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Title: Evaluating the Effects of Gaze-Enabled Target Locking on Player Experience and Performance in Action Games

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Abstract:

Though eye-tracking has begun to see more widespread use in the gaming industry, it is most often only used for very simple game mechanics. Target locking as a gaze-enabled game mechanic is an unexplored area within the gaze-enabled gaming sphere. Therefore, this paper explores the use of eye-tracking as a supplement to, and replacement of, traditional controller-based input for target locking in a custom action game. The game utilizes three different techniques for target locking: a controller-only solution, acting as a control version, a gaze + controller hybrid, utilizing gaze-tracking as a supplement to traditional controller input, and finally, a gaze-only version, which completely replaces the need for controller input with target locking. The game was used to evaluate the player experience, system usability, and player preference through an experiment using a within-subjects design. Our results indicate a significantly higher sense of flow in the controller + gaze condition, which also shows favourable scores in most other measurements of the study. All participants also disclosed that they preferred the gaze-enabled solutions to the controller-only version. While not conclusive, this provides evidence that future gaze-enabled games can benefit from involving gaze-based target locking controls.

Evaluating the Effects of Gaze-Enabled Target Locking on Player Experience and Performance in Action Games

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ABSTRACT

Though eye-tracking has begun to see more widespread use in the gaming industry, it is most often only used for very simple game mechanics. Target locking as a gaze-enabled game mechanic is an unexplored area within the gaze-enabled gaming sphere. Therefore, this paper explores the use of eye-tracking as a supplement to, and replacement of, traditional controller-based input for target locking in a custom action game. The game utilizes three different techniques for target locking: a controller-only solution, acting as a control version, a gaze + controller hybrid, utilizing gaze-tracking as a supplement to traditional controller input, and finally, a gaze-only version, which completely replaces the need for controller input with target locking. The game was used to evaluate the player experience, system usability, and player preference through an experiment using a within-subjects design. Our results indicate a significantly higher sense of flow in the controller + gaze condition, which also shows favourable scores in most other measurements of the study. All participants also disclosed that they preferred the gaze-enabled solutions to the controller-only version. While not conclusive, this provides evidence that future gaze-enabled games can benefit from involving gaze-based target locking controls.

KEYWORDS

Eye-Tracking, Gaze-Tracking, Gaze-Interaction, Tobii, Video Games, Game Mechanics, Target Locking

1 INTRODUCTION

As eye-tracking technology has become more widespread, it has started to gain traction within the gaming industry as a substitute for various control schemes and input modalities. While often used for the sake of accessibility, eye-tracking as an input modality still sees very restricted use as it is often utilized only for very simple tasks. In order to better integrate eye-tracking into the gaming sphere, whether for accessibility or for general use, it is therefore necessary to develop eye-tracking compatibility for more core features and their control schemes. What these features are often depend on the genre the game is designed for. For 3D Action-Adventure games, combat is essential to the core gameplay. Since the early days of 3D games, it has been a prominent feature to lock the camera onto desired enemies, so players could more easily see them in the three dimensional space and aim their attacks toward them with ease. One would therefore expect that gaze-enabled Action-Adventure games would allow this feature to be controlled via eye-tracking. To investigate this expectation, we reviewed all 160 (as of the writing of this paper) gaze-enabled games available on the Tobii gaming platform [1], and categorized them based on which gaze features they utilize and to which genres they belonged. Similar gaze-enabled features were grouped together. As can be seen in Table 1, aiming assistance, camera control, and UI functions were of the most utilized gaze-enabled features used across the entire library. However, we found that gaze-enabled target-locking was incredibly rare with only two games (Assassin's Creed: Origins and Assassin's Creed: Odyssey) fully utilizing the feature, both Action-Adventure games, despite there being vastly more games of the Action and Adventure genres present in the gaze-enabled library. Many of those games still featured target-locking using ordinary controller/keyboard modalities. This makes it apparent that gaze-enabled target-locking is still fairly unexplored in the current day of gaze-enabled gaming, meaning how to effectively implement it, and the effect it has on gameplay and game experience, are still unknown.

Feature		Genre	
Camera	136	Action	75
UI	63	Adventure	69
Awareness	8	Arcade	5
Aiming	46	Horror	6
Aiming + Interaction	53	Indie	58
Aiming + Auto-Interaction	36	Mystery	1
Visual Effects	20	Open World	6
Navigation	10	Platformer	2
Auto-Pause	4	Puzzle	10
Head Mirroring	5	Racing	9
		RPG	12
		Simulation	40
		Sport	2
		Stealth	3
		Strategy	13
		Survival	2

Table 1: List of gaze-enabled features, grouped, used in the games present on the Tobii gaming platform and the number of games that utilize those features, as well as the genres those games belong to and how many games are present within each genre. Notice how Action and Adventure vastly outnumber the other genres.

2 RELATED WORK

2.1 Eye Movements

The human eye is limited to moving in a set of particular ways. Modern eye-tracking technology is capable of distinguishing between each of the eye's particular types of movements, and thus eye movements are widely used for both analysis and as input types. Here we will briefly describe what the different types of eye movements are based on previous works [2–4]: (1) *Fixations* are the eye movements that allow the eyes to focus on a stationary object by stabilizing the retina over it so that its image falls clearly on the fovea. (2) *Saccades* are rapid eye movements used for repositioning the fovea between fixation points. (3) *Smooth Pursuits* are smooth movements that allow the eyes to fixate on a moving object. Smooth pursuits cannot be faked, so without a moving object to fixate on, the eyes will move in saccades instead. The velocity of the eye's smooth pursuit is relative to the velocity of the object being tracked. (4) *Compensatory Movements* are smooth reflexes that allow the eyes to stay fixated on an object while moving the head. (5) *Convergent and Divergent Movements* are when the eyes rotate toward or away from each other when fixating on objects that are closer to or further away from the eyes, respectively. (6) *Optokinetic Nystagmus* is a combination of smooth pursuits and saccades used when tracking a continuous object or multiple objects moving across the field of view. The eye uses smooth pursuit to track the object till it leaves the field of view, then uses saccades to return to where it started. An example to better understand this is when watching trees of a forest pass by while in a car.

For use with eye-tracking in video games, only the first four eye movement types are relevant, particularly fixations. In Action games where players would have to use their eyes to target moving enemies or objects, smooth pursuit becomes more relevant as well.

2.2 Gaze-Tracking Categorization

Multiple studies have categorized several gaze-tracking use cases within the field of eye-tracking research.

2.2.1 ***Gaze-Based Input Types For Games.*** Velloso et al. categorizes three ways gaze input can be used in gameplay [2]: (1) *Continuous-Only* input types utilize the user's fixation point continuously. This can be broken down into three sub-categories: (1a) *target pursuit*, where the user must actively locate objects on the screen that are activated by gaze, (1b) *target avoidance*, where the user must avoid looking at certain objects on the screen, and (1c) *always-on*, where the fixation point is always affecting the game world, such as by affecting the camera. (2) *Discrete-Only* input types instead directly utilize eye movements rather than fixation points. These are categorized as *Eye Gestures*, and can use a variety of eye movements or combinations of eye movements as input, such as blinking or specified sequences of saccades. (3) *Continuous + Discrete* input types combine continuous gaze tracking for aiming/pointing with a secondary input modality for selection/confirmation. This secondary input modality can be eye-based or not.

In the context of this study, Continuous-Only target pursuit and target avoidance, as well as Continuous + Discrete with eye-tracking for aiming and controller input for selection, provide the most promising potential solutions.

2.2.2 ***Gaze Interaction Applications.*** Gaze-based input has also been categorized based on the level of intention required from the user. Majaranta et al. defined a continuum with four levels, ranging from overt intentional to covert unintentional [5]: (1) *Explicit Eye Input (Command & Control):* With this interaction type, the user is intentionally using their eyes as an input source, e.g. through mouse emulation [6] or character locomotion [7]. Velloso et al. have broken this down further into three types of game mechanics: Navigation, Aiming & Shooting, and Selection & Commands [2]. (2) *Attentive User Interfaces (Eye-Aware Systems):* In this second category, the user is not required to actively use their gaze as input, rather the system is made aware of where the user is looking and can adapt automatically. Velloso et al. also broke this category down further, into Implicit Interaction and Visual Effects [2]. Implicit Interaction could for example be how NPCs are made aware of the user's gaze in *The Royal Corgi* [8]. (3) *Gaze-based User Modeling (Activity Recognition):* This category is less concerned with where the user is looking and more with how the user is looking. Here gaze behaviours, independent of point of regard, are analysed to predict information, e.g. intention prediction [9, 10]. (4) *Passive eye monitoring (Diagnostic Applications):* In this final category, the user's gaze is monitored and recorded for later use, so no real-time analysis is conducted. This type of interaction can, for example, be used for research purposes, like long-term behavioral monitoring as done by Balling et al. [11].

2.3 Gaze-Based Interaction

While one of the most commonly used selection methods for gaze enabled systems is dwell-based selection [12], other research have found that alternative selection methods can be superior both in terms of speed and robustness, and can reduce the risk of accidental selection of on-screen elements [6, 13–17]. This accidental selection refers to the action of triggering selections through eye-gaze without the intention of actually selecting them. The intention could simply be to view an item rather than to select it. This phenomenon is referred to as the Midas Touch problem [18]. In Action games, being able to quickly target an enemy could mean the difference between success and failure. Accidentally targeting the wrong enemy could be fatal, and therefore a system that avoids the Midas Touch problem is essential.

Several methods have been proposed to speed up selection. Komogortsev et al. proposed a system where selection is done through saccades rather than fixations. This system was indeed much faster than dwell-based fixation selection, however it was also more prone to errors [13] and therefore isn't a valid option in cases where both speed and accuracy is important. The use of other eye movement patterns has also been suggested. Lohr et al. conducted an experiment which compared the accuracy and speed of fixation-based selection to smooth pursuit-based selection when the spatial accuracy of the eye-tracker becomes increasingly worse. They found that smooth pursuit-based selection greatly outperformed fixation-based selection in terms of accuracy, and slightly so in terms of speed [14], as the eye-tracker's accuracy becomes worse.

Most of the previously mentioned research papers are examples of systems where eye-gaze is exclusively used for input, and does not consider other alternatives such as mechanical button presses. Some of this research is aiming at assisting disabled people who have little to no ability to use modalities other than their eyes for selection, and while this is an important topic, it is not the focus of this paper. And so, a potential option for our topic could be a system where multiple modalities are used, e.g. a system where aiming is achieved through eye-gaze but selection through a button press. Agustin et al. facilitated an experiment where they, amongst others, compared gaze-based aiming with button selection, and gaze-based aiming with expression recognition (EMG). They did not find any significant difference between the two selection methods, and EMG was noted to be natural to use. However, they found that eye-gaze was fatiguing to use [19]. In a similar study, Dechant et al. compared five different control schemes for aiming and selecting with each other: using only mouse, using only controller, using gaze to aim and controller to select, and finally two hybrid gaze-controller schemes for aiming with controller for selection. In the study, the three gaze-based interaction methods were shown to both be more error prone and slower than the two other methods [20]. In another study, Hansen et al. compared gaze-, head-, and mouse-based aiming with dwell-based selection and click selection. Contrary to the previously mentioned studies, they found that dwell-based selection was slightly faster for all aiming methods, and similarly to Agustin et al., they found that gaze-based aiming, as well as head-based aiming, was more mentally and physically demanding than mouse input [21].

Since dwell-based selection is found to be faster in certain contexts, it could be a potential solution as an alternative target-locking method. However, the Midas Touch problem could be of concern since players may accidentally dwell on unintended targets. Therefore, another possible solution could be aiming through gaze and selecting with a button press, similar to the previously mentioned hybrid gaze-controller schemes. This could negate the dwell time and potentially provide faster selection, while also preventing the Midas Touch problem. But this solution could pose other issues, such as confusion from having to use two different modalities to complete a single task.

2.4 Target Assistance in Games

Target assistance is a game balancing technique used to help players stay in a state of flow while playing the game. Flow is a mental state that is achieved when a game does not cause anxiety nor boredom in the player, often designed for through a balance between challenge and skill [22]. To help players stay in the state of flow, the goal of target assistance is to allow players to be quicker and more accurate when targeting enemies and objects on-screen, eliminating the frustration manual target aiming can cause.

Many target assistance techniques exists, with varying degrees of automation involved [23–25]. Bullet Magnetism bends the trajectory of a bullet (or similar) towards the target if it is going to just barely miss. Sticky Targets slows the movement of the player's cursor or camera when it is above the target. Target Gravity pulls in the player's cursor or camera when it draws near the target by simulating gravity. Area Cursor is as the name suggests, changing the cursor from a point to an area, usually circular in shape. Finally, Target Locking "locks" the cursor or camera onto the target so that it becomes virtually impossible to miss.

As a research topic, target assistance in games has mostly been looked at through the lens of the First-Person Shooter genre. Here, it has been found that even in multiplayer settings, players feel target assistance is fair and benefit the games it is used in [23]. Likewise, it has also been found here that target assistance techniques do not harm the players' skill development [24], nor does disclosing that target assistance techniques is being used hurt the players' overall experience of the games [25]. However, research into target assistance in games of other genres – especially Action games – has not been conducted to the best of our knowledge.

2.4.1 ***Target-Locking.*** Unlike First-Person Shooter games, where target locking is found to be too obvious [26] and interferes with skill play, in many Action-Adventure games its usage has become somewhat of an industry standard since its debut in *The Legend of Zelda: Ocarina of Time* in 1998. Target locking usually functions by the player activating it by pressing a dedicated button. When multiple targets are on screen, the game usually locks onto the target closest to the player's front. To change which target is locked onto, the player must often repeatedly press the button as the game keeps targeting what it considers to be the "next best" target, or the player can press two buttons – or flick a control stick to the left or right – to cycle through the targets present on-screen.

A downside with target locking is that, when multiple targets are present, the game may not be able to determine which target the player intends to lock onto, causing the player to lock onto the wrong target. This can cause frustration and potentially take the player out of the flow state, especially if it takes multiple tries to lock onto the intended target, which can cause the player to take damage or miss their hit opportunity if it takes up too much time. This is particularly often the case in Hack-and-Slash games, a subgenre of Action games that features many enemies at once, and it is therefore important to consider when designing such games.

3 EXPERIMENTAL DESIGN

3.1 Experimental Scenario

With focus on visual analysis of gameplay data, Burch et al. created a classification framework meant to aid future researchers in clarifying their experimental scenarios [27]. Based on this framework, we define our scenario as a classical post-experiment analysis of gaze-assisted gameplay, meaning we aim to develop a digital single-player game with gaze-assisting features that we will be testing in a standard experiment, and analyze the collected data afterwards.

3.2 Task Design

The game used for our experiment was designed to fit the Action game genre. Participants will control a player character capable of engaging in combat with enemies in a three dimensional space. The player character can run and attack, and the camera can be moved freely as well as be locked onto nearby enemies. The goal is for the participants to utilize this target-locking to defeat all the enemies in the game to win. The game was designed with contemporary Action games in mind as inspiration, such as Hyrule Warriors: Age of Calamity, Final Fantasy XV, and Assassin's Creed: Odyssey.

3.2.1 ***Controls.*** Based on our findings, we designed a target locking system for use in a singleplayer Action game. This system is controlled via three different modalities, acting as our experiment's three conditions: controller-only selection, controller + gaze selection, and gaze-only selection. The two gaze modalities feature

Explicit Eye Input [2, 5]. The controller + gaze modality features Continuous + Discrete controls where the participants aim with their gaze and select (lock their camera onto the target) with a controller button. The gaze-only modality features Continuous-Only target pursuit (for intended targets) and target avoidance (for enemies they do not want to target) controls, where they must both aim and select with their gaze.

The game is controlled using an Xbox 360 controller. Character- and camera movement is controlled with the Left- and Right Control Sticks, respectively. As mentioned, all three modalities are controlled in exactly the same way, except for target locking selection. For controller-only, target locking is activated by pressing the Xbox 360's LB button and selects the enemy closest to the player within a certain distance. For controller + gaze, the LB button is also used to activate target locking, but rather than being proximity-based, the game selects the enemy the participant is actively looking at. For gaze-only, target locking is activated automatically by dwelling your gaze on an enemy. The most optimal dwell time for this was determined using Jacob's findings [18] and fine-tuning it via playtesting, for a final dwell time of 500 milliseconds. Dwell time was used as the selection method based on Jacob's findings on the Midas Touch problem's influence when using dwell-based selection, where he found that Midas Touch is not an issue for players so long as failure to select the intended target is not of significance. The game does not feature a cursor or the Tobii gaze circle, as that might have been distracting for the participants. Aside from the target locking control modalities and corresponding tutorial UI, the game is identical across all three conditions.

Figure 1: The player (blue) standing next to the dummy (brown). Notice the arrow above the dummy's head, indicating that the player can target-lock it.

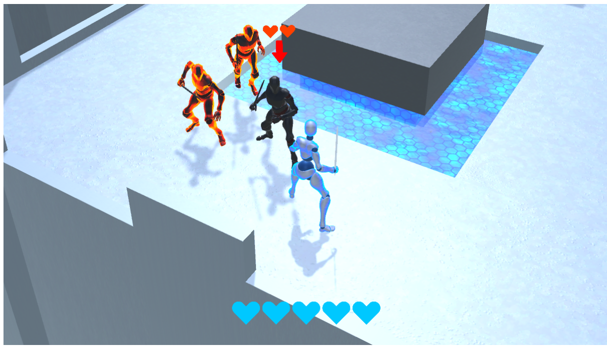

Figure 2: The player fighting three enemies, two of which are orange and one of which is black. Only the black enemy can be hurt.

Figure 3: The player fighting seven enemies in the final level. The black enemy is hit and about to die, after which one of the orange enemies will turn black.

3.2.2 ***Game Design.*** To take into account varying levels of experience with video games, the Action game genre, and with eye-trackers, we designed the game to progress in five connected levels. This was to introduce an intentional learning curve so that participants who were unfamiliar with Action games or eye-tracking would have their data be less affected by this lack of familiarity, since we are specifically testing an Action game feature – target locking – and how it performs with eye-tracking controls.

The first two levels act as a tutorial for the participants. In the first, they are greeted by a small introduction on how to play the game alongside a non-moving dummy enemy, seen in Figure 1, to test the gameplay controls on. In the second, they will fight a single active enemy that teaches them the enemies' behaviour. The third and fourth levels act as a learning curve to get the participants familiar with the gameplay in action, first pitting them against three enemies at once, seen in Figure 2, and then five enemies at once, both in environments with objects present to simulate a proper Action game environment. The final level is against seven enemies at once, seen in Figure 3, without obstacles to ensure there are no distractions that might interfere with the participants' target locking performance.

To ensure that the participants utilized the target locking feature, the game only allows one enemy at a time to be damaged, and the participants must be locked onto it to deal the damage. Enemies that cannot be hit yet are orange, with the one enemy that can be hit being black. Once the black enemy is defeated, one of the remaining orange enemies will turn black.

3.2.3 ***Apparatus.*** The game was developed in Unity3D version 2019.4.22f1 using the C# programming language, with JetBrains Rider version 2020.2.2 as the integrated development environment (IDE). Various free assets from the Unity Asset Store, Adobe Mixamo, and Zapsplat were used. The eye-tracker used was a Tobii Eye Tracker 5. The controller used was an Xbox 360 controller.

4 EVALUATION

With the findings from Section 2 in mind, the null hypothesis (H_0) and corresponding alternative hypothesis (H_1), which can be seen below, are evaluated using the system proposed in Section 3, with the experimental methods described in this section.

- **Null hypothesis:**
  Using either of the proposed gaze-enabled target locking methods, as an alternative to traditional controller-based target locking methods, *will not* have a significant favourable effect on the gameplay experience.

$$H_0 : \mu_E < \mu$$

- **Alternative hypothesis:**
  Using either of the proposed gaze-enabled target locking methods, as an alternative to traditional controller-based target locking methods, *will* have a significant favourable effect on the gameplay experience.

$$H_1 : \mu_E > \mu$$

For the experiment, the three conditions were Condition 1: controller-only, Condition 2: controller + gaze, and Condition 3: gaze-only.

4.1 Experimental Methods

The experiment was conducted using a within-subject design, and the sequence of which test participants were exposed to the conditions was determined using a Balanced Latin Square design to reduce order-effects. As mentioned, three conditions were tested during the experiment: a controller-only version, a gaze + controller hybrid version, and a gaze-only version. After the test participants were exposed to each of the conditions, they answered the System Usability Scale [SUS] [28] questionnaire and a slightly modified version of the core Game Experience Questionnaire [GEQ] [29]. The GEQ was modified by removing one of the sub components from the questionnaire, namely the Sensory and Imaginative Immersion component, as it wasn't relevant for this study. The remaining components of the GEQ evaluated in this study were (1) Competence, (2) Flow, (3) Tension, (4) Challenge, (5) Negative Affect, and (6) Positive Affect. Furthermore, the test participants were given a demographics questionnaire to collect basic information.

Apart from the three questionnaires, various gameplay metrics were collected during each of the three conditions. The metrics were: (1) how many times they died total, (2) how much HP they lost total, (3) the total amount of times they successfully targeted an enemy, and (4) how much active play time it took to complete each condition, measured in seconds.

Finally, after completing the three conditions and subsequent questionnaires, they answered a short final questionnaire which consisted of two questions: (1) "Which condition did you like the most?", of which they could select one of the three conditions, and (2) "Do you have any final notes or comments?", where they could fill in a long format qualitative answer.

4.2 Procedure

Due to the ongoing Covid-19 pandemic, getting participants proved difficult and the evaluation was split into two almost identical methods: one conducted remotely where participants tested from a remote location all with the same setup, and the other conducted in-person at a set location using the same setup for each session.

4.2.1 ***Remote Evaluation.*** The evaluation conducted remotely was done using the online communication tool Discord [30], with the assistance of a remote helper, who was responsible for bringing and setting up a laptop with the game, the Xbox controller, and the Tobii eye-tracker.

For the purpose of both the remote- and in-person evaluations, all four questionnaires were converted into an online format using Google Forms. The evaluation session was monitored using Discord by having the test participant share the laptop screen while a test facilitator was communicating with the participant in a voice call. First, the participants were asked to give verbal consent, which was recorded. They were then asked to fill in the demographics questionnaire, and afterwards helped through the calibration of the Tobii 5 eye-tracker. When the calibration was complete, they were informed which of the three conditions they were supposed to play, and the test facilitator confirmed that they chose the right one. They then played through the condition while the test facilitator was monitoring them. Upon completion, they filled out the SUS and GEQ. They then completed the other two conditions in the same manner as the first, the test facilitator told and confirmed which condition to pick, and when done, the participant filled in the questionnaires again after each condition. Afterwards, they were asked to fill in the final questionnaire. When all the remote test participants were done, the remote helper sent all the collected gameplay metrics to the test facilitator over Discord.

4.2.2 ***In-Person Evaluation.*** The procedure for the in-person evaluation was almost identical. First, the test participant was asked to give consent in the same way as previously mentioned, then fill in the demographics questionnaire. Afterwards, the Tobii 5 eye-tracker was calibrated for the test participant. When the calibration was complete, the procedure was the same as in the remote evaluation up until the participant had completed the final questionnaire, where in this version of the evaluation, the test facilitator would save the gameplay metrics for the test participant.

4.2.3 ***Equipment.*** In both evaluations, the eye-tracker and controller mentioned in Section 3.2.3 were used for gaze- and gameplay input, respectively. The PC monitor was a 15 inch laptop screen in the remote evaluations. For the in-person evaluations, a 24 inch monitor was used, where the participants were sitting approximately 70 centimeters from it.

4.2.4 ***Participants.*** Before the evaluation began, a power analysis was conducted to estimate how many participants would be needed to show reliable statistical significance, and according to that, a minimum of 33 test participants would be needed. Due to the ongoing pandemic, that proved difficult and only a total of 12 participants were able to be included in the evaluation in the end. Four were included in the remote evaluations while the remaining eight participated in the in-person evaluations.

The participants were aged between 21 and 25 with a mean of 23.17. Five were female and seven were male. Two play video games 5-10 hours a week, five 10-15 hours, two 15-20 hours, and three 20+ hours. Of the participants, all but one play Action games, four of which play Hack-and-Slash games or similar a little, and another four a lot. Three of the participants had previous, however just a little, experience with using eye-tracking.

4.3 Results

4.3.1 ***GEQ.*** The results from the GEQ were averaged according to how it is described by Poels et al. [29]. The results from the six different components can be seen in Table 2.

Table 2: GEQ Descriptive Statistics

Competence	Mean	SD
1	2.150	1.066
2	2.558	1.044
3	2.183	1.234

Flow	Mean	SD
1	1.883	1.177
2	2.533	0.924
3	2.317	1.204

Tension	Mean	SD
1	1.183	0.802
2	0.933	0.792
3	1.533	1.277

Challenge	Mean	SD
1	2.000	0.995
2	2.117	0.679
3	2.367	0.785

Negative Affect	Mean	SD
1	0.729	0.670
2	0.479	0.548
3	0.667	0.651

Positive Affect	Mean	SD
1	2.433	0.957
2	2.783	0.556
3	2.433	1.147

4.3.2 ***SUS.*** Similarly, the SUS data was computed for each of the three conditions, with resulting usability scores of 70.63 for Condition 1, 77.5 for Condition 2 and 68.33 for Condition 3.

4.3.3 ***Gameplay Metrics.*** The gameplay metrics collected were averaged for each of the three conditions and a mean of total deaths, total HP lost, total enemies targeted, and total active play time in seconds was computed, the results of which can be seen in Table 3.

Table 3: Gameplay Metrics Descriptive Statistics

Deaths	Mean	SD
1	1.167	2.038
2	0.333	0.651
3	2.583	6.775

HP Lost	Mean	SD
1	20.250	16.804
2	16.583	5.791
3	30.917	46.438

Targets	Mean	SD
1	32.667	23.918
2	22.417	5.931
3	43.167	34.936

Time	Mean	SD
1	148.202	67.764
2	142.264	65.244
3	202.422	174.364

4.3.4 ***Final Questionnaire.*** From the first question of the final questionnaire it was found that 50 percent of the participants preferred Condition 2 and the other 50 percent preferred Condition 3, and thus no one preferred the traditional controller-based scheme of Condition 1. Five of the 12 participants answered the final question and commented on the evaluation.

4.4 Statistical Analysis

The statistical evaluation method chosen for evaluating the computed GEQ data was the non-parametric Friedman test, as each component of the GEQ have three conditions, the experiment uses a withing-subject design, and the computed data type is discrete. The Friedman test was conducted on each of the six components of the GEQ, the results of which can be seen in Table 4.

Table 4: GEQ Friedman Tests

Factor	df	p
Competence	2	0.620

Factor	df	p
Flow	2	0.005

Factor	df	p
Tension	2	0.142

Factor	df	p
Challenge	2	0.662

Factor	df	p
Negative Affect	2	0.377

Factor	df	p
Positive Affect	2	0.386

Of the six components of the GEQ, only (2) Flow showed a significant difference with a p-value of $p<0.05$ between the three conditions. A post hoc analysis in the form of a Conover test was conducted to see where the difference was, the results can be seen in Table 5

Table 5: Conover's Post Hoc Comparisons - Flow

		df	p	p_{bonf}	p_{holm}
Condition One	Condition Two	22	0.004	0.012	0.012
	Condition Three	22	0.046	0.138	0.092
Condition Two	Condition Three	22	0.278	0.833	0.278

The gameplay metrics were evaluated in the same manner as the GEQ data to see if any significant impact on the performance of the participants were present between the conditions. The data was evaluated using the Friedman test as the assumptions for conducting a one-way repeated measures ANOVA weren't met. The results can be seen in Table 6.

Table 6: Metrics Friedman Tests

Factor	df	p
Deaths	2	0.279

Factor	df	p
HP Lost	2	0.254

Factor	df	p
Targets	2	0.005

Factor	df	p
Time	2	0.338

Similarly to the results of the GEQ data, only one of the four game metric measures showed a significant difference between the three conditions. As can be seen in Figure 6, it was (3) Targets, with a p-value of p<0.05. Again, a Conover test was conducted to determine where the difference was and these results can be seen in Table 7.

Table 7: Conover's Post Hoc Comparisons - Targets

		df	p	p_{bonf}	p_{holm}
Condition One	Condition Two	22	0.117	0.350	0.233
	Condition Three	22	0.117	0.350	0.233
Condition Two	Condition Three	22	0.004	0.011	0.011

5 DISCUSSION

This section will discuss the results obtained through the evaluation conducted in Section 4.

5.1 Game Experience

The goal of the GEQ was to evaluate and compare the overall experience of the game with the three different target locking methods: controller-only selection, controller + gaze selection, and gaze-only selection. Using the results of the six different components of the questionnaire, the hypotheses outlined in the beginning of Section 4 were evaluated.

Of the six components of the GEQ, only (2) Flow showed a significant difference between the three target locking methods, specifically between Conditions 1 and 2. However, it can potentially also be seen to a smaller degree between Conditions 1 and 3 if we consider the p-value without any corrections. This difference indicates that using gaze-tracking as an alternative to traditional controller-based target locking can potentially significantly improve the feeling of flow within the game. This heightened feeling of flow can be considered a favourable effect of using gaze-tracking for target locking [22], and thus could indicate that the null hypothesis can be rejected.

Of the remaining five components of the GEQ, (1) Competence and (6) Positive Affect can be considered positive, whereas (3) Tension and (5) Negative Affect are negative, and (4) Challenge is neither positive nor negative as challenge should neither be too low nor too high. From the results of the GEQ it can be seen that none of these five components show any significant difference, which could indicate that no favourable effect comes from using gaze-tracking for target locking in these areas. However, it is worth noting that of the 12 participants, only three had previous experience with eye-tracking as mentioned in Section 4. So despite the fact that most of the participants had never used an eye-tracker before, the eye-tracking results of the GEQ still measured up to the traditional input method when one might have expected them to perform worse. Furthermore, while no other significant differences were found, Condition 2 still showed a more favourable score in most of these components of the GEQ. As could be seen in Table 2 of Section 4, it had the highest Competence and Positive Affect scores, and the lowest Tension and Negative Affect scores, which could indicate that Condition 2 is still more favourable than the other two conditions. However, Condition 2 is also the condition with the lowest standard deviation in all components of the GEQ, and with the small sample size of this experiment, it could potentially have skewed the numbers in favour of Condition 2.

Condition 3, on the other hand, had the highest Tension and Challenge scores, indicating that Condition 3 was the hardest and most frustrating of the three. However, it showed very similar results to Condition 1 in Competence and Positive Affect, and had a slightly lower Negative Affect. This could have been influenced by the fact that using an eye-tracker was a new experience for most of the participants, so the novelty factor of using this new input modality could have favourably influenced their opinion of both gaze-tracked conditions.

5.2 System Usability

The SUS was used to determine the overall usability of the three conditions. From the experiment it was found that all three conditions yielded a usability score above 68, which is considered above average [28], and thus all three conditions appear to have an above average usability. As can be seen in Section 4.3.2, of the three conditions, Condition 2 had the highest usability with a score of 77.5, Condition 1 had the intermediate score which was 70.63, and Condition 3 had the lowest with a score of 68.33. The lower score in Condition 3 cooperate the findings of the GEQ, as it would appear that using the gaze-only target locking method of Condition 3 made the system harder to use, and therefore made the gameplay more difficult compared to the other two conditions. On the other hand, using the gaze + controller hybrid of Condition 2 seems to provide the best usability, while still providing an adequate challenge to keep the player in a state of flow, as seen from the significantly higher Flow score in the GEQ.

5.3 Player Performance

The purpose of the gameplay metrics was to evaluate the performance of the participants as well as to examine whether the Midas Touch problem was present in Condition 3. As mentioned in Section 4.3, only the total number of enemies the participant locked onto showed a significant difference of the four gameplay metrics. It showed that Condition 3 did indeed have significantly higher amounts of target-locks compared to Condition 2, which indicates that the Midas Touch problem is in fact present in Condition 3. This could potentially play a role in the condition's lower usability score as well as its GEQ scores.

Though not significant, the other results of the examination of the gameplay metrics indicate that the participants had the best overall performance in Condition 2, with the lowest amounts of deaths, HP lost, and time spent to complete the condition. Performance-wise, Condition 3 was the worst, with the highest score in all four measurements. This further cooperate the findings of the GEQ and the SUS. However, as with the GEQ, Condition 2 had the lowest standard deviation across all measures, which as mentioned could influence the results.

It has previously been found that users tend to perform worse when using eye-tracking systems compared to more traditional systems [20]. In this study, it was found that Condition 3 cooperates that. However, Condition 2, on the other hand, had higher performance than the traditional controller-based system of Condition 1. This could potentially indicate that how you implement eye-tracking into a system will impact how it affects the performance of the user. As for the future of including gaze-based target locking into video games, this makes it apparent that how the target locking is implemented is of importance.

5.4 Player Feedback

The final questionnaire was used to see which condition the participants preferred the most, and here it clearly shows that the two gaze-based solutions were preferred as not a single participant preferred the controller-only version of the game. This could potentially be affected by the novelty factor of the eye-tracker as previously mentioned. However, this 50 percent preference of Condition 3 is present despite the Midas Touch problem observed through the gameplay metrics, and, after further examination, it was found that the participants who preferred Condition 3 averaged only 28.83 target-locks on their Condition 3 playthroughs, whereas the participants who preferred Condition 2 averaged 57.5 target-locks on their Condition 3 playthroughs, which is almost twice as many. This could indicate that the preference of Condition 2 over 3 for those participants might be a result of the Midas Touch problem, since they seemed to experience it to a much higher degree than the others.

It could, however, also be due to calibration issues with the eye-tracker, since lower eye-tracking accuracy could result in accidental selections or missed selections, which could negatively impact the participants' performance and opinions on the conditions. Inaccuracies with the eye-tracker could also have indirectly positively affected Condition 2, since in that condition the participants only had to briefly look at a target in order to be able to select it, and as such, inaccuracies would have less of an impact compared to Condition 3. Therefore, it can possibly be assumed that a system where eye-tracking inaccuracies is less of an issue would be ideal, especially in a video game context where players may not sit still, and may not want to re-calibrate the eye-tracker before each play session or during play.

From the low amount of qualitative answers given in the final question, nothing can be concluded. However, from the responses it would appear that some participants found Condition 3 quite overwhelming where others found it fun and natural to use. Overall, it could seem like some participants found using the eye-tracker for targeting very natural. One participant did not even notice it was on, despite still being able to play the game naturally. On the other hand, another person found Condition 2 stressful, which could show that different people will have different perceptions of the two gaze-based methods, which makes sense considering the 50-50 split in which condition they preferred.

5.5 Future Work

Considering the limitations of this study, improvements for future research can be made in various areas. The power analysis performed showed that a minimum of 33 participants where required for reliable results. This number could be increased based on the experimental design used, such as the Balanced Latin Square Design using three conditions preferring a participant number that is a multiple of six. Furthermore, the game was designed to take skill discrepancies into account for participants who might have been very familiar with or wholly unfamiliar with the Action genre's gameplay. A better approach when more participants would be available for testing would be to narrow down the target group to only include participants who are experienced in playing games of the Action genre and its sub-genres, such as Hack-and-Slash games. Lastly, using a singular setup so that every test is identical in hardware and procedure would be preferred.

As for the study subject itself, different target locking implementations could be looked into in the future. As mentioned in Section 2.4.1, many games that feature target locking also feature a way to switch which target the player is locked onto without having to untarget in the process. Furthermore, other gaze-based solutions could be explored as well. This study utilized dwell time for selection in the third condition, but other gaze-based selection methods exist that could also be explored, such as gesture selection or gaze-based intention prediction. Lastly, one participant mentioned that one of the gaze-based conditions was straining on their eyes. This could be looked into in the future to see if there exist discrepancies between different gaze-based solutions in regards to how prevalent or severe the eye strain may be in participants who experience it.

6 CONCLUSION

In this paper, we evaluated two gaze-enabled modalities for target locking in an Action game. One modality utilized gaze as selection with controller input for confirmation, where participants would be able to target lock enemies they were looking at via a button press. The second gaze modality utilized dwell time for confirmation and circumvented the need for controller input for target locking altogether. A standard, non-gaze modality was evaluated as well to compare the two gaze solutions to, which exclusively used the controller. Our results show that using either of the two proposed gaze-enabled target locking methods has a favourable effect on the gameplay experience compared to the controller-only modality. This is seen in the significantly higher flow score for the gaze + controller modality measured in the Game Experience Questionnaire, in how every participant reported that they preferred the gaze-enabled solutions over the standard controller-only modality, and in how multiple of the participants reported that they would like to see gaze-tracking be utilized more in video games. Albeit the sample size was too low to conclude anything for certain, it seems that our null hypothesis can likely be rejected if similar results could be achieved with a large enough sample size.

As the use of eye-tracking modalities becomes more common in the gaming industry, it becomes increasingly important for game designers to develop compatibility with their games' more important features. For Action games to become fully gaze-enabled, combat features such as target locking requires gaze-based interaction solutions. This paper provides evidence that gaze-enabling target locking can enhance the players' experience with Action games, and that it is important to evaluate which gaze solution is chosen for the target locking implementation as different gaze modalities can impact the players differently.

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