Shaping Interactions and Experiences: Investigating the Effects of a Game-Specific Custom Controller on Player Experience in a Digital Game Environment

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ABSTRACT

This paper explores the impact of game interface technologies on player experience. To investigate this, an original game and a game-specific custom controller were designed and tested on a sample of 32 participants. The experiment was conducted through a quantitative research approach with twelve data points to measure both the objective reality and subjective experience of the participants. The results suggest emergent trends pertaining to (i) objective data distribution; (ii) perceptions of the self; and (iii) playstyle differences. The findings revealed that the custom controller group had more similar objective results to one another than the mouse input group did, suggesting a more commonly shared experience. The custom controller group also appeared to be more goal-oriented, with a quicker completion time and focus on evading enemies, while the mouse input group achieved higher amounts of player-dealt damage. This research contributes to the existing studies on tangible user interfaces and game input research. The results may encourage game developers, academics, and artists to create controllers to alter the player experience for their uniquely designed game mechanics in experimental or creative projects.

Keywords

human-computer interaction, player experience, game controllers, user experience, game design, tangible user interface

INTRODUCTION

The medium through which people interact with technology can shape their experience, both in their subjective outlook and in their objective outcomes. Thus, game controllers, as the primary method of interaction in video games, hold significant value to game developers and researchers. This paper analyses the current literature on human-computer interaction (HCI), intuitive/natural interaction, user experience, game immersion, player physicality, and the economic potential of peripherals; and discretely categorises and defines custom controllers. Following this, an experimental design was employed to develop an original game and a purpose-built game-specific custom controller. The game recorded six individual data points to quantitatively measure objective differences in gameplay between using a mouse and

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the game-specific custom controller. After playing, each participant also filled out a NASA TLX workload sheet with six scalar ratings (Hart 1986). This pilot study helps reveal aspects of the complex nature of subjective experience in the context of custom controllers and emergent trends in the use of alternative devices. The primary research question of this paper is: how is the game experience changed when using a traditional input device compared to a custom one? This research aims to encourage practitioners, academics, and artists to design controllers for experimental or creative projects.

Custom Controllers in Context

Before exploring how a custom game controller can influence a player's experience, it is essential to thoroughly and contextually define the term. Interpreting the works of Blaine (2005), McMahan et al. (2010), and Cummings (2007), four discrete categories of custom controllers are revealed: game-specific controllers, passive props, subsidiary controllers, and specific-function devices (Tables 1 & 2). Game-specific controllers are the epitome of custom controllers; they are input devices designed for a specific game, such as the *Donkey Kong Jungle Beat* (2004) 'DK Bongos' controller. Such devices are regularly created in the game's style and are regarded as a device to allow for a more enjoyable and immersive experience (Blaine 2005). Passive props are non-digital casings for existing controller devices, designed to enhance game immersion by modifying player-device interaction, such as Nintendo's 'Wii Racing Wheel' (McMahan et al. 2010). Subsidiary controllers are input methods that enhance or provide additional gameplay experiences for multiple games, such as Nintendo's 'Nunchuk'.

The final category of custom controllers is specific-function devices. These HCI devices are designed to replace, without reliance on, a console or computer's original input method for multiple games, such as the Konami NES LaserScope (Cummings 2007). The intended purpose of the device is to provide an atypical or unique experience beyond what is expected from a game controller. For example, Microsoft's Xbox Series X controller provides an almost identical design, button configuration, and interaction interface to its predecessors from the last decade; in contrast, Logitech's flight yoke system controllers provide a different collection of possible interactions, look physically distinct, and require the user to hold/operate the device in a novel way. Interestingly, Cummings (2007) notes that certain mainstream controllers (i.e., the input method sold with the game console) have also been specifically designed to provide novel interactions, such as the Atari 5200 (potentiometer) controller and the Nintendo Wiimote (motion control). Similarly, and most recently, the Switch and Switch 2 offer five interaction techniques: traditional gaming (similar to the Xbox Series X and PS5), retro gaming (using one Joy-Con horizontally to mimic a lesser-function retro controller), handheld gaming with touchscreen and controller capability, 3D motion tracking while holding either one or two Joy-Cons (similar to Oculus VR [virtual reality] tracking), and 2D motion tracking (similar to the Wii or PS Move). Therefore, all HCI devices that do not conform to the status quo of controller design should also be included in the specific-function device classification of custom controllers.

Through analysing any game controller or HCI device with this framework, an accurate determination of whether the device is a custom controller (and which specific subtype) can be concluded (see Table 1). While such a definition is essential for meta-analysis research on this topic and provides the context for individual game controllers, in terms of purpose and design, it would also be insightful to address the means of engagement for these devices. With reference to the engagement technique concepts presented by Besançon et al. (2017), McEwan et al. (2020), and Bergström et al. (2019), an input method is either tangible (i.e., something that can be held, pressed, or interacted with) or intangible (i.e., motion tracking from video, IR, and wearables). However, some input devices that require only taps or strokes could provide a similar experience without a physically interactive device; thus, they are inherently distinct from tangible devices (Besançon et al. 2017). For example, all possible touchscreen or trackpad inputs could be emulated by a gesture-capture camera (e.g., projection keyboards) without altering the experience. Hence, such input methods should be considered intangible devices. While this binary classification is far too broad to capture the nuances of interaction techniques and is unsuitable for comparison, it becomes beneficial when accompanied by an examination of how the dimensionality of individual HCI devices affects engagement techniques.

Game-Specific Controllers	**Passive Props**
Tiny Bee *Final Fantasy X* 2 Gun Controllers	Nintendo Wii Wheel
Capcom *Onimasha 3* Katana Controller	TNP Wiimote Zapper Gun
Dreamcast *Bass Fishing* Fishing Rod Controller	Fastsnail Nintendo Switch Joy-Con Grips
Sega *Samba De Amigo* 2 Maraca Controllers	Nintendo Switch Labo Cardboard 'Toy-Con'
Nintendo *Donkey Kong Jungle Beat* 'DK Bongo'	Nintendo NES Speedboard
Product Council *Tony Hawk Ride* Skateboard	Skywriter Atari 2600 Stick Station
Subsidiary Controllers	**Specific-Function Devices**
Nintendo Nunchuk	Logitech Flight Yoke System
Microsoft Xbox 360 Kinect	PlayStation Move Motion Controller
Interactive Light Sega Activator	Nintendo Wiimote
Bandai Game Boy Pocket Sonar	ByoWave Proteus Controller
Sony Glasstron	Konami NES Laser Scope
Olympus RS28H Triple Foot Pedal	Atari 2600 MindLink

Table 1: Categorisation system for custom controllers

		Tangible	**Intangible**	**Linear**	**Mono-Planar**	**Multi-Planar**
Dimensional Interaction Affordances Present in Various HCI Devices	Computer Mouse	x		x	x	
	Computer Keyboard	x		x		
	Laptop Touchpad/Trackpad	(x)	x	x	x	
	Laptop/Tablet Touchscreen		x	x	x	
	PS5 DualSense Controller	x	x	x	x	
	Xbox Series X Controller	x		x	x	
	Nintendo Switch Joy-Cons	x		x	x	x
	Microsoft Xbox 360 Kinect		x		x	
	Sony PlayStation Move	x		x	x	
	Nintendo Wiimote	x		x	x	
	Meta Quest Touch VR	x		x	x	x
	Apple Vision Pro Headset		x	x	x	x
	Interactive Light Sega Activator		x		x	

Table 2: Dimensional interaction affordances present in various HCI devices

All actions achievable by humans in the physical world occur on one of three dimensions. Firstly, linear interactions are one-dimensional with two states (e.g., 0 and 1); a path/line must be possible between the two states, and values in between can be expressed if desired (e.g., triggers/bumpers on game controllers). Secondly, monoplanar interactions are two-dimensional (e.g., moving a cursor across a screen along the X and Y axes) and can involve a single axis of rotation (e.g., a mouse scroll wheel). Thirdly, multiplanar interactions are three-dimensional (e.g., hand tracking in VR) and can have three axes of rotation (i.e., pitch, yaw, roll). Necessarily, HCI devices, as the link to the game world, have multiple of these interaction elements to allow for the operation of multiple discrete functions, such as the keys on a computer keyboard or the buttons on a game controller (Khandaker 2010). However, the first two of the three action dimensions are often combined for multifunctionality, such as both computer mice and game controllers, which combine linear actions (buttons) with planar navigation (cursor movement and joysticks/d-pads) (see Table 2). This analysis and recategorisation of HCI devices, with a focus on dimensional user interaction, inherently prevents discrimination between custom controllers and traditional input methods; thus, it should be used in conjunction with the primary definition/categorisation to enable the most comprehensive, consistent, and intelligible discussion possible.

Player Immersion and Natural Interaction

Immersion is arguably the most essential element in retaining players for extended periods (Boyer 2009), with Pallasmaa (1996) establishing that those immersed in an experience become one with the device they are operating. Blaine (2005) asserts that immersion is enhanced through physical involvement, and Spöhrer (2022) suggests that physical interaction with HCI devices can help develop players' identification with digital avatars, the game's environment, and the overall game experience. Brown and Cairns (2004) identified three core elements of immersion in users: attention, an altered sense of time, and a loss of self. While all HCI devices (tangible and intangible) contain some degree of user physicality, the sense of immersion and connection through the use of the body cannot compare to that of controllers intentionally designed to achieve this goal (Khandaker 2010). The level of physical involvement in traditional gaming, such as wrist and finger movement required when using standard game controllers or keyboard and mouse setups, is dwarfed by the physicality required for full-body gestural actions in motion control and VR games (Pallavicini and Pepe 2019). Additionally, Nacke's (2010) study on full-body controllers vs. standard controllers revealed the importance of physicality in game experiences for immersion, noting that self-location spatial presence in the game world was experienced significantly higher when using a Wiimote controller compared to a PS2 controller. Thus, the physical interactive affordances of a HCI device require individual attention during evaluation.

Player physicality and involvement not only impact the sense of immersion but also the methods of interaction with technology. Xu (2005) notes that although most children can stack blocks and build complex shapes with various materials, most adults cannot design simple 3D structures using computers. Inherently, standard game HCI devices limit natural engagement techniques (e.g., picking up an item in a digital environment requires pressing a button) and the number of actions a user can perform (Spöhrer 2022). As the physical form of such devices directly shapes how users interact with a device and influences their strategies while playing (McArthur et al. 2009; McMahan et al. 2010), methods for exploiting this include developing a game-specific custom controller or a custom housing/casing for an existing device (passive props). By using either a custom-built tangible device for a specific experience or a gestural interface (as opposed to traditional game controllers), not only would such engagement fulfil a natural desire, but as Francese et al. (2012) argue, in many instances, may enable quicker learning due to the simplified user interface (Besançon et al. 2017; Sturman and Zeltzer 1994).

Regarding the effect of interacting with physical devices, three studies explored how user subjectivity is affected through the use of custom controllers. The results revealed a generally positive view of the non-standard input devices, with no negative responses (Besançon et al. 2017; McEwan et al. 2020; McMahan et al. 2010). While objectively better performance resulting in more positive participant emotion is somewhat unsurprising, McMahan et al.'s (2010) test on custom controllers, which showed the Wiimote with the passive prop wheel to achieve the worst results (slower times), recorded the highest positive reports of fun (68.8%), with 31.3% of the participants liking it most overall compared to two traditional controllers and the Wiimote without the prop. Additionally, even studies that have explored custom controllers without a focus on objective testing, such as a musical instrument emulator using a Wiimote (Miller and Hammond 2010) and a controller joystick improvement (Shim et al. 2023), received positive reactions from participants.

PURPOSE AND METHODOLOGY

To provide a heuristic basis for better informing future research in the field of novel HCI devices (i.e., recommendations for design techniques, research questions, and limitations), as well as to further develop the understanding of the effects of custom controllers on players, an original game and a custom game-specific 3D-printed controller were developed. Alongside this, a pilot study was conducted with 32 participants who volunteered from a game design bachelor's program (to ensure familiarity with technology and games). The participants were randomly assigned into two groups, one playing with the custom controller and the other with a mouse, so that each group would experience the game for the first time. Each experiment was conducted one-on-one in a pre-booked room, lasting a maximum of 20 minutes, although most lasted around 12 minutes. Participants were read to from a script for the introduction to each test to avoid as much variation as possible (Smith 1998). Each participant was briefed on why they were being tested, what would happen, and the nature of the test. The briefing was then followed by a two-minute demonstration of how the game worked. Due to the test comparing mouse input (MI) and custom controller input (CC), there was a marginal difference between the game demonstrations. Participants were then assured that they could ask questions about the game anytime.

The choice of feedback method was NASA's Task Load Index (TLX), which comprises six scalar workload-related questions related to user experience: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. The scalar rating ranges from 0 to 100, in increments of 5. Each participant received this sheet, a pen and the original definitions page (of the six TLX elements). It should be noted that Babaei et al. (2025) argue that despite its prevalence in HCI research, it was not designed for interactions with digital technologies, there may be potential confusion of definitions for interviewees (most notably mental workload), and it generates non-linearly scalable data (i.e., a workload response of 80 is not 33.3% more intense than 60). Thus, when using this response system, in any HCI research, the researchers must be cognizant of such shortcomings. However, it was chosen for this experiment for numerous reasons:

1. The questions have been rigorously tested and trialled by tens of thousands of academics (Hart 2006).
2. The six-question system is simple, can be completed within one or two minutes, and has a definition page for the six categories, which prevents confusion or bias in explanation (Hart 1986).
3. The high resolution of the scalar system of twenty-one choices provides a more accurate representation than traditional systems of 0-10 (eleven choices) and 1-5 (five choices).
4. The survey focuses only on the participants' self-perceptions, not on how much they enjoyed the experience or how good they thought the input device was. This avoids further potential bias from participants trying to give what they might perceive as the correct answers.
5. Finally, as another academic used the system (Besançon et al. 2017), parallels and comparisons can be made after the results are collected.

Despite its original intention of being used solely to calculate the entire perceived workload (adding up all six figures), this experiment, as done by Besançon et al. (2017), assesses each section of the workload individually. In addition to the TLX responses, ages and self-identified genders were recorded for comparison and context of the findings. Each participant also gave themselves a temporary participant identifier, such as their initials, name, or whatever they felt comfortable sharing (only one participant left this space blank). The purpose of this temporary identification was to avoid duplicate data entries during the collection and input. Once all data had been entered, these identifiers were converted to numeric values. To ensure anonymity, the genders and ages were removed from the data set tables. Another element for the continued safe data collection procedure was to inform participants that they could leave at any time and exclude themselves from the collected data (no participant availed of either option).

Developing Custom Software and Hardware

Many previous experiments of CCs have used/adapted existing game software (Francese et al. 2012; McEwan et al. 2020; McMahan et al. 2010) or created a novel, simple digital environment to test a specific task (Bergström et al. 2019; Degraen et al. 2019; Kouroupetroglou et al. 2011). However, this experiment was designed to emulate a game-like digital environment while also being able to measure specific objective elements (Argelaguet et al. 2016; Balcomb et al. 2023). The advantage of this type of digital environment is that it retains a sense of play and enables players to test their skills without feeling evaluated (Matjeka and Mueller 2020). The concept of designing a play space that allows for emergent game strategies or personal goals played a core role in this game's design process. Thus, in the design process for this game, it was essential to not only have one main goal (e.g., reaching the objective) but also a secondary goal (e.g., eliminating enemies). The game and controller were designed in tandem over a six-week period. From playtest feedback during development, it was discovered that the game was slightly too long (the distance to the final objective was reduced), and the wires of the CC were prone to tangling (fixed after the playtests).

The game was created in the Unity Game Engine and was played on a Windows laptop. The 3D models for the submarine, equipment, enemies, and buoys were designed in Blender. The user interface (UI) elements were created in Photoshop 2024, and the 3D models were textured using Adobe Substance 3D Painter (see Figure 1). The design for the final CC drew inspiration from previously produced custom devices (Cummings 2007) and others designed for experiments (Matjeka and Mueller 2020; Yuan and Folmer 2008). The shell of the controller was designed as multiple pieces in Blender. Each part was converted to a 3D-printable file, printed, and glued together. As Poretski et al. (2019) note on the importance of visual realism and connection to the game world, the controller was spray-painted and sanded to give it a weathered aesthetic (see Figure 2).

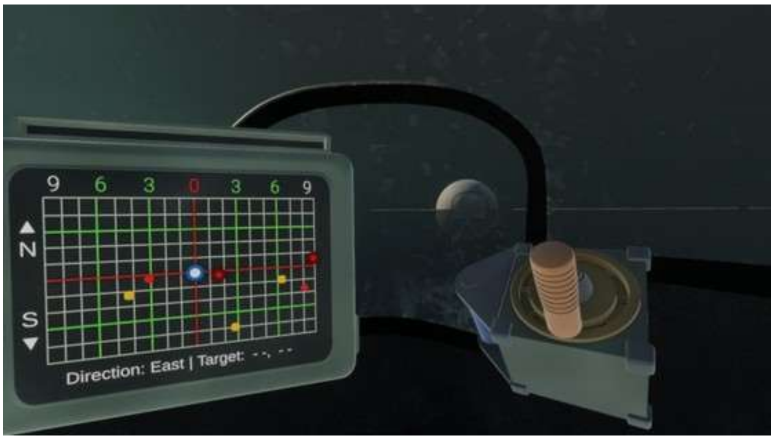

Figure 1: Screenshot of game tested by participants

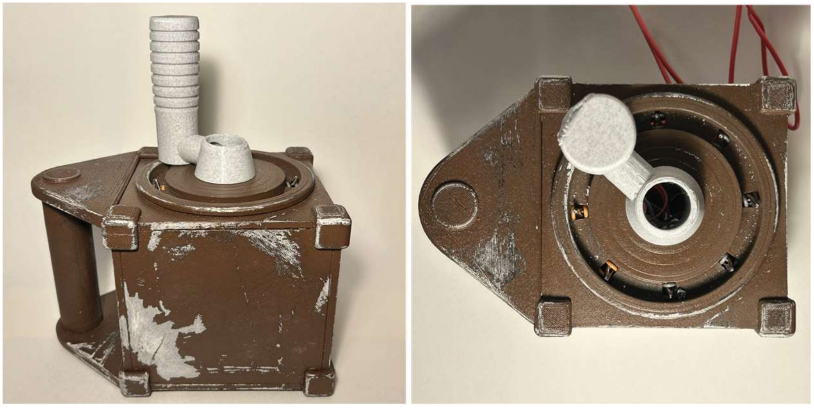

Figure 2: The developed custom controller

Game and Controller Overview

The game requires players to drive a submarine to a blue buoy marker point, following yellow marker points along the way. The game takes place in a submarine with a large open window looking out under the sea (see Figure 1). On the left side of the game screen is a radar console that positions the player's submarine in the middle, with a 180x100-meter grid and lines at 10-meter increments. This screen displays the buoy markers, enemy submarines, and enemy missiles. The player can press the 'Tab' key on the keyboard to activate their periscope to look out for enemy submarines off their radar. This raises the player's view above the water level, allowing them to see the tops of enemy submarines and buoy markers.

The submarine travels in either north-south or east-west directions at a time; the player can toggle between the two by pressing the space bar. The submarine moves by rotating a wheel clockwise or counterclockwise, and, depending on the toggled direction, results in north/east movement or south/west movement, respectively. The rotation of the wheel, and thus the movement of the submarine, is achieved either by using the custom-made 3D-printed controller with a rotating handle or by clicking and dragging the on-screen handle around its axis. Along the journey to the blue marker, there are enemy submarines, some of which fire missiles at the player, which the player can either avoid or destroy by firing missiles at them, similar to Battleship (1931) (secondary goal). Enemies (and their missiles) show up on the radar screen and the player can fire their own missiles by typing in 'N' or 'S' (north/south), followed by a distance (between 0 and 6), then 'E' or 'W' (east/west), followed by a distance (between 0 and 9), and finally shooting by pressing the enter key.

The game-specific CC is a 130mm cube with a fixed handle on its left to keep it steady when operating (see Figure 2). On top is a rotatable handle (made with conductive material) that the game tracks its position in real-time. The controller is fitted with a remapped Makey Makey Classic with eight inputs connected and can be accessed through an ellipsis hole (95mm x 85mm) at the back of the controller (i.e., not visible when playing).

In-Game Data Collection

All objective data points for the experiment were recorded in-game and hidden from the participants. Once participants had left the room, this data was accessed (by typing in an eight-digit code) and transcribed on the bottom of the participant's NASA TLX response sheet. When deciding on potential recorded data, the first two chosen were game completion time and player missile accuracy, similar to data recorded in other experiments (Argelaguet et al. 2016; Bergström et al. 2019; Kouroupetroglou et al. 2011). The final four pieces of data were chosen to reveal potential differences and similarities between mouse and CC inputs. In total, there are six pieces of data which are recorded through gameplay:

1. Game Completion Time: the time a player took to reach the blue marker from when they started moving. This aims to show how good or bad the input method is for this game. The more intuitive input method should yield a faster completion time.
2. Total Damage Taken: The number of enemy missiles that successfully hit the player. This aims to show how well or poorly the players perform with quick evasion from enemy missiles.
3. Accuracy of Missiles: percentage of player-fired missiles that hit an enemy submarine. This acts as a control between the two groups (MI and CC), as they both use a keyboard to input this value. The final data should show similar percentages for both.
4. Longest Continuous Distance Travelled: the longest distance between the player starting and stopping moving. This aims to show the trends of different playstyle methods between groups.
5. Submarines Destroyed: the number of successfully destroyed submarines by the player. This aims to show the trends of different playstyle methods between groups.

6. Used Periscope: this checks whether the player has pressed the tab key to use the submarine's periscope. This aims to show trends in how carefully each group reads the pre-game instructions.

FINDINGS

Thirty-two game design students participated in this study with a mean recorded age of 21.66 (range: 19-27) and a (self-identified) gender ratio of 23:5:4 (male:female: non-binary). Each test recorded 12 data points per participant. While many of the findings from this small-scale pilot study (sample size of 16 per group) are insightful and may later be generalised with experiments on other HCI devices, it is paramount to understand the data in this context. The first six data points were for the Subjective Experience (SE) and were collected via the NASA TLX subjective survey (see Table 3). The other six data points were for the Objective Experience (OE) and recorded each player's performance in-game (see Table 4). The OE data was not revealed to the players to avoid impacting their subjective responses.

	Mouse Input (MI)			**Custom Controller (CC)**		
Metric	**Mean**	***σ***	**95% CI**	**Mean**	***σ***	**95% CI**
Mental Demand	65.67	246.6	65.67 ± 120.83	59.06	17.96	59.06 ± 8.80
Physical Demand	47.19	20.38	47.19 ± 9.99	56.25	24.46	56.25 ± 11.99
Temporal Demand	43.75	26.66	43.75 ± 13.07	61.88	17.58	61.88 ± 8.61
Performance	49.69	18.66	49.69 ± 9.15	39.38	15.7	39.38 ± 7.69
Effort	54.06	21.95	54.06 ± 10.76	68.75	10.38	68.75 ± 5.09
Frustration	43.14	20.91	43.14 ± 10.24	44.06	15.02	44.06 ± 7.36

Table 3: Subjective Experience: NASA TLX participant-reported workload dataset comparison between MI and CC (including the mean, standard deviation, and 95% confidence interval range estimation)

	Mouse Input (MI)			**Custom Controller (CC)**		
Metric	**Mean**	***σ***	**95% CI**	**Mean**	***σ***	**95% CI**
Accuracy of Missiles (%)	87.88	12.25	87.88 ± 6.00	92.19	11.09	92.19 ± 5.43
Longest C. Distance (m)	1092.5	192.65	1092.50 ± 94.40	967.75	109.77	967.75 ± 53.79
Completion Time (mins)	7:13	2.05	7:13 ± 1:00	6:14	1.47	6:14 ± 0:43
Submarines Destroyed	6	1.58	6.00 ± 0.77	4.13	1.54	4.13 ± 0.75
Used Periscope (%)	62.5	4.74	63 ± 2.32	25	4.69	25.00 ± 2.24
Total Damage Taken	8.94	5.2	8.94 ± 2.55	6.69	3.58	6.69 ± 1.76

Table 4: Objective Experience: In-game recorded dataset comparison between MI and CC (including the mean, standard deviation, and 95% confidence interval range estimation)

Analysis of NASA TLX Findings

The overall NASA TLX workload is relatively similar between both groups, with a mean total workload of 50.58 for MI and 54.90 for CC. Similar to Besançon et al.'s (2017) analysis of the self-reported NASA TLX responses, clear differences emerge when all six components are evaluated separately. The differences between MI and CC pairs in the self-reported effort and temporal demand categories showed the most significant variation. The physical demand and performance categories showed moderate variation, and the mental demand and frustration categories showed the least variation. Temporal demand, the amount of time pressure experienced by a participant, showed a 61% increase from the MI to the CC group. Smaller increases from the MI to the CC group are present in both the physical demand and effort data sets, with 19% and 27% increases, respectively. Smaller decreases from the MI to the CC group are present in both the performance and mental demand data sets, with 25% and 11% decreases, respectively. Lastly, the difference in frustration is negligible, with an increase of 2% from the MI to the CC group.

Analysis of In-Game Datasets

One of the most insightful findings in the in-game objective (OE) results is the distribution of data within the two groups (as evident from the delta value). Isolating the three core datasets, which pertain to movement and evasion (i.e., comparing MI and CC use), reveals a trend of comparatively tighter grouping in the CC group; these three datasets include the longest continuous distance travelled without stopping, completion time, and total damage taken. This is most clearly visualised through a normal distribution curve of the collected OE data (See Figures 3 & 4). The remaining three metrics (i.e., those requiring keyboard use and not directly influenced by the CC or MI) exhibit a much more similar distribution of data across the two groups.

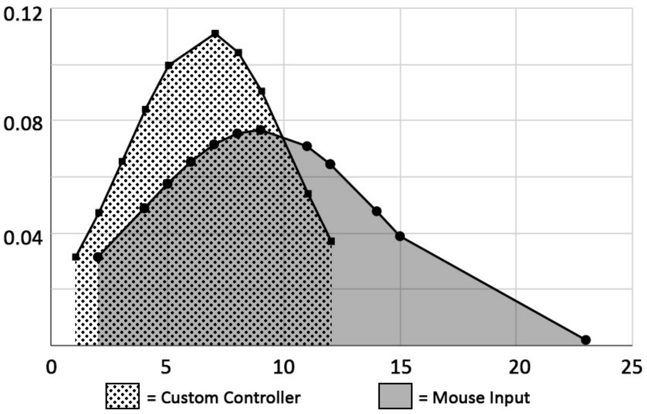

Figure 3: Normal Distribution of total damage taken, probability density (y) and number of hits taken (x)

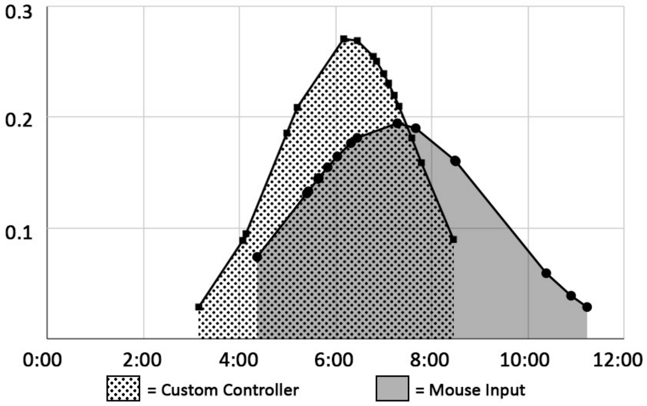

Figure 4: Normal distribution of session times, probability density (y) and minutes played (x)

In terms of comparisons in the OE results between the two groups, the most similarity is found in the missile accuracy category. The numerical data (87.88% [MI] and 92.19% [CC]), which reveals a numerical ratio of 1:1.05 (MI:CC), alongside the similar delta ratios 1:1.10 (CC:MI), suggest a negligible statistical difference. As this data set relied on the participants using a keyboard to fire the missiles in both groups, the reason for player accuracy being almost identical between both groups should be self-evident. Despite a similar accuracy percentage, both the number of submarines destroyed and total damage taken by the player are lower for the CC group compared to the MI group: 31.2% and 25.2% lower in CC, respectively.

An interesting correlation emerges with a comparison between perceived performance (recorded through the NASA TLX survey) and participant damage (i.e., number of hits taken by the player from enemy missiles). While the MI group seems relatively unaffected by the number of hits sustained, the CC group shows a substantial decrease in perceived performance when more damage is sustained (see Figures 5 & 6).

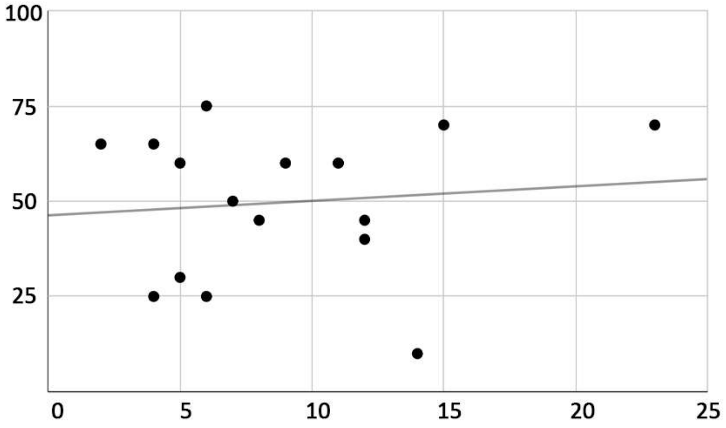

Figure 5: Correlation between self-assessed performance (y) and damage taken (x), mouse input

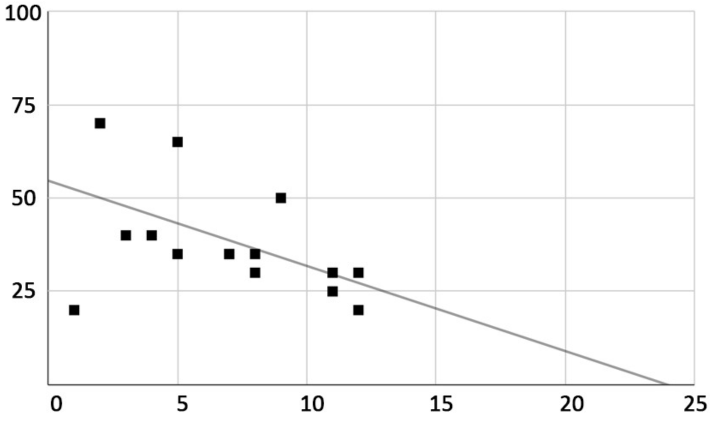

Figure 6: Correlation between self-assessed performance (y) and damage taken (x), custom controller

DISCUSSION

The overall trend presented in the objective data indicate that the two input methods significantly impacted the participants' playstyles. The CC group had a more movement-involved and goal-oriented playstyle (as confirmed by quicker completion times, lower ship damage, lower enemy damage, and shorter distances travelled). However, the MI group had a more attack-focused playstyle. A plausible interpretation for this result could be due to differences in the interaction techniques when operating the MI and the CC. The MI group were able to operate the mouse and keyboard simultaneously, while the CC group needed to use both hands when operating the CC (i.e., one holding and the other rotating). A similar occurrence of how physical objects affect interaction techniques is also noted by McArthur et al. (2009) with their study on passive prop housings for the Wiimote.

Another trend which becomes evident in the OE data is the tightness of the data distribution for the CC group in the objective measurements (excluding submarines destroyed and accuracy). This is especially clear when assessing the normal distribution curves. The completion time, longest continuous distance travelled, and total damage taken are the most pronounced examples of these tight groupings. Such a pattern suggests that the range of participant proficiency in using a mouse varied significantly and thus impacted the gameplay results. However, since all participants had no prior experience with this specific device, those using the CC had more similar results.

While many of the MI group showed interest and enthusiasm while playing, all participants in the CC group showed much greater excitement upon seeing the CC. The method employed to test excitement, and to avoid biased responses (although, in hindsight, asking participants to also rank their excitement levels before playing would have been beneficial), was to record whether participants thoroughly read the short instruction page (provided before playing). The periscope mechanic served little function in the game, other than allowing the player to look above sea level. However, as it was only referenced in the game instructions page, it can be used to determine how many players read closely before starting play. Interestingly, the number of players who activated the periscope in the CC group is less than half of the MI group (10:4). This result may have occurred for numerous reasons, such as the CC group being overwhelmed with the prospect of learning how to operate a new device, which impacted their engagement with the mechanics; or that they more excited to start playing and disregarded the need to read the instructions. However, both, and/or any other potential factors require further exploration.

Discussion of NASA TLX Findings

While the higher reported values for physical demand are expected as participants were physically engaging with an input device with their whole arm (CC) rather than just their wrist (MI), it is interesting that the temporal demand was also higher in the CC group. Potential causes for this include participants' closer focus on the goal at hand (as confirmed in the OE data for completion time), more overall stress from the physical demand and effort needed to avoid enemy missiles, and a higher number of enemy missiles to avoid (the CC group had, on average, 1.87 more enemies to avoid at the end of the game).

The similarity in the frustration between the groups is surprising, as the CC participants had to learn a new input method. Perhaps the lower-than-expected reported frustration for the CC group is due to the participants having fun playing with the CC and/or being game design students who understand that not all new experiences come without friction or strain. However, as with all non-commercial games, it also cannot be ruled out that playing with a mouse, in this specific game, could not have caused a higher than expected level of frustration. Although, even in the broader context of commercial games, pure numerical data would be unable to reveal such insight.

Finally, despite participants performing objectively better in the CC group (with an average faster completion time and less damage taken), perceived performance was lower (MI: 49.38, CC: 39.38). While this too is somewhat unexpected, the correlation between perceived performance and actual performance is often disconnected (Argelaguet et al. 2016; McArthur et al. 2009). One interpretation for the disconnect experienced in this study could be linked to a participant's belief that they could have done better in the task if given time to practice. However, this would need to be investigated further.

The most similar study to this topic is from Besançon et al. (2017). While the content of the experiment itself differs from this study (using a non-specific CC to rotate a teapot in the 3D modelling software Blender [1994]), the core concepts behind their experiment and the use of the NASA TLX rating sheet are similar. The clearest comparison between their paper and this one is the much quicker average completion time when using a specifically designed device to complete a task (compared to a mouse). Furthermore, when analysing the NASA TLX workload responses, the CC group showed a higher physical response rate in both this study and Besançon et al. (2017). While this seems intuitive, the self-reported effort of the CC group (which was higher than the MI in this study) was lower in the Besançon et al. (2017) study. This is likely due to their CC (a cuboctahedron) being nearly identical, in terms of physicality and effort required, to that of rotating a teapot (the object that participants had to move in 3D digital space); thus, the participants already had an intuitive understanding of the device. Conversely, in this study, the CC required players to alternate between operating the device and using a computer keyboard. Additionally, as the cognitive stress of performing one simple task is distinct from playing a multi-mechanic game (while also learning to use a new HCI device), this study cannot truly be compared in that regard.

Limitations of Research

In the development and testing of this experiment, there are four notable limitations. Firstly, the sample, which itself was small, comprised of young adult game design students. It is quite possible, if not likely, that such a cohort would be more comfortable in experimenting with novel devices. Secondly, it is essential to recognise that all novel software and hardware (i.e., not commercially available or widely tested/used) is open to scepticism from readers of a designer's potential intent to misrepresent reality and alter their hardware/software to falsify claims. Thirdly, as participants are provided with a pre-set-up workstation for testing procedures, typical issues regarding the perceived/real economic value of the device and its integration with a gaming setup and storage do not arise, which may affect their attitude to the device(s). Fourthly, it may be interesting to explore how a user's interaction techniques change as their familiarity grows with both the game and the hardware.

Regarding the choice of NASA TLX over various other feedback systems, it was selected for numerous reasons for this paper, most notably due to its historically positive use in HCI fields and with similar research. However, other models, such as the video game demand scale may provide different results and could be of benefit for exploring in future research (Bowman et al. 2018). Receiving feedback (positive or negative) on any experience with novel software/hardware is susceptible to bias, depending on the interpersonal relationship between the researcher and the subject (Gordon 2020). Additionally, the sample group were all game design undergraduate students and their sentiments towards novel technologies may differ from those outside the tech sphere. Thus, researchers must be aware of these issues before commencing their software/hardware design and testing.

Implications and Future Research

The results from this experiment have shown how game input devices shape player emotions, quality of play, and interaction methods. Accounting for their unique impact on game experiences, it is clear that CCs have a place in the current gaming market. This is especially true with the recent release of the Switch 2 (a multi-modal specific function CC), continued development of VR and mixed reality (allowing for both tangible and intangible multiplanar interactions), and the success of consumer-friendly 3D printing (which can enable print-and-play passive props). This paper proposes that game developers expand their design horizons to create passive props, adapt existing controllers, or create their own from scratch. This expansion would establish their niche in the gaming market, enhance perceived value, and add unique interaction techniques to their digital game.

Following the results, comparisons, and discussion of the experiment in this paper, areas of future research have emerged. Some of the areas yet to be explored for academics include:

1. Conducting a similar experiment with a larger sample size, including mixed demographics (i.e., older participants, those with less experience with technology, and those from various cultural backgrounds).
2. Conducting a similar experiment with commercially available products (software and hardware).
3. Testing the impacts of other input methods, such as traditional controllers, motion controls, and non-specific CCs (i.e., not designed for the game).
4. Allowing for discussion of reasoning behind NASA TLX ratings and/or exploring a qualitative approach with a smaller group to gather richer insights into the player experience.

CONCLUSION

This paper has synthesised and developed research on defining the four categories of custom controllers: game-specific controllers, passive props, subsidiary controllers, and specific-function devices. Exploration of HCI devices more generally revealed further nuance and a separate categorisation system based on the interaction techniques available with each device (one device can have many); these include tangible, intangible, linear, mono-planar, and multi-planar interactions.

The study explored how a game-specific custom controller impacts a player’s experience compared to traditional mouse input. The six objective performance metrics recorded in-game (and hidden from the player) and the responses from a NASA TLX survey helped reveal the differences and similarities between a game-specific custom controller and a computer mouse. The objective data showed a tighter distribution for the custom controller group, suggesting a more commonly shared experience. The self-reported physical demand and effort were higher in the custom controller groups. Additionally, the custom controller group's perception of performance was greatly affected by the damage taken, whereas the mouse input group's perception of performance was not.

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