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Abstract

A report discussing how the use of eye tracking technology can further improve the development of games through immersion and accessibility.

An investigation into Eye Tracking technology to further Game Development

CT6007 Independent Research Project

Contents

[Figures 2](#_Toc98505156)

[Introduction 3](#_Toc98505157)

[Aims 3](#_Toc98505158)

[Objectives 3](#_Toc98505159)

[Thesis 4](#_Toc98505160)

[Literature Review 5](#_Toc98505161)

[Overview 5](#_Toc98505162)

[Case Study 1 – Using Eye-tracking as alternate controls 5](#_Toc98505163)

[Case Study 2 – Using Eye-tracking for Accessibility 10](#_Toc98505164)

[Case studies comparison 14](#_Toc98505165)

[Alternatives to Tobii 15](#_Toc98505166)

[Summary 16](#_Toc98505167)

[Output Design 17](#_Toc98505168)

[Specification 17](#_Toc98505169)

[Justification 19](#_Toc98505170)

[Glossary 20](#_Toc98505171)

[References 21](#_Toc98505172)

# Figures

[Figure 1 Illustration showing how eye tracking works (Tobii, n.d.) 3](file:///E%3A%5CUni%20Work%5CLevel6%5CCT6007%5CAn%20Investigation%20into%20Eye%20Tracking%20Technology%20to%20Further%20Game%20Development.docx#_Toc98502384)

[Figure 2 Ratings on how fun Sacrifice was perceived comparing hand and eye inputs (Jönsson, 2005) 6](file:///E%3A%5CUni%20Work%5CLevel6%5CCT6007%5CAn%20Investigation%20into%20Eye%20Tracking%20Technology%20to%20Further%20Game%20Development.docx#_Toc98502385)

[Figure 3 Ratings on how fun Half-Life was comparing hand and eye inputs (Jönsson, 2005) 7](file:///E%3A%5CUni%20Work%5CLevel6%5CCT6007%5CAn%20Investigation%20into%20Eye%20Tracking%20Technology%20to%20Further%20Game%20Development.docx#_Toc98502386)

[Figure 4 Hits and misses for three different input configurations (Isokoski & Martin, 2006) 8](file:///E%3A%5CUni%20Work%5CLevel6%5CCT6007%5CAn%20Investigation%20into%20Eye%20Tracking%20Technology%20to%20Further%20Game%20Development.docx#_Toc98502387)

[Figure 5 Diagram showcasing MAGIC pointing (Zhai et al., 1999) 9](file:///E%3A%5CUni%20Work%5CLevel6%5CCT6007%5CAn%20Investigation%20into%20Eye%20Tracking%20Technology%20to%20Further%20Game%20Development.docx#_Toc98502388)

[Figure 6 Transparent overlay positions for looking around (left) and movement (right) (Vickers et al., 2013) 11](#_Toc98502389)

[Figure 7 Results on groups A and B completing the objectives (Vickers et al., 2013) 12](#_Toc98502390)

[Figure 8 Times taken for group A to reach waypoint with the modified interface (Vickers et al., 2013) 13](#_Toc98502391)

[Figure 9 Comparing unmodified and original tests (Vickers et al., 2013) 14](#_Toc98502392)

[Figure 10 In-game observation rooms in Portal 2 (Valve, 2011) 17](#_Toc98502393)

[Figure 11 Tobii Eye Tracker 4C and Tobii Eye Tracker 5 specifications (Tobii, 2020) 18](#_Toc98502394)

# Diagram showcasing how eye-tracking technology worksIntroduction

Eye-tracking is an input method that uses high-resolution cameras, near-infrared, and algorithms. These collect data on eye movement and activity, such as blinking and staring. (See Figure 1) (Tobii, n.d.). With the data collected from the user, it can be used as a type of input used to select objects on the screen, like a mouse. This is used in a range of tasks ranging from simulations to video games. Another use is for accessibility, allowing disabled people to use a computer with ease.

Figure Illustration showing how eye tracking works (Tobii, n.d.)

Tobii, the largest producer of eye-tracking, has 167 commercial games, demonstrating that there is a market for this technology (Tobii, n.d.). Nonetheless, it remains a niche accessory and when it is used, it is not used to its full potential (Almeida, et al., 2011). Even though the Producer of Assassins' Creed Rogue describes eye-tracking as "easy to use," only a small portion of the Tobii Eye-functionality Tracker is used (Vasiliu, 2015).

## Aims

This paper aims to research how eye-tracking includes can be utilised by game developers. The paper will also identify the benefits and drawbacks that should be considered when using eye-tracking.

## Objectives

The objectives for this paper are to:

* Analyse case studies investigating how beneficial eye-tracking is in different scenarios.
* Evaluate ways Tobii Eye-tracking can add accessibility.
* Evaluate feature the Tobii Eye-tracker has that can enhance a game.
* Review what needs improvement within the technology and potential solutions suggested.
* Develop a plan for what should be looked at when considering eye-tracking.

## Thesis

The purpose of this investigation is to discuss how eye-tracking can improve games. Using it as an input that could replace traditional input controls, such as a mouse and keyboard, in some cases and as an extra input. The paper will examine both positives and negatives of using eye-tracking for gaming. This will provide a balanced overview of how game developers could apply eye-tracking.

# Literature Review

## Overview

This will cover a variety of eye-tracking applications, with a focus on Tobii Eye-Tracking and the range of tools provided. This review will examine two case studies where games were created with eye-tracking implemented differently. Participants had played these games and their thoughts on the experience were recorded along with suggestions on improvements. The paper will also investigate possible solutions for common issues.

## Case Study 1 – Using Eye-tracking as alternate controls

Interviews with experts in the field, as well as focus groups, were used by Jönsson (2005) to collect data on the use of eye-tracking in computer games.

People with a variety of gaming backgrounds played the FPS games Sacrifice and Half-Life in these focus groups. An SDK was used to alter the latter to allow for eye-controlled interactions. There were five demos available to try out different methods of integrating eye-tracking. Each game focused on either traditional inputs or the participants' eyes, with a final demo on Half-Life combining the two. The player used their eyes to control the weapon's aim and their mouse to control the Field of View (FOV). While playing the game, participants' comments and reactions are recorded. After that, they were asked about their impressions, with a focus on enjoyment, ease of use, and future improvements (Jönsson, 2005).

Fourteen people were invited to take part in the test. However, only eight were able to partake due to calibration errors.

In Sacrifice, Jönsson (2005) reports that “five of the test subjects experienced greater control when interacting with the eyes than with the mouse”, with it later mentioning that Half-Life had similar responses. One participant commented that “it was faster to find the targets with the eyes than with the mouse” (Jönsson, 2005). Vickers, et al. (2010) reported similar findings, stating that "Users will typically look at the area of the screen where they wish to move before physically operating a mouse," and that "eye movement will be faster than any physical movement."

All participants thought eye-tracking was more enjoyable than traditional controls (see Figure 2), with one person describing it as "easy, new, and exciting." Despite this, some comments were claiming that the game was played for a longer duration. It was reported that the game would quickly become boring due to a lack of challenge, though this could be a comment on the gameplay itself. Other comments included one person's eyes drying out after a while and another's "he did not feel relaxed since he has to remain in the same seating position when using eye-tracking," which relates to calibration issues (Jönsson, 2005).

Figure Ratings on how fun Sacrifice was perceived comparing hand and eye inputs (Jönsson, 2005)

In Half-Life, the results were separate to compare hands and eyes and then looked at combined controls separate. Jönsson (2005) justified this by saying that the weapon sight was not locked to the middle of the screen, causing an extra variable.

"Six of the participants experienced better control when steering with the mouse," Jönsson (2005) wrote. This may be because a mouse is a common tool. "The naturalness of using the hand is due to experience," says one participant, reinforcing the point. According to Isokoski and Martin (2006), "with continued training, the performance with the eye-tracker might improve more than the performance with the other devices."

With similar results to Sacrifice, half of the participants stated that they found the eye-tracking controls more fun and engaging. One of these participants stated that “It feels more like it is yourself that moves around” (See Figure 3) (Jönsson, 2005).

Figure Ratings on how fun Half-Life was comparing hand and eye inputs (Jönsson, 2005)

The final test conducted used eye-tracking in conjunction with mouse controls. The inclusion of testing eye-tracking as an extension to traditional controls is an important test due to the popularity of the assisted features utilised in games that use eye-tracking games. In Tobii’s game archive, there are 167 commercial games, with the top three features used being extended view (controlling FOV with your eyes) where 97 out of the 167 use this feature, then followed by 61 games using clean UI (UI becomes translucent when not looking at it) and 43 games using aim at Gaze (Tobii, n.d.).

Six of the eight participants in the final test rated the combined inputs as providing similar or better levels of control than using them separately, with many of the improvements being compared to the eyes (Jönsson, 2005). Yet, Isokoski and Martin (2006) disagree with this point. Their test recorded how many times the players hit a target over ten sessions. These tests looked at using Xbox 360 controller, traditional PC controls, and finally mouse and keyboard with eye-tracking assistance. These tests discovered that the Tobii assistance was performing worse than traditional controls, but better than using a controller (see Figure 4). This could be caused by a previous point of the familiarity of using a mouse.



Figure Hits and misses for three different input configurations (Isokoski & Martin, 2006)

Along with better control, Jönsson (2005) recorded that five of the participants felt that combined inputs were less straining than using the eyes; and half the participants also said that it was also improved string compared to mouse inputs. "More relaxing for the eyes when they can wander around without the view following them," said one participant. "There is a lower risk of motion sickness than in the previous case" (Jönsson, 2005). These results show evidence that eye-tracking works better to assist the traditional controls, reaping the benefits of both input types. Similar results appeared when Dechant et al. (2018) performed similar tests where they got participants to complete a Fitts task (moving a pointer between set markings) to see how long it took to go through each waypoint. This task was used to compare controller, mouse, gaze, and then implemented gaze controls in two different ways with the controller. Although the results did show signs that using gaze interactions alongside the mouse can improve reaction times, they were minimal improvements. Dechant et al. (2018) explained these minor improvements were because the human eye performs small and rapid eye movements. These movements can cause difficulty tracking the exact point the user is looking at.

Alongside the focus groups, Jönsson (2005) interviewed professionals in eye-tracking, computer games, and human-computer interactions (HCI). Within these interviews, they discussed their thoughts and opinions on the use of eye-tracking and how it can impact gaming in the future.

Shumin Zhai was an HCI researcher at the IBM Almaden Research Centre. Zhai explained that the hardware would not be able to replace the mouse and would have the most benefit in special cases, where traditional controls may not be useable. Yet, he feels that eye-tracking will find more success as an aid to the mouse using methods such as MAGIC pointing (Jönsson, 2005). In a previous study, Zhai et al. (1999) stated that MAGIC pointing is an interaction technique that uses the user's gaze point to teleport the cursor to where they are looking with minimal mouse movement (see Figure 5).

Figure Diagram showcasing MAGIC pointing (Zhai et al., 1999)

Returning to Jönsson's (2005) interview, Zhai details what he considers to be the requirements for eye-tracking to be successful. These requirements include allowing user movement and at least a 30Hz refresh rate. These requirements are implemented into Tobii's latest eye-tracker, Tobii Eye Tracker 5, through head tracking and having an image sampling rate of 133Hz and a non-interlaced gaze at 33Hz (Tobii, 2020).

Ulrik Lindahl was a game developer and CTO of Liquid Media. Lindahl spoke about the games industry, explaining how it is always changing and how gameplay is essential for a successful game. He stated that in an FPS game “the player views the environment from his perspective and becomes immersed in the game”. When asked about using eye-tracking in gaming, Lindahl stated that eye-tracking could contribute to better gameplay and that it can make the player more “immersed in the game in a new way” (Jönsson, 2005). Vickers et al. (2010) agree with Lindahl’s opinion on eye-tracking with it having “potential to add new levels of gaming immersion”. They expanded on Lindahl’s viewpoint by claiming that it can be used for direct input (replacing traditional controls) or “by using a more passive attentive approach (e.g., making NPCs aware of where you are looking and having them respond)” (Vickers, et al., 2010).

Peter Lönnqvist was a psychologist and doctoral student at the Department of Computer and Systems science researching HCI. Lönnqvist was not asked about eye-tracking specifically, but more on what he believed would be used to interact with computers in ten years. Lönnqvist responded that wearable equipment, such as VR headsets were not going to be successful due to being “too heavy and bulky”, with it being limited to rings or watches (Jönsson, 2005). However, this point of view is not entirely conducive, as VR is a very popular wearable technology that has become more comfortable to wear as overtime hardware has become more lightweight and is not as bulky. Some of the latest VR headsets have eye-tracking implemented that allows the use of features like Foveated Rendering, where the data collected about the player’s gaze point determines what sections of the game have the highest amount of detail which can help with game performance (Tobii, n.d.).

## Case Study 2 – Using Eye-tracking for Accessibility

Vickers et al. (2013) documented how eye-tracking can help people with motor-related disabilities to play games where they control a character with their eyes.

Vickers et al. (2013) conducted tests on two groups of people. Group A consisted of four cerebral palsies (CP) patients who were believed to benefit greatly from the use of eye-tracking. Group B consisted of eight people with muscular dystrophy (MD) that did not require eye-tracking but would benefit from it. In these tests, the participants played in a private World of Warcraft server where they could explore freely where they controlled the character by looking in a set region on the screen (See Figure 6). The participants took part in two 15 to 30-minute sessions, two weeks apart from each other. The amount of success was recorded dependent on whether the participant could:

1. Start and stop their avatar from moving
2. Follow simple instructions (by moving to set waypoints)
3. Move their avatar in all directions



Figure Transparent overlay positions for looking around (left) and movement (right) (Vickers et al., 2013)

The character was controlled by a Tobii eye-tracker and Snap Clutch. Snap Clutch is software designed to help with a common problem known as Midas Touch. Midas Touch is caused by the eyes constantly being used and the eye-tracker can detect certain movements and mistake them for a click (Istance, et al., 2008). Jacob (1990) suggested alternative, simpler methods that could be used that are adding keyboard inputs as button clicks, elongated blinks as selection confirmation, and dwell time. Dwell time is the use of staring at an object long enough that it declared the stare as a selection (Jacob, 1990).

From the beginning of the testing, Vickers et al. (2013) noted that there were already patterns between group A and group B. In group A, three of the four participants had trouble setting up and calibrating the eye-tracking to the participant, group B only had one out of the eight having issues. The main cause for these issues was the eye-tracking having difficulties finding the participants due to the natural positions their heads were in. Only the second participant in group A (referred to as GPA-2) had calibration issues due to head movements causing eye-tracking to not locate her eyes. Pi and Shi (2019) suggested an online calibration that estimates the user’s eye positioning by using previous data on eye positioning. However, this method needs more research and time working on.

All of Group A in Vickers et al.’s (2013) test were able to start and stop their avatar in the first session, but GPA-1 was unable to in the second session. GPA-1 was thought to be having more problems because of "involuntary head movements, causing the eye-tracker to fail to track his eye." (Vickers, et al., 2013). GPA-2 was able to complete all three tasks after some adjustments were made to the individual’s wheelchair, to the point where they could explore the map with few problems. It was also noted that as GPA-2 continued to play WoW, she got more comfortable and less anxious which resulted in fewer involuntary head movements. GPA-3 and GPA-4 were able to move the avatar in both sessions but not turn it around. Although not as successful as GPA-2, GPA-4 showed a similar trend in which his head movements decreased over time. These results showed an overall conclusion that one of the requirements for future eye-tracking should be to improve the calibration and the tracking of a user’s head, a point that Zhai made when interviewed in the previous case study (Jönsson, 2005).

Seven of the eight group B participants were able to complete all three objectives with full control over the avatar. Only GPB-2, who already had issues with calibrating the eye-tracking due to his natural head position, had issues completing the tasks (see figure 7). This further proves the requirement for better head tracking.



Figure Results on groups A and B completing the objectives (Vickers et al., 2013)

A second test was performed involving the original group participants. This time, a baseline was created using twenty able-bodied participants (group C). In this test, the participants were put back into WoW with a modified interface where the regions to move the character are put in places that the participant could gaze at more reliably. The interface modifications were made unique for each person who had trouble with the default controls through using a diagnostic test. A diagnostic test has the user try to stare at random segments on a screen for a fixed amount of time; the longer it takes to look at the right section, the poorer the reliability score (Vickers, et al., 2013).

Despite only GPA-2 reaching all the checkpoints using the traditional interface, group A showed large improvements to the control of the avatar. GPA-1 initially could only move forwards whereas GPA-3 and GPA-4 could look to one side or move forward (not both together). With the modified interfaces, group A participants were able to move forwards and turn left and right while in motion. However, this was not reflected as much within the results table as the participants did not reach the designated waypoints due to getting stuck on a game object. GPA-3 was unable to reach past the first waypoint as she “appeared to ignore the instructions and explored the areas of the world that she wanted” (see figure 8). (Vickers, et al., 2013).



Figure Times taken for group A to reach waypoint with the modified interface (Vickers et al., 2013)

Six of the eight participants from group B did not need modifications, only GPB-2 and GPB-3. All of group B were able to complete waypoint one with 88% completing the test, group C has 89% of people complete all three waypoints. GPB-2 was only able to complete one waypoint, but similarly with group A, improved what they were able to do from being able to only start and stop the avatar, to be able to move forward and turn in one direction. GPB-3 was able to complete all three waypoints, albeit at a slower pace than the other members of Group B due to some calibration issues (see figure 9). (Vickers, et al., 2013).



Figure Comparing unmodified and original tests (Vickers et al., 2013)

The improvements made by all the participants shows that the inclusion to customise the interaction screens allows games to be made more accessible and give people the chance to play games how they want to. Hui and See (2015) commented on allowing the user to be able to customise the User Interface, saying that it “enhanced usability experience”. This idea to allow the user to customise the UI could be used in eye-tracking as UI elements, such as an in-game button, can be changed to be larger so some users will be able to select items with better accuracy. The idea of increasing the size of interactable objects is explained by Deng et al. (2014) when talking about Midas Touch where accuracy struggles with smaller game objects, but it has been reported that “gaze can provide good performance when an object is large”.

## Case studies comparison

When it came to researching eye-tracking technology, Vickers et al. (2013) and Jönsson (2005) had different goals in mind. Jönsson focused on the use of eye-tracking as an enhancement to games with Vickers et al. looking at how it can benefit people with disabilities as an accessibility tool. Yet, these papers showed similarities as to what works well for eye-tracking and points out the improvements that can be made.

Both studies comment on the difficulties with having to keep the user’s head still otherwise there are calibration issues. Vickers et al. (2013) recorded that some participants had issues calibrating due to their natural head positioning making it tricky to track their eyes, with one participant only having their left eye being able to be tracked. Jönsson (2005) interviewed HCI researcher Shumin Zhai about the potential use of eye-tracking in the future in which he responded by creating a list of requirements detailing what needs to be focused on for eye-tracking to be successful. Zhai stated that future instalments should allow the user to be able to move their head freely without disturbing the calibration. This issue may not be as major anymore because in recent years technology has improved where eye-trackers can now not only track the user’s eyes but also added head-tracking (Tobii, 2020).

The inclusion of head-tracking in recent years brings further benefits to eye-tracking as it can act as another input source. This can be accomplished by controlling the player's FOV with head-tracking, an eye-tracking technique that Jönsson (2005) identified as an effective way to extend the player's control. This is accomplished by turning your head to one of the screen's corners and moving the game camera in that direction This frees up the eye-tracking system for other tasks like game object interaction. This FOV control can also be altered for accessibility so that head-tracking is used to turn the character around and eye-tracking is only used to control when the player is moving forwards, solving the issues Vickers et al. (2013) discovered.

## Alternatives to Tobii

Along with the technical issues that arise with the use of eye-tracking, there is also the cost for a professional eye-tracker, with the Tobii Eye Tracker 5 being £250. In recent years, however, some games can use basic cameras. Before Your Eyes (2021) is a game in which the player controls the game by blinking, this is detected by a camera. It does not matter if it's a professional camera, a phone camera, or a built-in laptop webcam; all it needs to do is detect basic eye movements.

EyeCommander is an alternative method for achieving full gaze detection that has been in development since 2021 (AceCentre, 2021). Although EyeCommander is a communication tool that was not designed for gaming, it could be altered in the future. It is a desktop application that uses a front-facing camera to detect eye movement and blinks. Although it is still in its early stages, it shows signs of making eye-tracking technology more affordable and reducing the need to buy new hardware.

## Summary

Eye-tracking is a useful tool that can be used to enhance video games through either adding accessibility or through being used as an extension to the traditional mouse and keyboard controls. For accessibility, eye-tracking can be used to allow people with disabilities to be able to play games by moving their eyes to segments of the screen that begins a particular action, such as moving forward or turning. Eye-tracking can also be used to enhance gameplay through acting as an aid for basic controls where a player can use their eyes to turn the camera slightly or to assist aim in shooting games.

However, eye-tracking is not perfect and still has issues that are being investigated. Calibration can cause people to not be able to use eye-tracking, but work has been done to improve it where the player does not have to always keep still. Another issue faced is little accuracy caused by a constant eye or head movements. A solution for this is to add interactive customisation. This would allow players to move interaction commands to more convenient locations on the screen, as well as change the size of the UI button. Misclicks is also an issue caused by the eye always being tracked. This can be solved by adding an interaction key to the keyboard, a blink, or a dwell time that selects after a certain amount of time. All these primary issues have potential fixes available and are constantly being looked at on how to improve eye-tracking.

In Summary, eye-tracking technology is a tool that should be utilised more in gaming. It can be used to both allow people who struggle with playing games with traditional controls and enhance games by acting as extra forms of input to increase immersion. The major issues with eye-tracking today are either being worked on for a solution or can be solved through added customisation and minor precautions.

# Output Design

The project that will be created following this paper will be a 3D puzzle game that uses Tobii eye-tracking technology as extra input to add immersion.

## Specification

With inspiration from the Portal games, the product will be in a basic 3D environment with clean, basic looking room designs (see figure 10). This simple design allows the game's content to take precedence over the environment's high level of detail. The game will be split into individual rooms that will have small tasks that the player can attempt. Some of these tasks will utilise an aspect of Tobii eye-tracking, such as a Simon says game. Others will only have more assisted benefits to using eye-tracking, an example being the control of a light source that can move along with the player’s eye instead of requiring the player to move the mouse and the whole character.



Figure In-game observation rooms in Portal 2 (Valve, 2011)

The game will be created using the Unity 2021.2.8f1 game engine (Unity Technology, 2022), using white boxed models and free unity assets. White boxed and premade assets will be used due to the limited time to create the product. This will allow time to focus on implementing eye-tracking controls, which will be programmed in C# within the IDE Visual Studio 2022 (Microsoft, 2021). Unity is being used as it has access to the Tobii SDK and the documentation to help guide the use of the tools.

Tobii Technology has released the Tobii SDK and documentation on how to create games with Tobii eye-tracking (Tobii, 2020). With this being available, the game will be using the Tobii Eye Tracker 5. The Tobii Eye Tracker 5 is the most recent release from Tobii and contains the latest specs (see figure 11) and is still having support should any issues arise. Another reason for the use of the latest Tobii eye-tracker is that it allows for head-tracking.



Figure Tobii Eye Tracker 4C and Tobii Eye Tracker 5 specifications (Tobii, 2020)

Using the requirements of both Tobii hardware and Unity, a basic game specification can be predicted as follows:

* Windows 10 (64-but) RS3 or newer
* USB 2.0 or later (for eye-tracker, Tobii Eye-X requires USB 3.0)
* 6th Gen Intel Core (i3/i5/i7-6XXX) CPU and later (or AMD 64-bit equivalent), minimum of 2GHz
* 8GB RAM
* Graphics card with DirectX-10 or later

## Justification

The product will serve as a demonstration of what can be done with eye-tracking technology. Within this game, the use of extended FOV controlled by head-tracking would remove requirements of constantly moving the mouse, and in turn the entire character. The choice of using the eye-tracker as an assistance to the mouse was down to in the paper it is illustrated that assisted controls are seen as being more effective use for the tool.

One consideration that needs to be considered is the option to allow users to customise tobii interaction points. Allowing users to modify elements of the game helped make the users more comfortable using the eye-tracker and in return improved immersion. The customisation options will involve allowing the user to change the border size which would be used to detect when the player wants to turn that character’s head in-game.

# Glossary

CP – Cerebral palsy

CPU – Central Processing Unit

CTO – Chief Technology Officer

FOV – Field of View

FPS – First-Person Shooter

Gaze – the process of measuring where a person is looking

GB - Gigabytes

GPA – Group A

GPB – Group B

HCI – Human-Computer Interaction

IBM – International Business Machines

IDE – Integrated Development Environment

MAGIC pointing – Manual and Gaze Input Cascaded pointing

MD - Muscular dystrophy

NPC – Non-playable character

RAM – Random Access Memory

SDK –Software Development Kits

Software Development Kits – tools used for writing software applications

UI – User Interface

USB – Universal Serial Base

VR – Virtual Reality

WoW – World of Warcraft

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