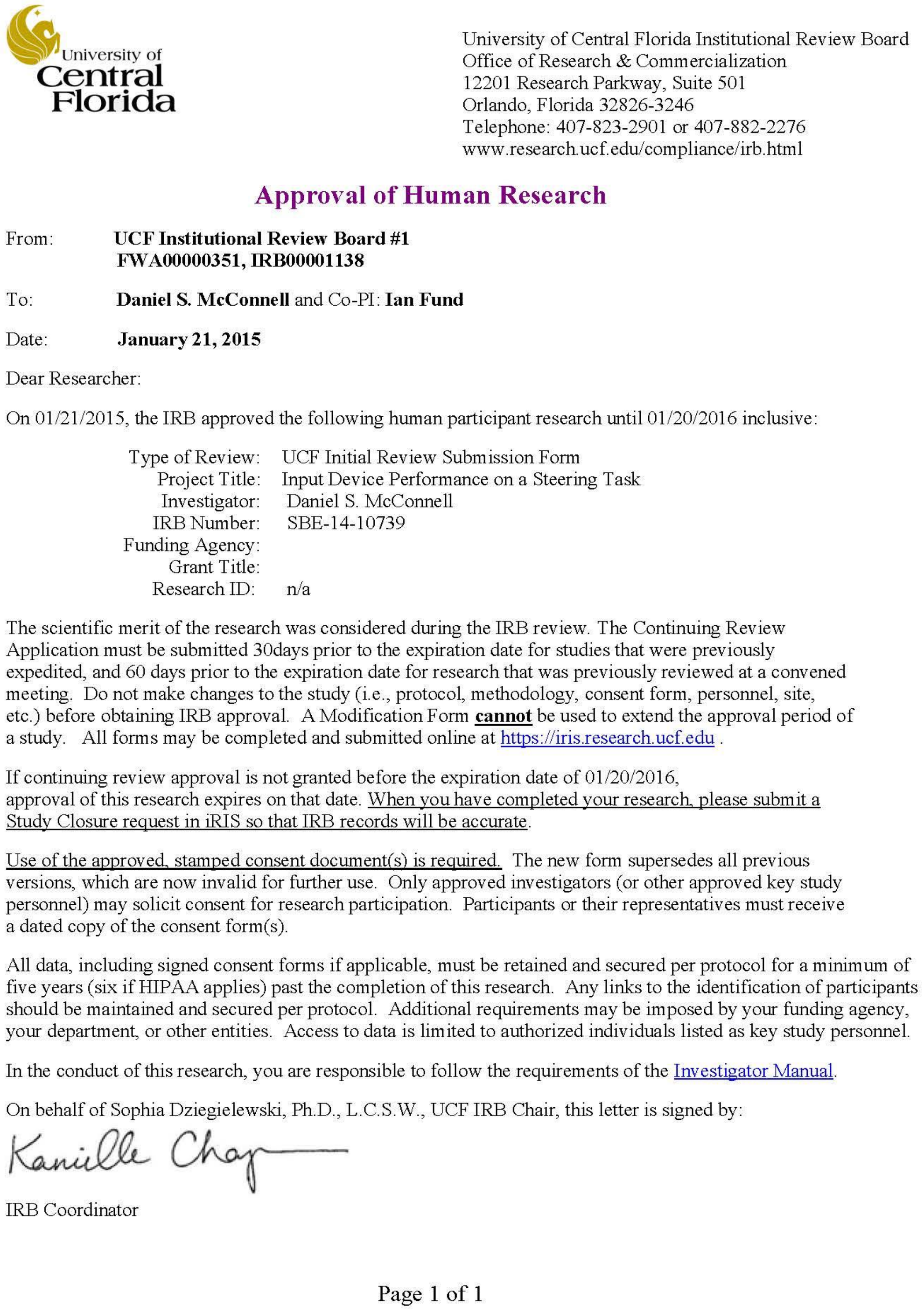
Steering wheels were not included in the experiment as in input device because they are not typically used in the field. However, steering wheels perform well on steering tasks because they are either good at those types of tasks or the amount of practice we have with them in vehicle use gives them an edge in performance. Also, steering wheels are not easily mobile which makes its practicality in the field lower. Perhaps a small steering wheel on a handheld device, such as some toy racecars have, could be an input device that performs well on steering tasks, and future studies using such a device may provide a different result in comparison to the mouse.

A possible explanation for the mouse outperforming the other devices is that the mouse requires less overall movement. The only time the mouse is moved is when the participant encounters a turn. Other than turns, the mouse is mostly kept still. The Xbox controller and the joystick both require constant force and adjustments to keep on the path. It may be useful for further research to investigate device performance on a task where all input devices are constantly being used and require adjustments.

Our results indicate that the best input device for a steering task, and therefore UGV navigation, is a mouse and keyboard. Some limitations of the usefulness of the mouse and keyboard for UGV control in the field is the requirement of having a hard and flat surface to use the mouse on. Mouse is not ideal for field use, thus more research on input devices for steering that can overcome the problems the game controller and joysticks that we found but are still usable in the field.

Since the nature of this research is focused on finding the best input device for operators of UGVs, more research in the field is required. Safety is the number one concern when it comes to using UGVs, and it is possible that using a better input device could save lives in combat areas.

# Appendix A: IRB Approval



University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

## Approval of Human Research

From: **UCF Institutional Review Board #1**
**FWA00000351, IRB00001138**

To: **Daniel S. McConnell** and Co-PI: **Ian Fund**

Date: **January 21, 2015**

Dear Researcher:

On 01/21/2015, the IRB approved the following human participant research until 01/20/2016 inclusive:

Type of Review: UCF Initial Review Submission Form
Project Title: Input Device Performance on a Steering Task
Investigator: Daniel S. McConnell
IRB Number: SBE-14-10739
Funding Agency:
Grant Title:
Research ID: n/a

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 01/20/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a dated copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Kanielle Chap

IRB Coordinator

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# Appendix B: Female and Male Stops

**Figure 1**

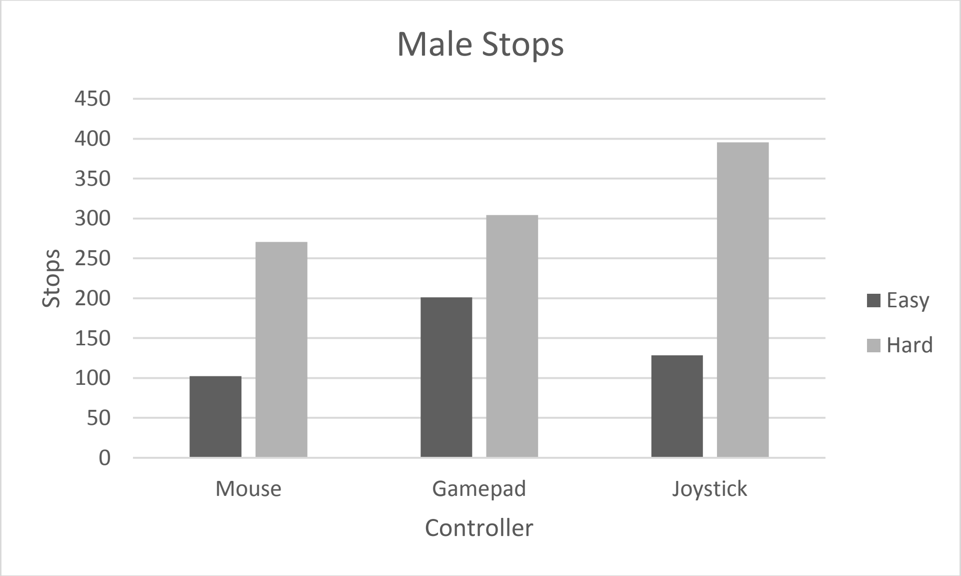

**Figure 2**

# Appendix C: Female and Male Proportion of time off path and total time

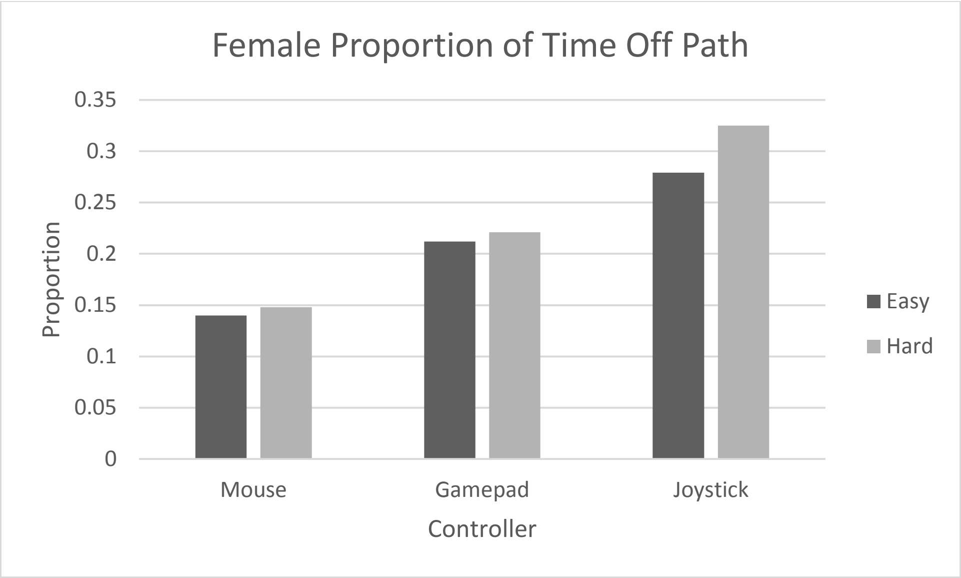

**Figure 3**

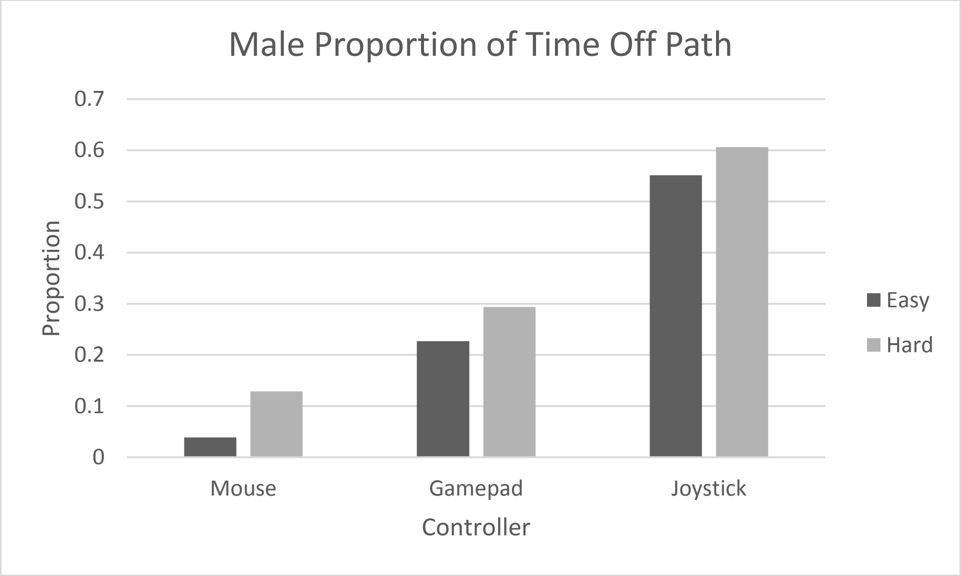

**Figure 4**

# Appendix D: Female and Male Total Time

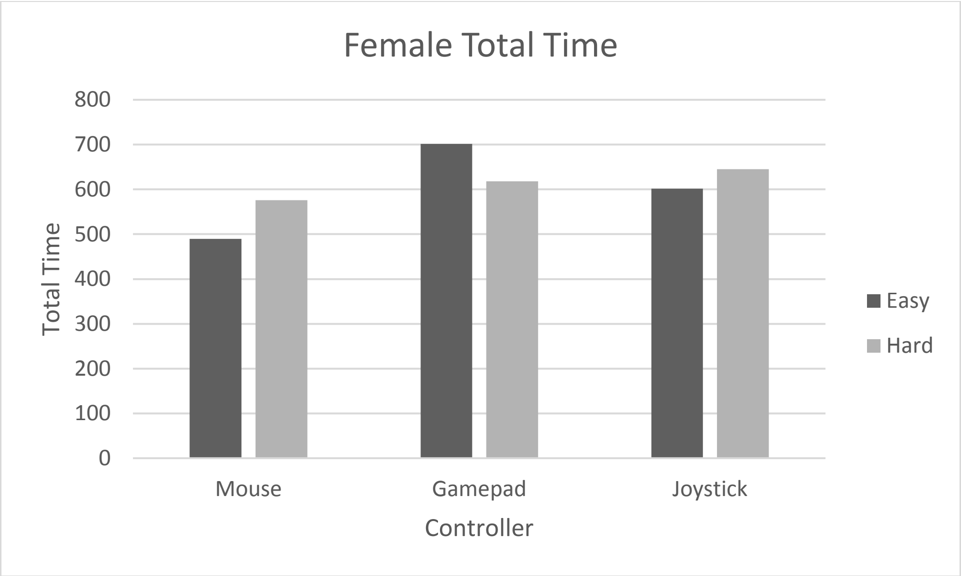

**Figure 5**

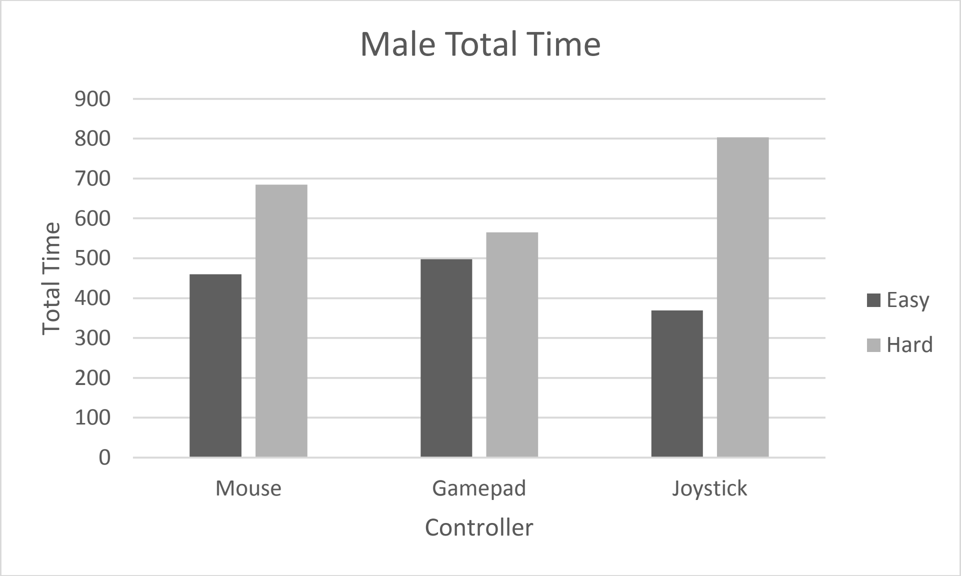

**Figure 6**

# Appendix E: Female and Male SUS Scale

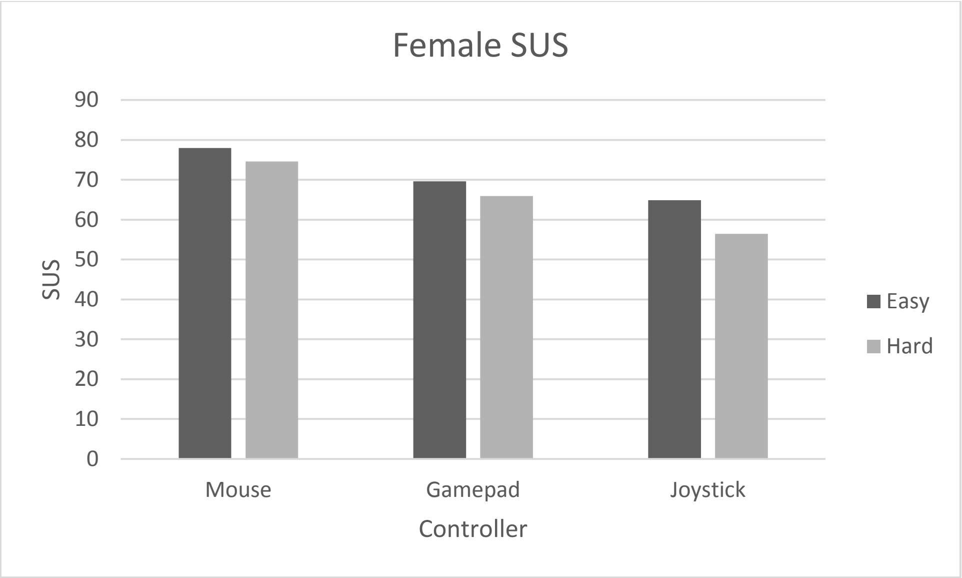

**Figure 7**

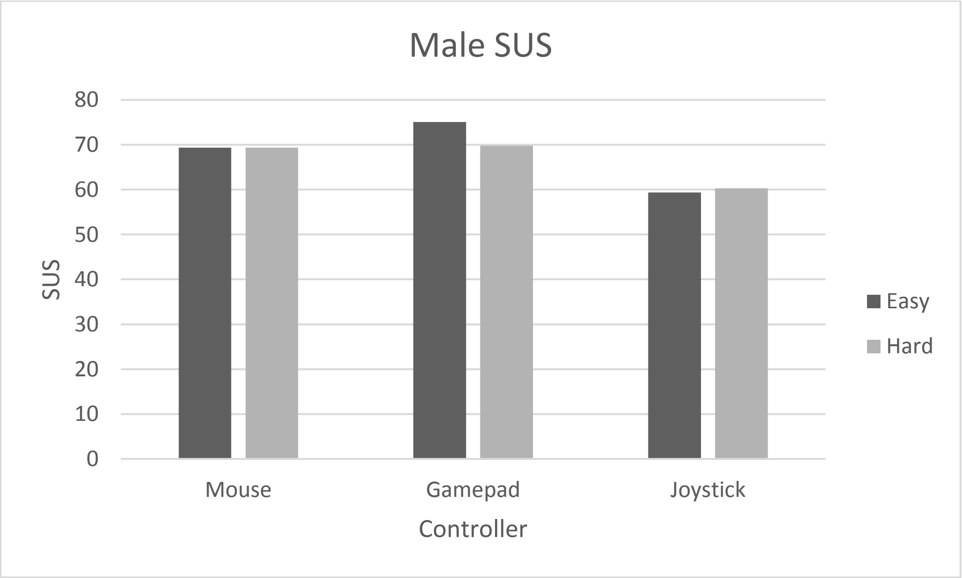

**Figure 8**

# Appendix F: Sex and Variables

**Table 1**

| Sex | Frequency | Percent |
|---|---|---|
| Female | 35 | 68.6 |
| Male | 16 | 31.4 |
| Total | 51 | |

**Table 2**

| Variables | Mean | Std. Deviation |
|---|---|---|
| Comp d/w | 6.7551 | 0.6301 |
| Comp h/d | 4.4314 | 2.8792 |
| Gamepad d/w | 1.42 | 2.0809 |
| Gamepad h/d | 1.4804 | 3.0446 |
| Mouse d/w | 5.5918 | 2.3266 |
| Mouse h/d | 3.9412 | 5.9276 |
| Music d/w | 4.6863 | 2.3366 |
| Music h/d | 2.3745 | 1.8599 |
| Video games d/w | 2.3745 | 2.265 |
| Video games h/d | 1.902 | 3.0637 |

# Appendix G: Descriptive Statistics for Easy and Hard Falls and Stops

| Device | Mean | Std. Deviation |
|---|---|---|
| Mouse | 16.88 | 27.124 |
| Xbox | 128.65 | 102.705 |
| Joystick | 77.78 | 77.194 |

**Figure 9 Easy Falls**

| Device | Mean | Std. Deviation |
|---|---|---|
| Mouse | 32.31 | 34.197 |
| Xbox | 111.12 | 77.802 |
| Joystick | 94.56 | 73.385 |

**Figure 10 Hard Falls**

| Device | Mean | Std. Deviation |
|---|---|---|
| Mouse | 124.81 | 94.965 |
| Xbox | 256.53 | 187.486 |
| Joystick | 186.2 | 144.057 |

**Figure 11 Easy Stops**

| Device | Mean | Std. Deviation |
|---|---|---|
| Mouse | 237.06 | 95.397 |
| Xbox | 310 | 143.523 |
| Joystick | 294.5 | 143.323 |

**Figure 12 Hard Stops**

# Appendix H: Descriptive Statistics for Proportion of time off path

| Device | Mean | Std. Deviation |
|---|---|---|
| Mouse | 0.124 | 0.256 |
| Xbox | 0.215 | 0.185 |
| Joystick | 0.354 | 0.359 |

**Figure 13 Easy Proportion of Time off Path**

| Device | Mean | Std. Deviation |
|---|---|---|
| Mouse | 0.145 | 0.242 |
| Xbox | 0.253 | 0.165 |
| Joystick | 0.409 | 0.348 |
| | | |

**Figure 14 Hard Proportion of Time off Path**

# Appendix I: Images of Courses

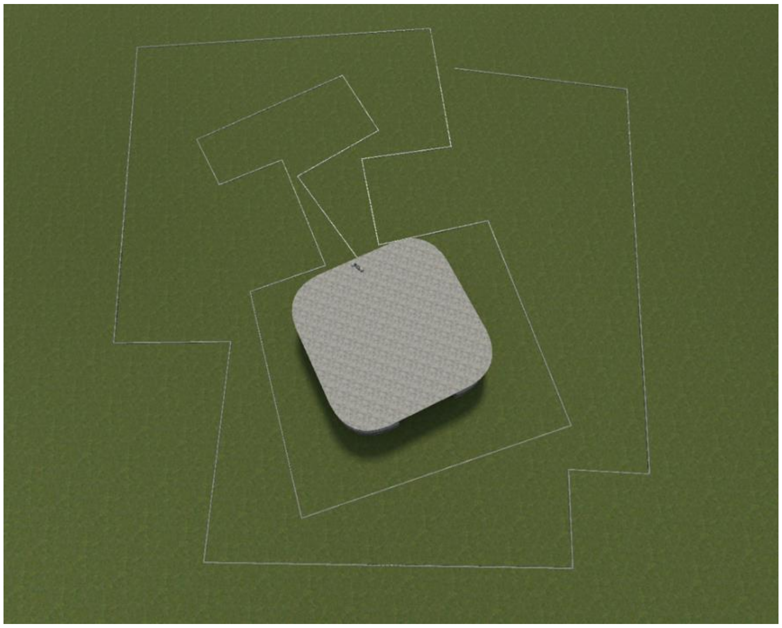

**Image 1 Easy Course**

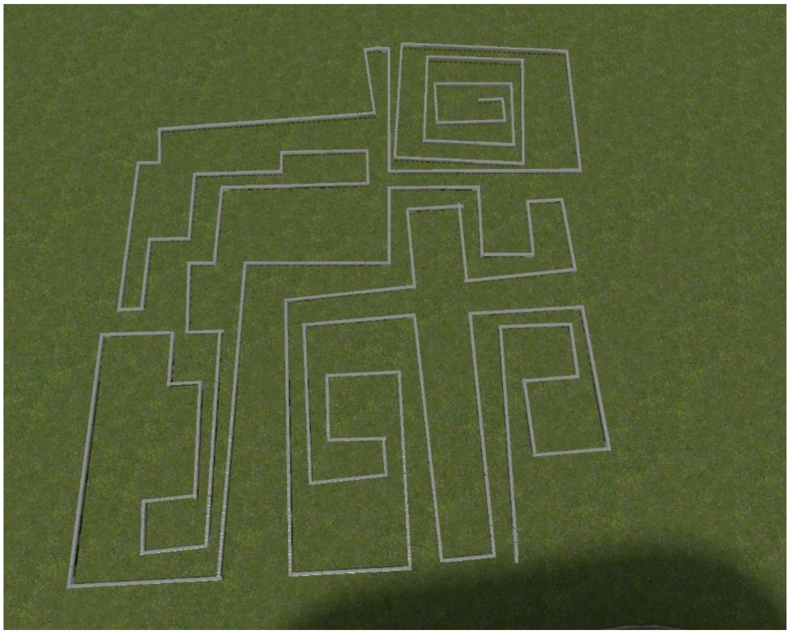

**Image 2 Hard Course**

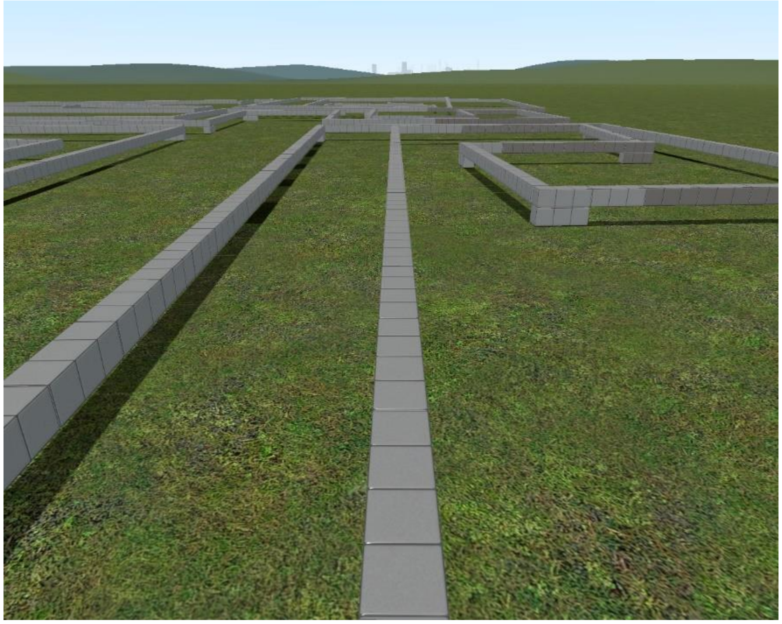

**Image 3 Starting Point**

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