Controller Interface Comparison in Unity Hospital Simulation

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INTRODUCTION

This project aimed to conduct a comprehensive analysis of two different interfaces, the Steam controller and the PlayStation 4 DualShock 4 controller, for controlling a robot. In order to streamline this process due to a 7-week course, it was decided to use a simulation of a robot in an environment for a deeper analysis. For this analysis, the robot used for comparing the interfaces is the IONA robot, which is a shared autonomous mobile humanoid robot used for nursing and living assistance. The objective of this robot is to create a versatile supporting structure that facilitates the flexible integration of system components and expand the manipulation workspace of robotic arms. This robot is implemented inside of a Unity-Ros simulation representing real-life hospital. Inside of this simulation, there are a variety of tasks that a user can complete with the robot such as navigation, carrying different objects, pushing carts, and obstacle clearance. To compare these interfaces, each controller was mapped to the simulation and students of WPI were asked to complete certain tasks. Data was taken from their experience such as ease of use, speed and efficiency, precision and accuracy, user satisfaction, task specific performance, and error handling.

OBJECTIVES

For this analysis we set out with a set of objectives on how to evaluate these two controller types. The first objective was to build and integrate these controllers into the existing unity IONA simulation. The second objective was to use the simulation to evaluate whether analog sticks (PS4) or haptic trackpads (Steam) are better for controlling the robot. The last objective was to use all this data to evaluate which controller is better suited for the implementation on autonomous mobile humanoid robots.

METHODOLOGY

A. Research Design:

This project employed an experimental research design to systematically evaluate and compare two distinct controller interfaces, the Steam controller and the PlayStation 4 DualShock 4 controller, as means of controlling the IONA robot within a Unity-Ros simulation environment. This design was chosen for its ability to provide controlled and structured assessments of the two controller types.

B. Participants:

The participants in this study consist of students from Worcester Polytechnic Institute (WPI). A total of six participants were selected to take part in the evaluation process. Inclusion criteria encompasses students with varying levels of experience in Unity Simulations and gaming to capture a broader range of perspectives.

C. Data Collection:

Data collection involved four steps, with the first step being the integration of controllers. Both the Steam controller and the DualShock 4 controller were integrated and mapped into the Unity IONA robot simulation, allowing users to control the robot and complete the tasks via these interfaces. The next step was task completion. This step first begins with the students being instructed on how to use each controller for robot control. From here they were tasked with performing a series of predefined activities within the simulation environment. These tasks included navigation, carrying objects, pushing carts, and obstacle clearance.

D. Procedures:

- Participants were given the same amount of instruction on how to use both the Steam controller and the DualShock 4 controller to control the IONA robot.
- Participants were asked to complete tasks in randomized order to minimize order effects.
- Data collection occurred during and after each task to capture performance metrics and user feedback

E. Controller Implementation

PS4 Controller:

Steam Controller:

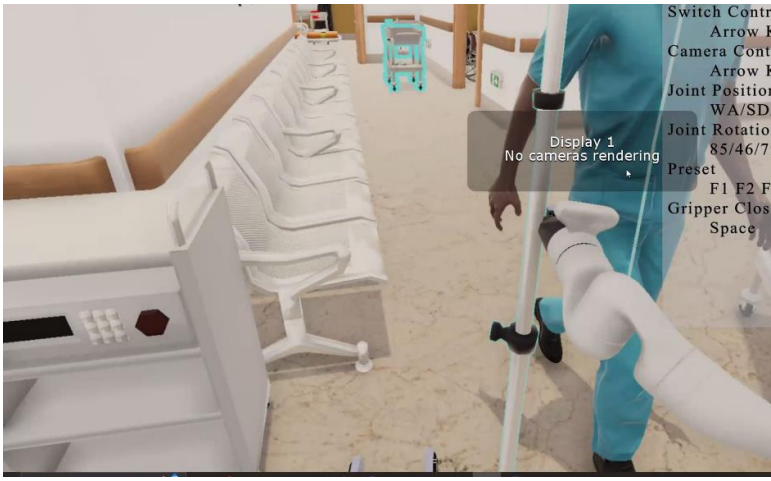
F. Tasks:

Task 1: Navigate to Goal Point

For the first challenge, players had to use triggers on the Steam controller and the D-Pad for the PS4 controller to navigate to a goal point within the simulation.

Task 2: Grab and Hold IV Pole

In the second challenge, participants had to control the robot arms and hold an IV pole while the robot arm end-effector (EE) was attached. This involves navigating to the IV pole, moving the arm towards the pole, and grasping it with the end-effector.

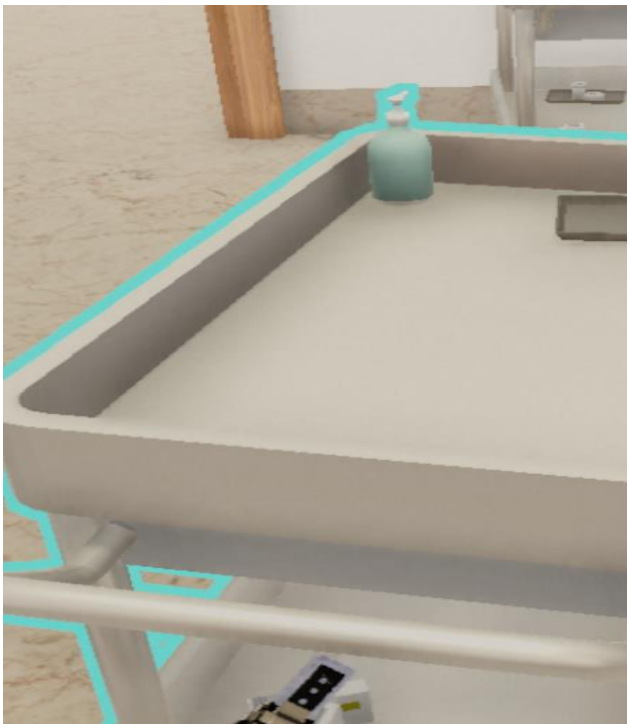


Task 3: Move IV Pole to Designated Area

This task consists of holding on to the IV pole while moving the robot, ensuring that the robot can navigate through obstacles while not letting go of the pole.

Task 4: Put End-Effectors on Cart

This task consists of orientating each end-effector and grasping both on to a cart.



Task 5: Move Cart With End-Effectors to Designated Room

This task consists of making sure that the end-effectors do not ungrasp the cart whilst moving the robot and the cart into a designated room at the end of a hallway, navigating through obstacles such as workers walking by.

G. Data Analysis:

Data analysis involved two main methods. The first method was statistical analysis where quantitative data such as speed, precision, and task-specific performance was analyzed using statistical tests to compare the performance of the two controllers. Qualitative analysis was conducted to identify recurring patterns and themes in each participant's assessment as well as a post survey where participants could highlight their experiences during the procedure.

H. Evaluation Objectives

To meet the objectives of this project the objectives were as follows:

Objective 1: Building and Integrating Controllers:

- The controllers were successfully integrated and mapped into the Unity IONA simulation, allowing the users to control the robot.

Objective 2: Evaluating Analog Sticks vs. Haptic Trackpads

- This objective was addressed by assessing and comparing the effectiveness of each for controlling robot arm movements through each task completed in the simulation.

Objective 4: Assessing and Comparing Each Controller’s suitability

- The collected data was analyzed to determine whether the Steam controller or the PS4 controller is a more suitable interface for robot control.

I. Ethical Considerations

Ethical considerations included obtaining informed consent from participants, ensuring the privacy of their data, and obtaining any necessary approvals.

J. Limitations

It is important to acknowledge the potential limitations, including the use of student participants, which may not fully represent the target user population, and the controlled nature of the simulation environment, which may differ from real-world applications.

K. Replicability

This methodology here is intended to provide a replicable framework for future research studies interested in evaluating different controller interfaces for robot control in simulated environments.

EXPERIMENT

L. Experiment Plan: Background

For this project, the study took place at Unity Hall WPI as all the students are WPI students. The experiment lasted two days with 3 participants for each day. Each experiment lasted around 50 minutes as well as a 5 minute training period where we showed participants how to use the interfaces in the simulation. One researcher was watching the participant during the simulation while the other was recording observations such as how the participant responded to each interface. The data was analyzed after each day and compared on the day after all studies were completed.

M. Experiment Plan: Training Period

In order to make sure each student had relatively the same knowledge on each interface in the simulation, we ran a training period prior to the start of the experiment. This was a two minute demo of the PS4 Controllers on the IONA robot and a two minute demo of the Steam controller as well. We then gave each participant some time to use each interface with the robot in an open area so that they could become comfortable with the simulation.

N. Experiment Plan: Running Simulation

For evaluating the participants we first ran them through a small set of trials using the robot to push a cart and pick up objects. This was done to also evaluate how the users got better as they became more comfortable with each interface as well as the robot as a whole.

O. Participant Demographics

For this experiment we chose 6 participants ranging from 19 - 21, all of which study at WPI. We do understand that this is a small n value, as well as the fact that it is not very diverse when it comes to occupation and age, but for the sake of time due to the 7 week course, this was ,the best fit for the project. These participants were all engineering students but not all Robotics majors. We looked to diversify the results of the study by picking participants that have a range of knowledge levels when it comes to their experience with robotic simulations as well as each controller interface but we were under the assumption that many of these students have no prior experience with Robot simulations. This idea lead to better results due to the fact that everyone was on the same playing field when it came to the experiment.

P. Hypothesis: Which Interface Is Better For IONA

We believed that the steam controller would be a better user interface when it comes to precise movements. Since so many people are familiar with the PS4 controller, we hypothesized that this would be the choice that many people pick but if it was a real lab setting where one could be instructed on how to use the controller for a longer period of time, the Steam controller would be the way to go.

Q. Evaluation Metrics

During the experiment, one researcher took notes on the participant and how they were interacting with the simulation. The main topics they looked at were task completion time, accuracy, efficiency, and error rate. The questions are shown below.

Task Completion Time	How quickly were participants able to complete Did you notice any significant differences in the interfaces?
Accuracy	How accurately were participants able to control Were there instances of errors or mistakes? If so the other?
Efficiency	Which interface allowed participants to complet Did you feel that one interface required less effo
Error Rate	How many errors or collisions occurred with eac Did one interface lead to more errors or misunde

R. Evaluation Metrics: Survey Questions

After the experiment, we sent out a survey so that the participants could provide input on their opinions on each interface. These questions were mainly subjective

regarding topics such as ease of use, learnability, satisfaction, preference, fatigue and comfort, feedback and awareness, and suggestions for improvement. The questions are shown below.

Which controller was more intuitive and user-friendly?
Did one interface make it easier for you to stay aware of the robot's pose and behavior?
What modifications would you suggest for either interface?
How quickly were you able to understand and be proficient with each?
Did one interface have a steeper learning curve?
One a scale of 1 - 10, how satisfied were you with each controller
Were there any aspects of one interface that you particularly liked or disliked?
If given the choice, which controller would you use for similar tasks in the future?
How tiring was each interface to use?
Did one interface make it easier for you to stay aware of the robot's pose and behavior?

PILOT STUDY

S. Participant Demographics

For the pilot study we decided to have Sam test out the experiment as he owns both controllers and has more access to the robot simulation. Sam is a 20 year old robotic engineering senior studying at Worcester Polytechnic Institute. As far as experience using robot simulation, he has some due to taking RBE 3002 (Unified Robotics IV) and testing the project that we will be conducting for the past couple of weeks. His experience with games such as Minecraft is around a ⅗ and for 3D games such as Zelda he is more proficient with a 5/5. For his experience with PS4 controllers, he is very well versed but not so much with the Steam controller (⅖). His experience manipulating robot arms is a ⅘ due to taking an industrial robotics class as well as RBE 3001 (Manipulation).

T. Pilot Experiment: Training Plan

Since Sam was the one who designed the interfaces and was setting up the training period was ignored. We realized while designing that it is less user friendly and harder to learn than we thought so we extended the training period to make the users had a better understanding of the controls. The training period will still consist of each participant using the interfaces on the IONA robot as well as time to move around in open space inside of the hospital to get a feel for each input and bind. We will be explaining to them each control as they go.

U. Pilot Experiment: PS4 Controller

For the first run with the PS4 Controller the total experiment took 8 minutes and 59 seconds. The first task, navigating to the goal point took 13.13 seconds. Grabbing the IV pole was done on the first attempt but took some time to rotate the robot arm so that the end effector was orientated correctly (28.89 seconds). Moving the IV pole was much harder, causing 6 total drops (2 minutes 20 seconds). Putting the end effectors on the cart was also a hard task lasting 2 minutes 33 seconds. The right arm was placed on the first attempt but due to the fact that we struggled to change the camera view, the left arm took 3 attempts to connect to the cart. The longest task was moving the cart to the room which took 3 minutes 6 seconds. There were 6 failures as the end effectors did not stay on the cart and the cart got stuck in the hallway. To fix this, Sam had to walk around the hallway to grab the cart from the other side.

V. Pilot Experiment: Steam Controller

For the first run with the PS4 Controller the total experiment took 6 minutes and 42 seconds*. The first task, navigating to the goal point took 10.25 seconds. Grabbing the IV pole was done on the first attempt but also took some time to rotate the robot arm so that the end effector was orientated correctly (32.26 seconds). Moving the IV pole caused 5 total drops (2 minutes 15 seconds). Putting the end effectors on the cart was also a hard task lasting 3 minutes 30 seconds. This task was ultimately stopped short due to the fact that the participant was frustrated and could not work the remote. The right arm was placed on the fourth attempt but kept unattaching and the left arm was not able to be grasped to the cart. For the 5th task, there were a total of 6 failures and the cart was ultimately moved to the room by the robots body pushing the cart.

W. Results: Evaluation Metrics

Task completion time:

How quickly were participants able to complete the assigned tasks with each controller interface?

PS4 Controller: 9 minutes

Steam Controller: Incomplete

Did you notice any significant differences in the time it took to perform tasks between the two interfaces?

The steam controller was faster pushing due to more experience moving things around

Accuracy:

How accurately were participants able to control the robot with each interface?

The steam controller was more accurate when it was not drifting but since this occurred a lot the PS4 Controller is a better interface for this.

Were there instances of errors or mistakes? If so, were they more frequent with one interface over the other?

Yes, mainly operating the end effectors due to the fact that changing the orientation was hard. In addition, the grippers had a hard time staying attached to things such as the cart and the IV.

Efficiency:

Which interface allowed participants to complete tasks with fewer steps or movements?

Depended on the task

Did you feel that one interface required less effort to achieve the same results?

PS4 Controller

Error Rate:

How many errors or collisions occurred with each controller interface?

PS4: 15 Total Errors (Experiment was completed)

Steam: 15 Total Errors before Stopping

Did one interface lead to more errors or misunderstandings with the robot's movements?

The steam controller during Task 4 (Put both EE on Cart)

The results of the evaluation metrics provided valuable insights into the performance of the two controller interfaces used in the study. In terms of task completion time, Sam exhibited varying speeds with each controller. While the PS4 Controller demonstrated efficiency with a completion time of 9 minutes, the Steam Controller's performance was incomplete. Notably, Sam attributed the Steam Controller having a slower pace due to a learning curve associated with its handling.

Accuracy in controlling the robot was a key aspect of the evaluation. The Steam Controller was acknowledged for its precision when not experiencing drifting issues. However, the frequent occurrence of drifting led to the conclusion that the PS4 Controller was a more reliable interface. Instances of errors or mistakes were primarily linked to operating the end effectors and faced difficulties in changing the orientation. Grippers struggled to maintain attachment to items like the cart and IV.

Efficiency, measured by the number of movements and failures required to complete tasks, varied based on the nature of the task. No clear advantage was attributed to a specific interface in terms of overall efficiency. However, Sam perceived that the PS4 Controller demanded less effort to achieve the same results in the tasks performed.

Error rate emerged as a crucial metric, with the PS4 Controller and Steam Controller both recording 15 total errors. Notably, the Steam Controller experienced errors that led to the decision to stop the experiment, particularly during Task 4, which involved placing both end effectors on the cart. This suggests a higher likelihood of errors and misunderstandings in the robot's movements when using the Steam Controller.

X. Results: Post Survey Response

From the Survey we found that Sam believed the PS4 controller was more intuitive and user friendly. He was able to understand both controllers the same, but this data cannot be taken due to the fact that he spent hours developing each bind for the interfaces so he has prior experience with each. He believed that the Steam controller has a steeper learning curve because when a hand is taken off the control pad, the input is still the same which causes a drift. Sam stated that he was more satisfied with a PS4 Controller (5/10) than the Steam Controller (3/10). When drift was not an issue the steam controller was very smooth and precise and the paddles to switch the modes also were user friendly. If given the choice, Sam would pick the Steam Controller if it had no drift. Each interface was tiring to use as the simulation had issues such as the gripper being very weak. “Sometimes when it feels like it should grab something it is not actually grabbing anything”. In addition to this, the arms sometimes reach singularities when one would not expect it and this then changes the orientation of the arms. One modification stated was to get rid of the steam controller and allow the mode switch to stop all of the movement.

Y. Comparison Towards Initial Hypothesis

The Steam controller benefits were not seen as much as we initially expected both due to drift on the arms as well as using the base joystick as a digital d'pad instead of an analog input. We found that the PS4 controller was a better interface to use as the task completion time was quicker and it was much more user friendly. It was also the only interface to fully complete the experiment.

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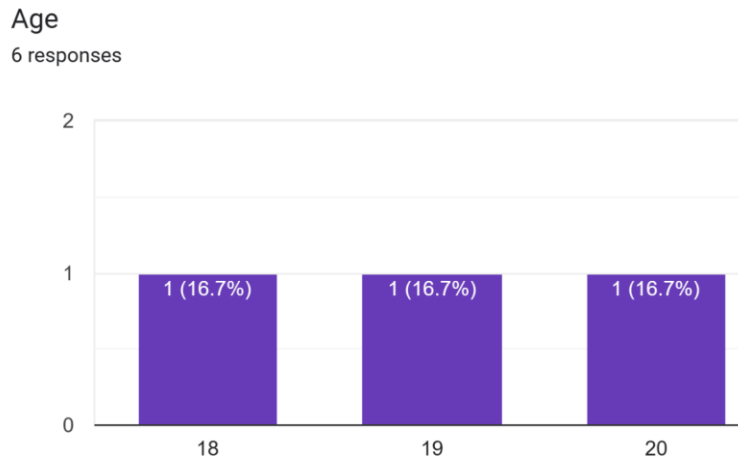
RESULTS

Z. Participant Demographics

In this study, we analyzed a total of six participants aged between 18 and 22, predominantly 21 years old (2/6) (as shown below). Regrettably, time constraints prevented the inclusion of participants beyond the typical college age range, potentially introducing bias to the overall experiment. All of the participants study in the STEM field, with 3/6 being robotics engineering students. We are confident that this does not lead to bias as the study relates to the comparison of interfaces on a robot, which is a task typically undertaken by engineers in the real world.



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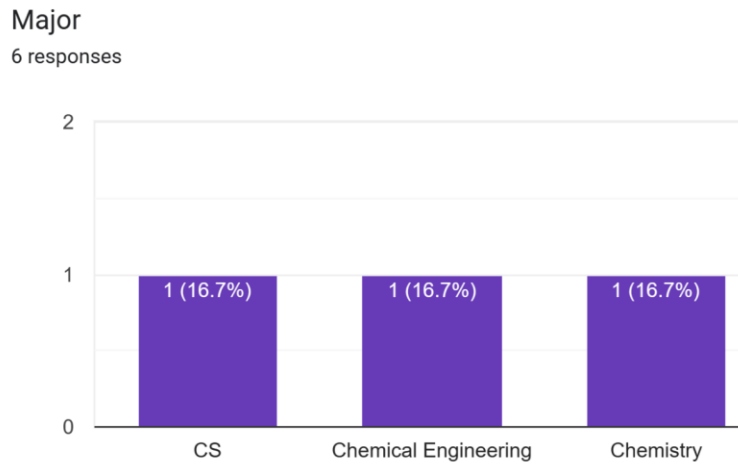
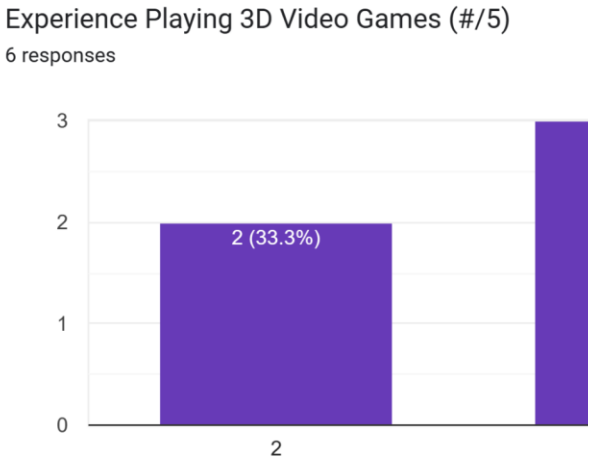
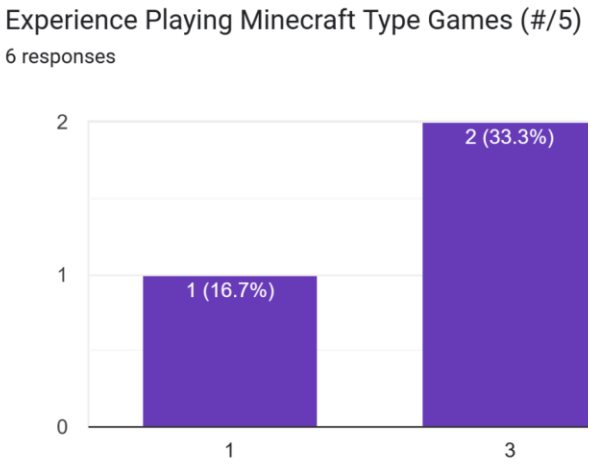


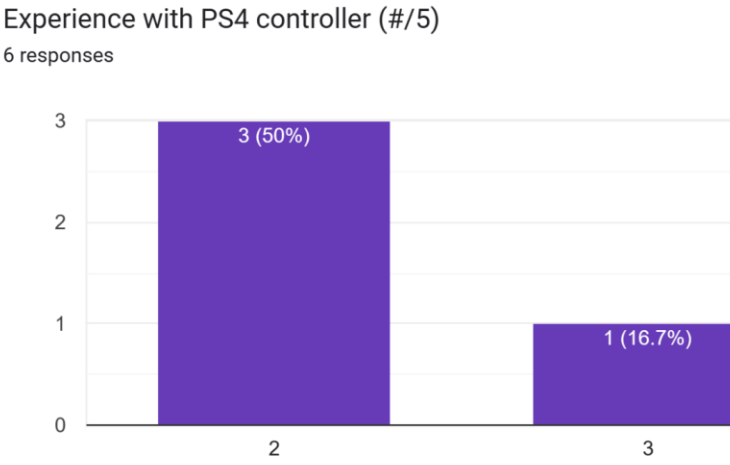
Regarding participants' experience with playing 3D video games, three rated their proficiency at ⅘, two at ⅖, and one at 5/5. This was asked to determine some of their spatial awareness which can help with reorienting the arm.



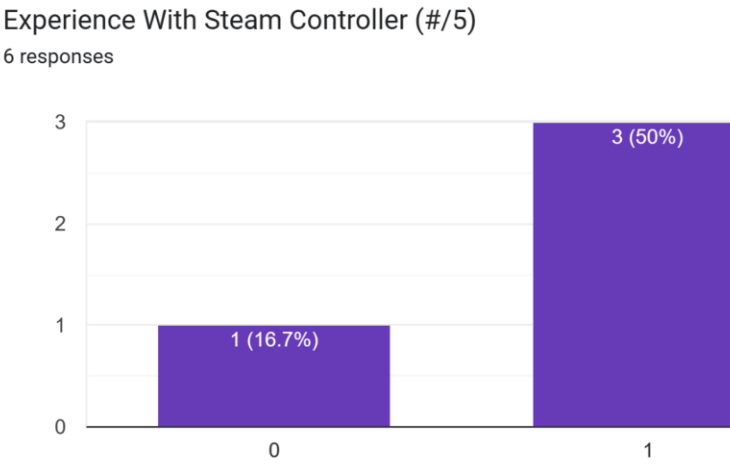
When asked about participants' experience with playing video games such as Minecraft, 1 rated their proficiency at 1/5, two at 3/5, one at ⅘, and one at a 5/5. This was asked to determine to additionally help serve with spatial intelligence but functions in a more rigid manner than many other 3d games. This is also separated due to studies showing the how Minecraft especially helps.



Among the six participants, three indicated a moderate level of inexperience with the PS4 controller (⅖), one had a proficiency level of ⅗, and the remaining two demonstrated a high level of proficiency at 4/5.

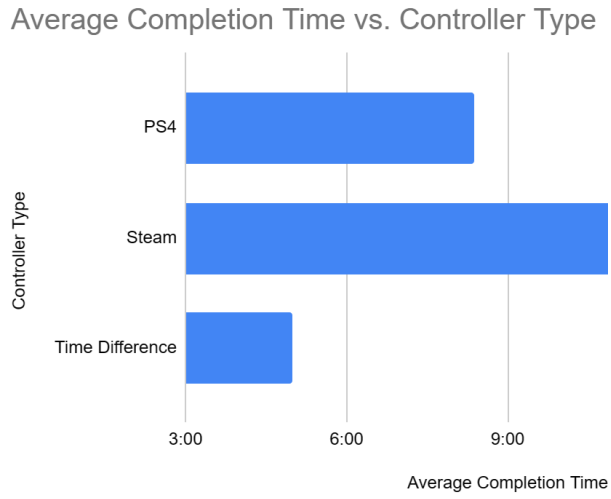


When evaluating their experience with a Steam controller, one participant reported no prior experience (0/5), three displayed a proficiency level of 1/5, and the remaining two indicated a ⅖ proficiency, collectively reflecting limited overall experience.



AA. Results: Data

The total completion time for all five tasks was 8 minutes and 22 seconds with the PS4 controller and 13 minutes and 22 seconds for the Steam controller. This is a difference of 5 total minutes. This does not account for times where individuals gave up on a task, which will be discussed later in the report.



Results: Data – Task 1

In the first challenge, players had to use triggers on the Steam controller and the D-Pad for the PS4 controller to navigate. The PS4 interface took an average of 10.16 seconds to complete, but the Steam controller took an average of 11 seconds. The tight alignment of these periods suggests a similar performance. This makes sense considering how simple the work is—it essentially consists of making sure the robot can move forward and make turns.

Results: Data – Task 2

In the second challenge, participants had to control the robot arms and hold the IV pole while the robot arm end-effector (EE) was attached. This task took the PS4 controller 46 seconds on average to complete, whereas the Steam controller took 4 minutes and 16 seconds, a significant discrepancy of 210 seconds. Interestingly, the PS4 controller took an average of 1.16 attempts to attach, while the Steam controller took an average of 2 attempts. This disparity implies that the Steam controller encountered more difficulties precisely controlling the arms.

Participants had issues with the Steam controller, specifically with the trackpad and drifting features. The longer completion time and the longer average attachment time for the Steam were caused by these difficulties.

Results: Data – Task 3

Moving the IV to a location without releasing the grip on the pole required two minutes and twenty-eight seconds on average for the PS4 controller and two minutes and forty-four seconds for the Steam controller. On average, it took both 4.2 tries to finish. It is worth noting that the data does not specifically document an instance using the PS4 controller, in which the robot needed to be returned back to the home orientation in order to resolve arm movement issues. The robot pushed the IV with its body rather than its arms because the arms were difficult to move correctly in this situation. With the Steam controller, this problem happened four times. These specifics provide important information beyond the task's typical completion durations and tries by highlighting additional complexities and difficulties encountered showing that the Steam controller may be suboptimal compared to the PS4 Controller.

Results: Data – Task 4

The PS4 controller took an average of 4 minutes and 27 seconds to complete the task of placing both end effectors onto the cart, while the Steam controller took 4 minutes and 40 seconds. This assignment in particular turned out to be difficult as there were a lot of interface-related problems, and many participants chose to give up on it.

Two students gave up on the PS4 controller, while a higher percentage of participants—five out of six—abandoned the job for the Steam controller. The main problems with the Steam controller were that it was having trouble reorienting and drifting, which eventually caused the controller to grip the robot's arms and take control of its movement. Students were clearly frustrated with this exercise, especially with the Steam controller, as seen by the high number of participants who chose to give up on their attempts.

Results: Data – Task 5

The PS4 controller completed the final task of moving the cart with the end effectors to a designated room in an average of 30.6 seconds, whereas the Steam controller took an average of 51.16 seconds. Notably, 3 students were unable to perform the assignment with the PS4 controller, instead using the robot's torso to push the cart. The difficulties were more obvious with the Steam controller, which caused all but one of the six students to push the cart with the robot's body. This highlights recurring concerns with maneuvering with the Steam controller, replicating difficulties encountered in the previous task involving grabbing onto the cart.

Post Survey Responses:

Participants generally appreciated specific features of both interfaces, such as the PS4 controller responsiveness and lack of lag, and the Steam controller back bumpers facilitating orientation mode changes. However, challenges were noted, such as the difficulty in navigating the arms

with the Steam controller and the precision required for its touchpads. Despite some differences, the controls were deemed similar, making the choice between buttons and trackpad the primary distinction.

In summary, participants had mixed preferences for each interface. The PS4 controller earned praise for its responsiveness and simplicity, particularly with joysticks that required less finger movement. On the other hand, the Steam controller was commended for its back bumpers facilitating mode changes and the separation of linear and rotational motion with variable speed. However, challenges with the Steam controller included difficulties in navigating arms precisely and mastering the touchpads. Ultimately, the decision between buttons and trackpad seemed to be the defining factor, as the overall control schemes were perceived as quite similar.

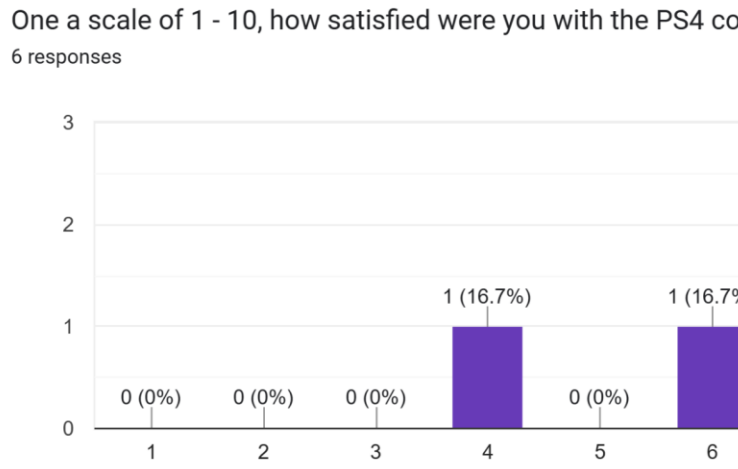
Based on their experiences with the PS4 and Steam controllers, participants made smart suggestions for interface changes. Recommendations include incorporating a return arms to home button, enabling variable speed driving with the joystick for the Steam controller, and improving grip strength sensitivity for both interfaces. While some people preferred the PS4 controller, recognizing its overall superiority, others saw the promise of the Steam controller with proper tweaking. These suggestions are intended to address issues encountered during specific jobs while also improving the overall usability and functionality of the robotic interface.

Participants generally found the PS4 controller quicker to understand and become proficient with, ranging from 1 to 2 minutes, while the Steam controller took longer, with one participant noting a 5-minute learning period. The physics engine posed challenges for quick mastery. Some participants, despite understanding basic functionality in 2 minutes, found it took longer to grasp more intricate details. Familiarity with the PS4 controller from past experience expedited the learning process for some, while others emphasized the ease of understanding but highlighted difficulties in distinguishing between manipulation and rotation.

The responses varied, with some participants perceiving both interfaces as equally challenging, while others noted a steeper learning curve with the Steam controller. Familiarity with the order of use influenced opinions, and difficulties were attributed to factors such as trackpad complexity and differences in orientation control.

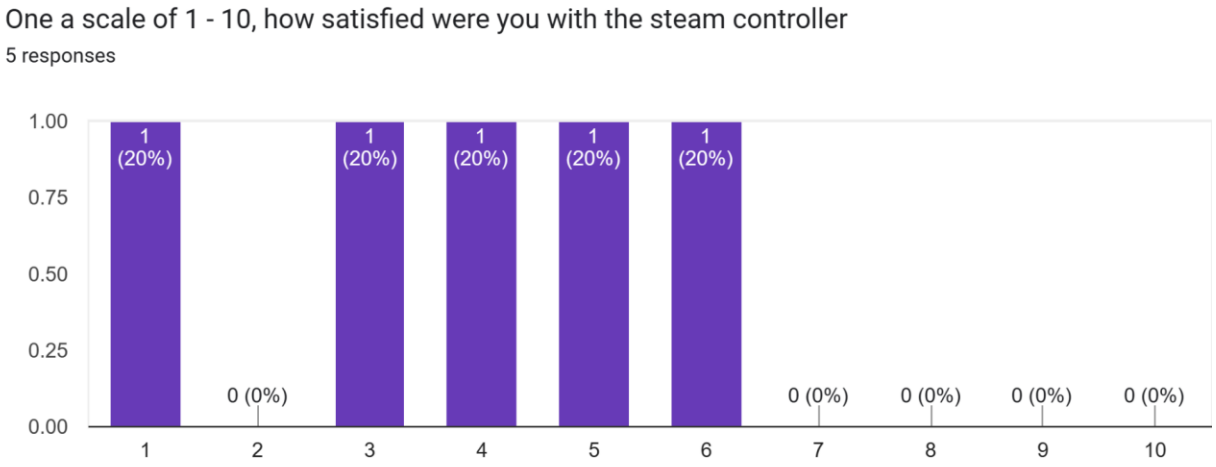
Post Survey Responses: Participant Satisfaction With the PS4 Controller

On a 1 - 10 scale, 50% of people rated their satisfaction with the PS4 controller an 8, while 16.7% each chose a 4/10, 6/10, and 7/10. The average of this is a 6.8 out of 10.



Post Survey Responses: Participant Satisfaction With the Steam Controller

The Steam controller received diverse ratings from individuals, ranging from 1/10 to 6/10 on a scale of 1 to 10. The average rating for the Steam controller was determined to be 3.8/10. Interestingly, this average is nearly half of the satisfaction rating for the PS4 controller, highlighting a substantial difference in the perceived satisfaction between the two controllers



Comparison to Hypothesis

The initial hypothesis proposed that the Steam controller, which includes additional analog inputs and trackpads, would provide finer control movements. The ultimate verdict, however, clearly favored the PS4 controller as the superior interface for controlling the IONA robot. In every task, the PS4 controller performed faster and had fewer failures than the Steam interface. The PS4 controller was unanimously preferred by participants, who cited its intuitive design and ease of use. The conclusion was unequivocal: the Steam controller was more tiring, and observations during the studies repeatedly pointed to a higher occurrence of problems and frustrations with the Steam controller. This obvious difference in performance and user preference highlights the superiority of the PS4 controller over the Steam controller in this study.