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User Preferences for Video Game Delivery

A Case Study of Cloud Gaming

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Abstract

In the recent years there have been a number of video game streaming platforms emerging on the market. Cloud gaming services like OnLive and PlayStation Now may ultimately prove successful in tapping the Internet to deliver instant streaming video games. However, there has been a limited research on these platforms, especially focusing on the end user preferences.

In this thesis, preferences of different gamer groups (hardcore and casual) are studied in order to identify possible development directions for such services.

A test has been designed and performed with users from the different groups. The commercial PC-based service OnLive has been used for testing the user experience and user acceptance of cloud gaming. A custom public game test has been conducted as well. Observation, user surveys and interviews have been used for data collection.

The experiments done focuses on the users' perception and response towards such a systems in terms of fidelity, usability, comparison to traditional game delivery and likelihood of buying into such a model. The thesis takes a holistic approach were not only the games themselves are tested, but the total experience in using the game service.

At large, the results indicate that casual gamers are more positive to the cloud gaming service model than hardcore gamers. The findings suggest that one of the reasons are that casual gamers choose convenience over high fidelity in their game preferences.

Sammendrag

I de siste årene har det kommet flere plattformer for strømming av videospill. Cloud gaming-tjenester som OnLive og PlayStation Now kan til sist vise seg å bli en suksess i å bruke internett for å levere umiddelbar strømming av videospill. Det har imidlertid vært begrenset med forskning på disse plattformene, spesielt med fokus på brukerpreferanser.

I denne avhandlingen er preferanser for forskjellige grupper spillere (hardcore og casual) studert for å identifisere mulige utviklingsretninger for slike tjenester.

En test har blitt designet og utført med brukere fra forskjellige grupper. Den kommersielle PC-baserte tjenesten OnLive har blitt brukt for å teste brukeropplevelsen og brukerakseptansen til cloud gaming. En egenutviklet spilltest i offentlighet har også blitt utført. Observasjon, brukerundersøkelser og intervjuer har blitt brukt til å samle inn data.

Eksperimentene som er gjort fokuserer på brukernes oppfatning og respons på slike systemer med hensyn til teknisk kvalitet, brukbarhet, sammenligning med tradisjonell spill-leveranse og sannsynligheten for å kjøpe seg inn i en slik modell. Avhandlingen tar en helhetlig tilnærming hvor ikke bare spillene i seg selv er testet, men totalopplevelsen ved å bruke spilltjenesten.

I det store og hele indikerer resultatene at casual-spillere er mer positive til cloud gaming tjenestemodellen enn hardcore spillere. Funnene antyder at en av grunnene er at casual-spillere velger bekvemmelighet foran høy teknisk kvalitet i sine spillpreferanser.

Preface

This project was performed as a master thesis in the course TDT 4900 at The Norwegian University of Science and Technology (NTNU) and concludes my master degree in Computer Science. The thesis is a continuation of the depth study in the course TDT 4501 Computer Science, Specialization Project, at NTNU. The task was created and given by the Department of Computer and Information Science (IDI) at NTNU.

I would like to thank the supervisor, professor Alf Inge Wang, for all help and advice during the project. I would also like to thank Egil Fors and Kari Hoås Moen for their feedback and Erlend Fors for proofreading. I gratefully and sincerly thank Heidi Moen Fors for her support and patience during this period.

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Ole Kristian B. Richstad

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Part I

Introduction and research

Chapter 1

Introduction

This chapter works as a readers guide for the report. The structure and problem definition of the project along with motivation and useful definitions are given.

1.1 Project structure

- **Part I - Introduction and research**
  The introduction explains the motivation and context of the project, as well as defining the research questions and research methodology for the project.
  It contains the chapters **Introduction** and **Research**.

- **Part II - Prestudy**
  The prestudy gives background information about the relevant technologies and trends as well as giving more information about cloud gaming in general and from the user perspective.
  It contains the chapters **The Game Industry**, **Cloud Gaming**, **Cloud Gaming Services** and **User Perspectives**.

- **Part III - Own contribution**
  In this part, the setup and testing of commercial services with participants are shown.
  Results and evaluation of the findings done is presented as well. It contains the chapters **Testing**, **Results** and **Evaluation**.

- **Part IV - Summary**
  The summary gives a conclusion to the research questions, and concludes the findings of the thesis.
  It contains the chapter **Conclusion**.

1.2 Motivation

With Spotify's popularity in the music field and a growing number of movie streaming services such as Netflix, the next natural step is a solution for instant video gaming on demand to break it into mainstream.

High-end video games are limited by relatively expensive hardware compared to other forms of home entertainment. Setting up a game can be a hassle, for instance waiting for installation and updates. Compatibility issues may also occur. Cloud gaming eliminates this by moving the hardware requirements and setup to the server. This means that the device and where the user is located is less important. "Gaming anywhere" is the mantra of many cloud services. This resonates well in a world were people are moving to lighter devices for their entertainment such as smartphones and tablets. However, technological hurdles such as latency may hurt the user experience.

2015 is seen as a turning point by analysts [25] as Sony and Nvidia among others launches new cloud gaming services worldwide. The infrastructure needed for such a distribution model is now becoming a reality in developed countries.

While there already exists many papers on cloud gaming, most of them take the pure technical approach measuring the Quality of Service (QoS) parameters such as latency and framerate in artificial tests. Papers that do focus on user experience such as Jarschel et al. (2011) [10] focuses only on the performance of the games, not how the service overall compares to conventional game distribution.

This project takes an in-depth look into how different gamer groups react to cloud gaming in practice and their likelihood of buying into such a distribution model.

1.3 Definitions

Here follows some important topics and "buzzwords" used frequently throughout this assignment.

- **Cloud Computing**
  Computer services where the needed hardware and software resources exists on remote servers in the cloud (a metaphor for the Internet).

- **Latency**
  The time interval between the stimulation and response, the delay caused by the underlying technology being used.

- **Smart TV**
  Television set or set-top box with an integrated computer system being able to access the Internet to use digital content and services.

- **Streaming**
  Delivery of data, video or audio in a flow from a sender to a receiver rather than having to download in advance. While streaming services could use techniques such

as buffering and temporary downloads, the information should appear immediate for the user.

- **User Experience**
  A person's perception and response toward a user system.

Chapter 2

Research

In this chapter the research questions are stated and the process of exploring the answers in terms of research methods.

2.1 Research methods

2.1.1 Case study

Case study is an in-depth, holistic and detailed study of a particular subject (case) and its context. A case can for instance be an individual, a small group or an organization. It is a popular research method in disciplines such as sociology and political science. While quantitative methods are good at finding out *what* is happening, case studies often ask the questions of *how* and *why* that is the case [21].

This thesis is done with a combination of qualitative and quantitative methods to provide a richer, contextual basis for interpretating and validating results. In-depth user observation and interviews have been done for a limited number of users. User surveys have been used for supplementing quantitative data statistics to this approach.

2.1.2 GQM Approach

The project uses the Goal Question Metric (GQM) approach where a research goal is defined first (conceptual level), then separate it into research questions (operational level) and finally describe the metrics in use for answering the research questions (quantitative level). The hierarchical, top-down tree structure is visualized in Figure 2.1. Although it has mainly targeted quantitative research, the GQM is here used for structuring questions of both quantitative and qualitative nature.

2.2 Research goal and research questions

The purpose of this project and overall goal is to identify user preferences for cloud gaming among different gamer types, namely hardcore and casual gamers.

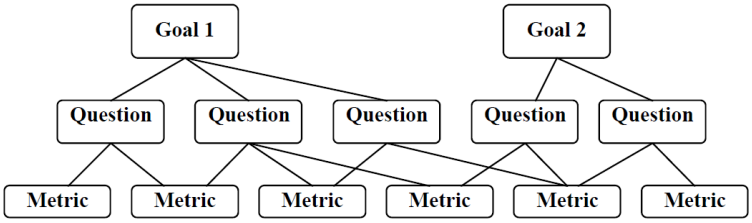

Figure 2.1: GQM Tree

This goal has been divided into five different research questions with their own metrics:

RQ1	How does the hardcore gamer and the casual gamer react to cloud gaming services in terms of quality of experience?
Metric	Observation Questionnaire (MOS, SUS etc.) Interview

RQ1 with metrics

RQ2	What is "good enough"? Does the quality threshold for being acceptable differ among the gamer groups?
Metric	Literature study Observation Questionnaire (MOS, SUS etc.)

RQ2 with metrics

RQ3	How does each group compare streaming to the local/traditional alternative?
Metric	Observation Questionnaire (MOS, SUS etc.) Interview

RQ3 with metrics

RQ4	What type of gamer is most likely to embrace cloud gaming?
Metric	Observation Questionnaire (MOS, SUS etc.) Interview

RQ4 with metrics

RQ5	What types of streaming services works best for the respective groups?
Metric	Questionnaire (MOS, SUS etc.) Interview

RQ5 with metrics

2.3 Evaluation approach

The assignment uses the DECIDE [19] framework for evaluation, which provides the following checklist:

- 1. **D**etermine the overall goals that the evaluation addresses.
- 2. **E**xplore the specific questions to be answered.
- 3. **C**hoose the evaluation paradigm and techniques to answer the questions.
- 4. **I**dentify the practical issues that must be addressed
- 5. **D**ecide how to deal with the ethical issues.
- 6. **E**valuate, analyze, interpret, and present the data.

Steps 1-3 mainly overlaps with the GQM approach in Section 2.2.

2.3.1 Practical issues

Some practical issues are important to address in advance.
For instance is the selection of participants a key element. They should be representative of the target group in question. Also the time scheduling, the presentation and the gathering of resources such as facilities and equipment needed must be thoroughly planned.

2.3.2 Ethical considerations

This project will involve collection of personal data, information that may directly or indirectly identify a person. It will be important to abide information privacy laws for any gathered data. not using any sensitive data (health issues, sexual orientation etc.). User need to know what information about them is stored and it should not be possible to identify users based on the data presented.

This project will follow NTNU's policy on the matter.

2.3.3 Data handling

The standard questions in questionnaires will mostly result in quantitative data while interviews and observation will result in qualitative data.

Some important properties to follow while interpreting the data:

Reliability is the degree to which an assessment tool produces stable and consistent results. Methods in use should produce the same results under the same circumstances on separate occasions.

Validity refers to how well a test measures what it is purported to measure. Measurements should be correct in terms of the intended use.
Bias is the lacking of a neutral viewpoint. It is for instance important to avoid leading questions as results may be affected.
Scope is to what extent the results can be generalized. For instance can some results only be suited for limited settings.
Ecological validity is the concern that the test environment may affect the results. For instance the fact that participants are aware they are being tested can contribute to this.

2.4 Metrics

2.4.1 System Usability Scale

ISO 9241-11 suggests that measuring of usability should cover effectiveness, efficiency and satisfaction. System Usability Scale (SUS) is used for measuring the services' usability. It was developed by John Brooke while working for Digital Equipment Corporation in 1986 [3]. The test consist of ten statements, for instance "I think that I would like to use this system frequently". The participant should then range how much they agree with each statement on a 1-5 scale. After some calculation it will result in a number on a scale of 0-100 regarding the ease of use of the product.
SUS has been used in addition to other questions in papers regarding the usefulness of a system [26].

The following 10 standard questions are being used:

- 1. I think that I would like to use this system frequently
- 2. I found the system unnecessarily complex
- 3. I thought the system was easy to use
- 4. I think that I would need the support of a technical person to be able to use this system
- 5. I found the various functions in this system were well integrated
- 6. I thought there was too much inconsistency in this system
- 7. I would imagine that most people would learn to use this system very quickly
- 8. I found the system very cumbersome to use
- 9. I felt very confident using the system
- 10. I needed to learn a lot of things before I could get going with this system

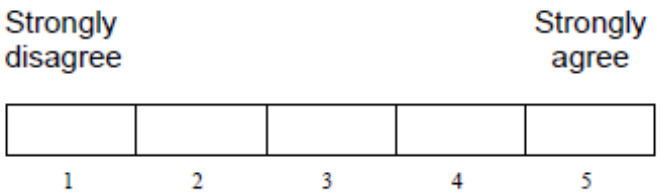

Figure 2.2: SUS questionnaire

2.4.2 Mean Opinion Score

Mean opinion score (MOS) is a test that originally has been used in telephony networks to obtain the human user's view of the quality of the network. Today it is a common way to test multimedia (audio, voice telephony, video etc.), especially when compression codecs are used. MOS provides a numerical indication of the perceived quality from the user's perspective. A single number in the range 1 to 5, where 1 is lowest perceived quality, and 5 is the highest perceived quality, is used as a measure.

2.5 Research process

The research process in this thesis follows the following stages:

2.5.1 Literature study

The project starts with a literature study. This aims to gather and structure current knowledge around cloud gaming, both in general and focusing on user experience. Evidence may be found in books, journals, news papers and the Internet. Results of papers and other documents will be analyzed to confirm an existing hypothesis or to improve the data collected in one project, with more similar data.

2.5.2 Test Setup

Different commercial cloud gaming systems are tried and tested. A custom testbed is developed to present a cloud gaming environment for the participants. Different software, hardware and network components are being used in a trial-and-error approach to find the technology best suited for the task at hand.

2.5.3 Observation

Observation of participants in actual use with the system provides important information on gamers' perception and reaction.

2.5.4 Questionnaires

After use the participants are asked the same questions for gathering quantitative information. Questions are both related to their personal gaming habits and experience with the system.

2.5.5 Interviews

Interviews are structured as informal follow-up questions after the questionnaire to a limited amount of people willing to express more in-depth their position towards such a system. Participants are encouraged to speak freely, but with relevance to the questions at hand.

2.5.6 Data gathering

Both quantitative and qualitative data will be gathered and structured in line with the properties mentioned in Section 2.3.3.

2.5.7 Analysis

An analysis is performed on the basis of the gatherings of the literature study and the results from the testing phase.

2.6 Tools

Google Forms is used for handling the questionnaire. Microsoft Excel and IBM SPSS are used for gathering data and statistics analysis.

Part II

Prestudy

Chapter 3

The Game Industry

In order to understand how cloud gaming will fit into the market, this chapter looks at the current video game market in terms of sales, players and games. The chapter also features recent trends and how they are about to change the field.

3.1 Sales

In many countries video games have surpassed both movies and music in the home entertainment market over the last decade. Games became the leading home medium in the United Kingdom in 2011 making up 40 percent of the market while video made up 38 percent and music 22 percent [9]. International video game revenue is estimated to be $81.5 billion in 2014. This is more than double the revenue of the international film industry in 2013.

3.2 Digital distribution

With the rise of high-speed Internet penetration we are seeing a huge transition from regular physical copies of games to digital sales where games are downloaded and paid for online. Buying new physical copies are in heavy decline. According to Wedbush analyst Michael Pachter the packaged goods market in 2008 was $22 billion in the Western world. In 2013 it was down to $11 billion, meaning it has been cut in half in just five years [18]. In Q3 2013 61% of US game sales were digital.

3.2.1 Steam

Steam is the most popular game distribution portal on PC. It has reached over 100 million active users as of October 2014. It is known among gamers for its sales around Christmas and Summer where they can reduce prices significantly in ways retailers of physical products are not able to. As Steam has evolved, more functionality has been introduced, like auto-updates to games and in general making the PC gaming experience more streamlined and less cumbersome.

3.3 Player types

While gamers comes in all types and sizes, the games industry typically divides players into two or three consumer segments:

Casual gamer
People with limited interest and time to play games. The ease and accessibility of the games are important. They rarely invest in a dedicated game system and they don't spend a significant amount of money on games or view it as a hobby.
Casuals are also less loyal to certain brands or series compared to more dedicated gamers.
Hardcore gamer
People who spend a significant amount of time and money on games and game systems. Complex and long games are valued. Completing and mastering a game is in focus. The competitive aspect of games can also be very important.

Mid-core gamer
People between the casual and hardcore categories. They enjoy more complex games as the hardcore gamer, but does not spend as much time and do not have the same dedication as the hardcore gamer.

3.4 Game types

Games are often divided in two categories, casual and hardcore.

3.4.1 Casual games

Casual games are video games aimed at the mass audience of players who do not play regularly. They rely on simple rules and intuitive ideas in order to be accessible for a very broad audience.
While games appealing to this audience have existed for decades the term gained popularity in mid-2000s with Nintendo systems Nintendo DS (2004) and Nintendo Wii (2006) as well as casual hits such as SingStar (2004) and Guitar Hero (2005). All of the above products could be seen as a return to simpler ideas. They use alternative, more intuitive input as opposed to the conventional and relatively complex gamepad. Nintendo DS was the first to introduce a touch screen in mainstream video games while Wii was first to market with motion controls.

The latter gained popularity with the massive hit Wii Sports, where several players can play together in very simple versions of known sports such as tennis and golf. Typically casual games do not have particularly impressive graphics. The visuals are clearly secondary to the gameplay. For Nintendo this approach really paid off. Not only are these games much cheaper to produce, they returned as a market leader in the home console business for the first time since the early 1990s. Wii sold over 100 million units [16], making it the most popular home gaming console of 7th generation.

Figure 3.1: Wii Sports (Nintendo, 2006)

A recent trend in casual gaming is using non-dedicated gaming devices such as the web, smartphones and tablets. Nintendo's successors to DS and Wii, the 3DS and Wii U have seen a dramatical fall in sales compared to their predecessors.

3.4.2 Core games

Meanwhile the traditional gamer market has followed a more iterative "bigger and better" approach with an aim for realistic graphics and complex gameplay. It is now common that high-profile titles are developed by 150-200 employees for 2-3 years. Rockstar game Grand Theft Auto V (2013) is one of the most expensive games to date with an estimated price tag of $265 million with almost a thousand people involved in the development process [15]. That is on par with a huge Hollywood movie budget.
The first-person shooter (FPS) has become one of the most popular genres among hardcore gamers, often with online multiplayer as the main attraction. Halo, Battlefield and Call of Duty are among the most popular franchises selling millions of copies on launch day. The best-selling Call of Duty, Modern Warfare 3, set a five-day worldwide sell-through record, with sales of more than $775 million. The number far exceeds opening revenues from any movie or album release [24] .
Core games such as modern first-person shooters have impressive graphics requiring powerful gaming hardware.

Figure 3.2: Screenshot of Call of Duty: Black Ops (Activision, 2010)

3.5 Current gaming trends

This section presents gaming trends likely to have relevancy for cloud gaming.

3.5.1 Indie games

An alternative to the escalating costs is indie games, short for independent video games. These are games usually create by one or just a handful of persons without the financial support and guidelines from the big game publishers. The games are usually distributed digitally through a custom website or popular digital services such as PSN, Xbox Live, Steam, Apple Store and Google Play.

They rely less on technical impressive graphics and focuses more on innovation. They are usually sold at a much lower price compared to most retail games. With the low cost of making and distributing the game as opposed to a big-budget retail game they can also take more risks. Braid, Minecraft and World of Goo are examples of very successful and innovative indie titles.

3.5.2 Player created content

The concept that players can modify and create game content themselves.

On PC, modifications (mods) are made by dedicated gamers or hobby developers with added content, changed settings or even have used the game engine to make a totally new game. The popular PC first-person shooter Counter-Strike started out as a mod for Half-Life. The recently very popular strategy subgenre MOBA began as custom

Figure 3.3: Screenshot of Minecraft (Mojang, 2011)

maps in Blizzard RTS' StarCraft and WarCraft III.

Lately games such as Sony platformer LittleBigPlanet and indie structure builder Minecraft focuses on users creating content for the gameworld within the game itself.

3.5.3 Piracy and second-hand games

While game piracy has been an issue ever since home computing was established in the early 1980s, the Internet has made illegal software easily available. Especially the big budget PC games tend to be pirated a lot. Some publishers claims that piracy has killed exclusive PC games which was more common before. The amount of pirated copies are claimed to be as much as 90 percent, although this is disputed [20].

Consoles are closed platforms with its own anti-copy measures, so piracy has not been as severe. However another problem has arisen for the game makers. Video game retail chains such as GameStop are offering second-hand games. Users can trade in their used games for an amount of money or another game in return. Many single-player games in particular go in the pre-owned section once they have been played through.

3.5.4 Apps

With the introduction of iPhone in 2008, apps, downloadable applications for mobile phones and handheld devices, soon became very popular. Low development costs and 70 percent share for the developer is seen as an attractive business model, especially for indie developers. The low cost and huge amount of developers has also assured a low price for the consumer. While boxed games are $40-60 in the US, games in the App

Store are usually $1-6 and many are even free. Google, Microsoft and other have similar app stores and business models. The largest mobile app success the world has seen so far is Angry Birds (Rovio, 2009) which was the first to be downloaded over 1 billion times [22].

3.5.5 Free-to-play

Free-to-play (F2P) refers to games you can download and play the main game without any payment. Instead the user can pay for extra in-game features such as valuable items and more levels in order to get the full experience. There may also be in-game advertisements. Free-to-play games are particularly prevalent in developing countries such as China were piracy is a major problem and incomes are low. Multiplayer strategy game League of Legends have become hugely popular with this model.

3.5.6 Browser games

Fairly simple games played within a web browser. They soon gained popularity with the rise of the of the web. Online games within social networks such as Facebook have proved to be particularly popular. The most popular ones like FarmVille uses the free-to-play model. They are very accessible due to low requirements, no need for installation and no upfront payment.

Chapter 4

Cloud Gaming

This chapter presents the basics of cloud gaming related to the thesis.

4.1 Cloud computing

Cloud computing is in essence the delivery of computing as a service rather than a product, whereby shared resources, software and information are provided to computers and other devices as a service over a network, in most cases the Internet.

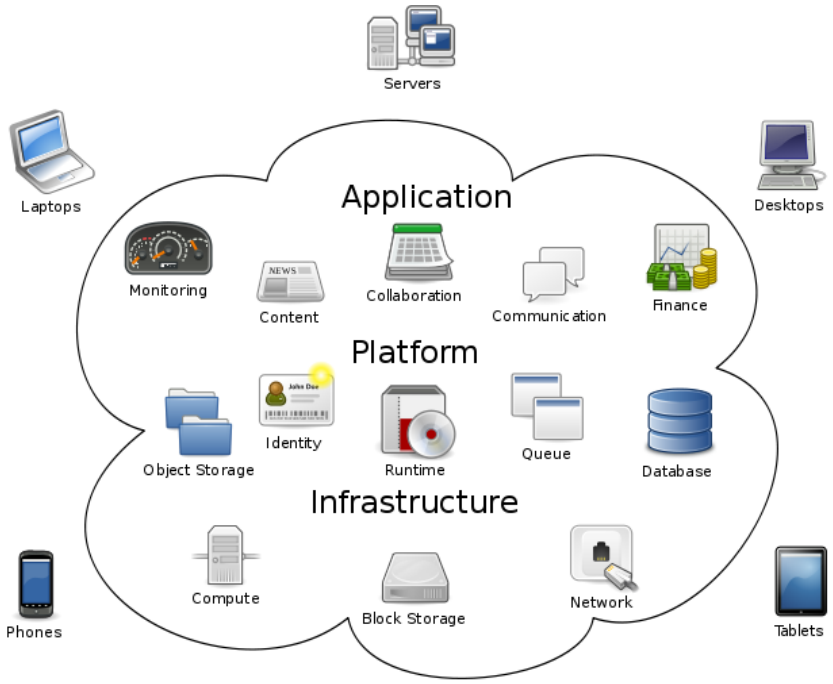

Figure 4.1: Cloud computing logical diagram [11]

The cloud represents different types of services that were traditionally seen as the

task of a PC or company LAN which can now be rented from other companies in the cloud as seen in figure 4.1.

Companies such as Amazon, Google and Microsoft are some the biggest competitors in offering IT resources through the cloud.

The three main categories of cloud computing services are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS).

4.2 Infrastructure as a Service

IaaS is a subset of cloud computing where users rent physical computer resources, either by subscription or on a pay-per-use basis. Physically the hardware and software in use are situated in a remote server farm, but through virtualization it can for instance appear for the user as a single, local computer. Typically the IaaS provider hosts hardware, operating system, user applications and internet components.

Leading IaaS providers include Amazon Web Services (AWS), Windows Azure, Google Compute Engine, Rackspace Open Cloud, and IBM SmartCloud Enterprise.

4.2.1 Amazon Elastic Compute Cloud (EC2)

EC2 is a IaaS by Amazon Web Services providing all resources needed for using a remote computer. It is elastic in the way resources and costs are handled. It is easy to change the amount of resources by current demand. One can for example add more storage capacity, alter RAM configuration or the number of computer instances (virtual machines) needed within minutes. Users also pay by the hour. At the time of writing, prices range from $00.20 to $4.60 per hour depending on hardware configuration. AWS provides both Linux and Windows server operating systems.

4.3 Cloud gaming

Cloud gaming, also called gaming on demand or game streaming, is a type of cloud computing based on IaaS where games are streamed directly from the internet to a user device. The game itself is stored, executed and visually rendered on a remote server, so the user client can be a very "light" device in terms of cost, computer power and mobility. Cloud gaming is seen as one of the most demanding and challenging tasks of cloud computing.

The usual method on how this is done is that a server runs the game as normal based on input from the player via the Internet, then creates a video stream of the visuals and sound and sends this back to the player. All this should happen so fast and with such a quality that it feels like the game is being played locally.

Cloud gaming presents several new aspects to gaming. The fact that you can use several different types of clients to play the exact same game is something entirely new. One can for instance retain state, turn off one machine, go home, power on and continue from the exact same place on another machine with different hardware and operating system.

There exists several types of services using streaming or the cloud in some form. There are hybrid services where parts of the code are running on the client-side and parts on the server. Some services like Kalydo, Approxy and SpawnApps use file streaming where the game files themselves are streamed. This however requires a machine capable of running the games natively. Others like Valve's Steam In-Home Streaming are limited to streaming within a network (for instance a home Wi-Fi) and requires a local server machine running the game.

There also exists games which are mainly running locally, but are using cloud gaming for additional features, such as Microsoft's Forza Motorsport 5 which is offloading some AI and physics calculations onto their severs [11].

This report will focus solely on technology where the only thing needed on the client side (apart from controls) is a device capable of streaming and outputting the video. The user device can have much lower hardware capabilities compared to what is needed to execute the game. The ultimate goal would be the ability to play any game anywhere. Chapter 5 presents the commercial services currently available.

4.4 Latency

Something that just won't be solved over time is the fact that information can not travel faster than the speed of light, c (approximately 300 million m/s). While blazing fast at around 0,7c (approximately 210 million m/s) in optical fiber cables, this is just in theory. A long-distance signal will not reach this maximum speed in practice. It will not follow a straight line and will have to go through several servers on its way. Several types of transmission problems such as packet loss must be handled as well. In practice, a signal to the other side of the world and back can take a third of a second, way too long for an instant service. This is both a geographical issue meaning the service should not be to far away from the user, but also a technological issue in how to transmit the signal in a fastest possible way over the Internet.
While packets for a webpage or even a video stream can take a roundabout it is crucial for high-demand gaming to take the shortest path possible.
Internet latency comes on top of latency in the game and delay in the system itself. There are several different types of latency which in sum may be quite considerable from pressing a button till there is change on the screen. We can identify 6 different stages of latency:

- L1. Local input latency
  User pressing a button.

- L2. Connection input delivery latency
  Input from local device to server.
- L3. Game latency
  The game itself executes the command.
- L4. System latency
  System encodes video for output.
- L5. Connection output delivery latency
  Sends the video back to the user.
- L6. Local output latency
  Displays the video on screen.

The sum of these stages, the time between the player input and the results appearing on the screen, is the games' response time.

For online games it is even more complex where people, at least in theory, should be given equal response time

Wi-Fi will add latency for L2 and L5, but mostly negligible compared to the response time. Being in the same house as the router should not cause more than 5 ms additional latency unless there is significant interference or thick walls degrading the signal. On the other hand, public Wi-Fi spots with long distances and shared connections may hinder a stable, low-latency connection. Mobile phone networks however will add significant extra latency. 100 ms or more is not uncommon even with 4G networks.

In other words, latency is the fundamental design challenge for cloud gaming.

4.5 Visual Quality

Two factors determine the visual quality in cloud gaming: 1) the visual quality of the game itself running on the server and 2) the visual quality of the video stream being sent to the user.

The hardware must be able to run the video stream, typically using the H.264 decoding standard.

Chapter 5

Cloud Gaming Services

This chapter focuses on commercial services delivering games via the Internet using video streaming. Several cloud gaming services of this type are as of 2015 available or coming soon.

5.1 OnLive

Released in 2010 in the United States and in Europe the following year, OnLive was the first cloud gaming service to make headlines in the gaming industry. In the beginning they were using fairly widely spaced datacentres with its own video encoding hardware. Their strategy was that low-latency game code and encoding will offset the high geographical delay. The company claimed their encoder latency was as low as 1 ms/frame. The system offered an impressive 60 frames per second (fps). The high framerate causes lower internal latency. Two video quality types were present: standard definition (1.5 Mbps) and high definition (5 Mbps). They were using a one-to-one approach where they needed a physical machine for each game running on the system. OnLive also launched a unique arena mode where the user can watch live video of what the other users on the service are playing, as seen in Figure 5.1.

In August 2012, OnLive filed for bankruptcy, many employees were fired and the company was transferred to one of its investors. Founder Steve Perlman subsequently left the company. It was clear that their first generation approach with setting up its own datacenters and not being able to virtualize users for a more efficient use of server hardware was not sustainable.

Since change of management in 2012, the service have seen several improvements. It could now make use of up to 11 Mbps. The visual output is significantly improved and they have outsourced server use which has lowered cost and improved latency. However, the resolution is set to 720p which is now getting outdated as most next-gen games on console targets 1080p and PC gamers have been used to higher resolution for years. As of 2015 it has around 250 games available.

In April 2015 OnLive ceased its operation and shut down the whole service. The patents the company was holding was sold off to Sony. Although it ultimately failed, in retrospect OnLive will be seen as the first pioneer in commercial cloud gaming.

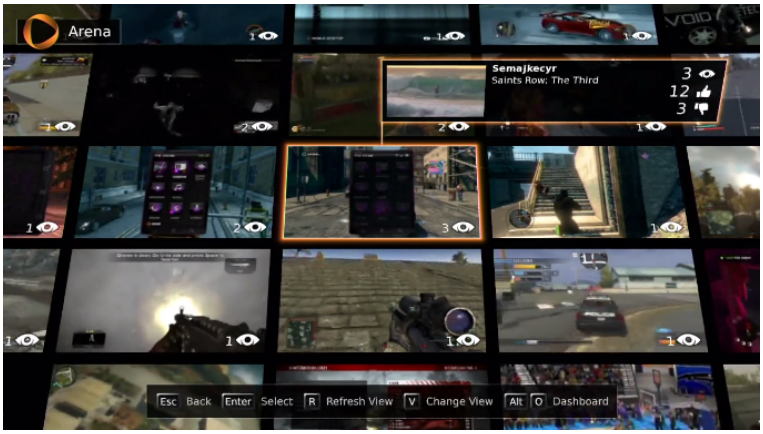

Figure 5.1: Arena mode in OnLive

5.1.1 Platforms

Starting out with a Windows version in 2010, they have since expanded to several platforms. Prior to shutdown in 2015, OnLive was available for PC (Windows, OS X), mobile devices (Android, iOS) and TVs (some Philips and LG models).
OnLive also released its own game system, the OnLive MicroConsole, which includes a wireless game pad and a HDMI connection for TV sets. Using only 6W in power consumption it retailed for $100 with a game controller in the United States.

5.1.2 Pricing model

Before bankruptcy OnLive had a traditional model where you could buy games for a comparable price to a physical copy in a store. They have since gone away from this focusing on monthly subscription packs.

PlayPack, their play-anything-you-want subscription, costs as of March 2015 $10 per month. This lets gamers stream their entire library of around 250 games similar to what for instance Netflix is doing with movie/TV streaming. As of 2015 there is however a severe lack of new titles, missing all the new major titles released in the latter years.

For $8 per month the service CloudLift lets you stream PC games that you already own on Steam onto laptops, Android devices and televisions. CloudLift hooks into users Steam account and any games that Cloudlift supports will then be available for streaming.

Figure 5.2: The OnLive MicroConsole

5.2 Gaikai/PlayStation Now

Officially launched spring 2011, Gaikai was OnLive's first competitor in the PC market.

This changed when Sony purchased Gaikai for $ 380 million in July 2012. The service was later rebranded as PlayStation Now. It will mainly be used in Sony's PlayStation consoles, with the eventual goal of making the entire PlayStation catalog available. Beta testing started in summer 2014 for US users. It will arrive in Europe in 2015 starting with United Kingdom in summer 2015.

Before the buy-out and the subsequent removal of the service on PC, the games ran at 30 fps as opposed to OnLive's 60 fps. This resulted in a slightly higher latency, but it had a higher decoder threshold to produce better video quality. The bandwidth costs were also halved this way.
They had smaller servers compared to OnLive, but generally closer to players. It could dynamically change the quality and the framerate that the user sees based on network performance.

5.2.1 Platforms

While focusing on the PC platform like OnLive, they had a different approach. Gaikai had their games running straight from a web browser without the need to download an application first.

They focused on demos, free demonstration versions of games, a perfect fit for streaming because it does not require time to download and install to try a game. They made

for instance a deal with Eurogamer.net in 2011 to stream the latest demos from their website. In 2012 they released their "Real games" app on Facebook. Demos featured a "buy now" button in the top right corner while playing.

Currently PlayStation Now, the main service the Gaikai team will support for Sony, will make use of PS3, PS4, Vita, Sony-branded tablets and phones and Sony TVs. Sony has also released PlayStation TV for $100, a microconsole that can connect to a TV and capable of running the PS Now service.

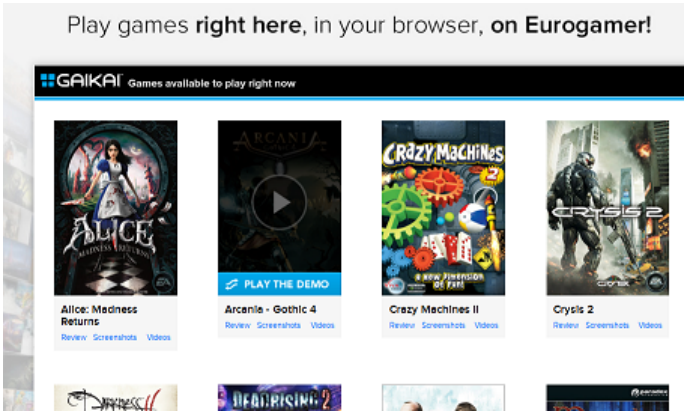

Figure 5.3: Game demos using Gaikai on Eurogamer.net

5.2.2 Pricing model

Sony started the open US beta with a rental model where participants had to pay around $5 for a weeks rent. You could choose to rent a game for several months, for a week and even only for a few hours. The price per hour was significantly higher compared to other services and were criticized by games media such as GameSpot.

In January 2015 they announced a subscription model. For $20 per month or $45 for three months players can get access to 100+ games very similar to the Netflix model. A free 7-day trial was also introduced.

5.3 GRID

Made by graphics card producer Nvidia, GRID is their cloud gaming project marketed as "supercomputer in the cloud". GRID was at first only available on the company's own Shield tablet and handheld, with an intention to launch a PC client in the future. It was released in The United States in 2014 and launching in Europe and Asia in 2015. It currently demands 6.5 Mbps bandwidth. The video stream runs at 720p at 60 fps.

In early 2015 Nvidia announced their Shield console which features 1080p resolution and 60 fps. A big step up from other services available. The Shield console launched in May 2015 in the United States.

Figure 5.4: Nvidia's Shield devices. From left to right: 1) Shield tablet 2) Shield console 3) Shield handheld

5.4 Ubitus/GameNow

Ubitus is a Taiwan-based company with success in providing cloud gaming in Asia, particularly to mobile phones using 4G (LTE) networks.
In late 2012 they launched ugamenow.com for the US market which also has PC and Smart TV clients. They have worked closely with Nvidia using their GeForce GRID.

You can rent games for 30 or 90 days for $5 and $10 respectively. A free trial for 30 minutes is available.

5.5 GameFly/PlayCast

Released by Israeli PlayCast Media Systems in 2010, it was the first to provide cloud gaming for cable and IPTV. PlayCast are now partnering with TV operators around the world. The service is integrated into the TV operators set-top box.

Amazon web services (AWS) are providing the servers needed removing the upfront structure cost OnLive had in the beginning.

GameFly, an American online video game rental service, bought the company in June 2015. They are originally a company renting out physical games by mail similar to how Netflix started as a rent-DVD-by-mail company. They now look to follow the same strategy by launching GameFly Streaming. The GameFly service is currently only available on Amazon media player/microconsole Fire TV.

5.5.1 Pricing model

Instead of the "all-you-can-eat" subscription used by most providers, gamers can rent bundles with particular themes (for instance a selection of first-person shooters) for $7

or $10 per month.

5.6 G-cluster

G-cluster (short for Gamescluster) is a Finnish company founded in 2000 that offers cloud gaming through IPTV set-top boxes. The first commercial rollout was an IPTV service for Cyprus Telecom Authority in 2005. In 2010 French operator SFR launched a service using G-Cluster technology. The service is currently available to 3.1 million French households on TV. The now Tokyo-based company teamed up with LG for their Smart TVs in 2013. In 2014 they were working with Japanese publisher Square Enix for a Japanese-only cloud service. They are primarily working with TV operators and mobile carriers who can incorporate and rebrand the underlying G-cluster service as their own.

5.7 Upcoming services

Services in development, but yet to be released.

5.7.1 Shinra Technologies

Square Enix unveiled Shinra Technologies at Tokyo Game Show in 2014, a new cloud gaming business to be led by Yoichi Wada, former president of Square Enix. Wada said they were disappointed that existing solutions only streamed games without offering new experiences. They want to achieve new gaming experiences with developers being able to use multiple GPUs and CPUs. Using the resources of a "virtual supercomputer" offering experiences not possible on PCs and consoles.

The new company has partnered with developer Avalanche Studios to develop games and technology. Beta testing started in Japan in early 2015 and it is expected to hit the United States in late 2015.

"The game's running in one place, and you're just adding a 'viewport' for each new player", according to Shinra's dev relations chief Colin Williamson. "The big draw to this is that all of the gameplay calculations are only happening once; the need to write complex network code for multiplayer games, well, thats basically gone" [30]

5.8 Summary

A brief comparison of services in use.

Service	Client Platforms	Pricing Model	Current availability
OnLive	PC, Android devices	Subscription	United States and Europe (closed down April 2015)
PlayStation Now	PlayStation 4, PS TV and PSVita	Rent separate games/Subscription	United States, UK (Open beta)
GRID	Nvidia Shield devices	Unknown (currently free for a limited time)	United States
GameFly	TV	Bundle	United States
Ubitus	TV, Mobile phones and PC	Rent seperate games	East Asia and United States
G-cluster	TV, Mobile	Unknown	Japan, France, Southern Europe

Commercial cloud gaming services

As seen a wide array of platforms are in use. However, OnLive was the only platform available in Norway in early 2015 and will be the test subject of this report.

Chapter 6

User Perspectives

This chapter presents what changes cloud gaming will imply for the consumer.

6.1 Quality of Experience

Cloud gaming may never achieve the performance and stability of a high-end local system, but may still be preferred. An interesting comparison would be the music industry where high-end formats like HD audio have failed while Spotify and iTunes with fairly low-quality bitrates have taken over. It would seem that people are preferring convenience and flexibility over audiovisual fidelity with a "just-good-enough" approach for the technical quality of the medium.

With cloud gaming you can have all your games in one place and play them anywhere and on any device as long as you have a adequate Internet connection. Also with ever-growing game sizes (modern games can be 40 GB or more), the advantage of not downloading and installing them are increasing.

In cloud gaming the whole process is highly automated for the user. They do not have to worry about free disc space, hardware requirements, conflicting drivers, updates and hardware upgrades. No digital rights management (DRM) issues to deal with either. The instant click-and-play is perhaps the biggest advantage cloud gaming has over local gaming.

The biggest issue is however whether the service can be stable and work as expected. For instance a connection-loss for even half a second will have fatal consequences for the end-user experience.

6.2 Latency and the human perception

There will be latency, but the important thing is that user does not *perceive* it as latency. So what is adequate latency for humans? Reaction time for college-age individuals are measured to be 160 ms for auditory detection and 190 ms for visual detection. [12]

There are different standards of what is good enough for both types of players and game genres.

Steve Perlman, the founder of Onlive, had an ambitious goal for response time. "The round trip latency from pushing a button on a controller and it going up to the server and back down, and you seeing something change on screen should be less than 80 milliseconds." [27]

Electronic Arts' CFO Eric Brown: "When it comes to videogames, particularly first person shooter games, anything less than a response time of 30 or 40 milliseconds is unacceptable"

According to user studies [7], gamers can notice 60 ms when playing a multiplayer title. Once the game exceeds 100 ms, they start to get annoyed. Jumping to anywhere from 150 to 250 milliseconds results in user engagement lowering by around 75 percent.

There is a strong correlation between latency and total playtime. Statistics in an MMORPG showed a steep decline in playtime beyond 180 ms network latency [4]. Studies of twitch-based shooter Unreal Tournament showed a significantly worse hit/miss ratio at 100 ms compared to 50 ms.

From this we can gather that in general over 200 ms is seen as unacceptable for a real-time single-player game or MMORPG, and for a hardcore competitive game such as a first-person shooter or real-time-strategy it needs to be less than 60 ms.

6.3 Consumer value

One could argue that digitally distributed games should be cheaper compared to a retail product where you get to own a case, instruction manual and a physical copy of a game itself. With cloud gaming you do not own anything. What you are buying is a license to use the game and the features of the service. So what will drive consumers to subscribe to such a model?

The user is in no need for a high-end computer or console to play the latest games. The hardware independence cloud gaming offers is the main economic factor. In this way the user are not only paying to play the game itself, but also paying to use the hardware the games run on.

In other words the consumers are outsourcing their hardware needs. With big and expensive game machines taking up a lot of space, heat and costing a lot of money this could be seen as interesting for a group of consumers. Also the need to not upgrade the computer or buy a new console will be tempting.

The user is able to use their current TV, laptop or mobile phone ending the need for a specific device to play games. Cross platform gameplay will also be very easy as a single game can run on multiple devices.

6.4 User rights

For the user, cloud gaming could lead to severe loss of ownership and control. The user has less freedom to for instance change graphical settings and modify the game in other ways. This could hurt user development and involvement in a game. The always-connected to high-speed internet is a basic requirement and the service can never guarantee a fast and stable internet connection. The provider is not able to give any guarantees on providing a stable experience. What will happen if a service closes down? At worse you can actually lose all your games and saves.

6.4.1 Privacy

Can cloud gaming lead to surveillance of the user? For instance OnLive hold their right to collect and sell all data players are giving within the system. A video stream is created of everything the players are doing in-game and the company is free to store it. The system can get hacked and a third party may get hold of this data.

6.5 Pricing models

Several pricing schemes can be established. The most common are:

1. Pay for the game. The traditional approach where the gamer buys the full game and has full access to it. In order for this to work, cloud services would need to charge close to full price for the game that the user do not even gets to own and can not ensure a flawless performance. This is the least likely successful model.

2. Pay to play. The user pays to play for a limited amount of time. For instance a user can buy 24 hour access to a game for a few dollars.

3. Free to play. The games are free, but users have to pay for in-game content to get the full experience. This could be the first successful model for CG as many will be highly skeptical about paying for such a service.

4. Subscription. Games are paid incrementally. The user pays a certain amount of money each month for access to a wealth of games for free or for a very low price. This is how many music and video services work. This secures a steady income for the operator and predictable for the user.

6.6 User acceptance

We can now identify some key buying criteria for cloud gaming:

- 1. **Fidelity** - hereby the technical quality of the output. The visuals and audio should be considered "good enough" for the player and game in question.
- 2. **Cost** - usage fee or subscription should be affordable.
- 3. **Compatibility** - a key selection of games should be available.
- 4. **Security** - protection of the users data.
- 5. **User-friendliness** - very high usability and flexibility.

Part III

Own contribution

Chapter 7

Testing

This chapter presents the testing done in this thesis. Both the test procedures planned in advance, the technical setup and the actual testing.

7.1 Test procedures

This section presents procedures for testing cloud gaming focusing on user-perceived Quality of Experience (QoE). The tests are done to find user acceptance and preference for such a system.

Not only the games themselves, but the overall experience with cloud gaming, the menu, setup and everything around the game is included in tests. The whole process of getting the game up and running including installation, waiting for loading etc. is considered part of the experience.

7.1.1 Test environment

An online home test can provide a test similar to a real-life scenario in an environment the participants are familiar with and where the product normally will be used. It is also easier to test the whole experience (setup + gameplay) and players can go more in-depth in the comfort of their own home.

On the other hand a fixed, controlled environment for all users with observation is better for testing certain key aspects such as acceptance for latency/bandwidth. Here we can avoid external factors such as different computer hardware and infrastructure affecting the outcome.

Both types of tests were done and supplemented with questionnaires and interviews. The two tests combined provide interesting qualitative and quantitative aspects.

7.1.2 Grouping the players

Two groups of players are compared, they represent the two main categories of players, the hardcore gamer and casual gamer as mentioned in Section 3.3.

There are several ways to divide the sample into these categories. For instance what amount of money the spend on games, their skillset or simply get participants to self-report what category best describes them. Arguably the preferred game genre og platform could also be used. Ultimately, the average amount of time spent on games weekly was being used as this is unambiguous and easy to establish.

7.1.3 Participant selection

In order to get both casual and hardcore players represented in the test, participants were recruited from different places. In the online test players were recruited from both gaming-related discussion forums and general non-gaming forums.

The same goes for the public test where the experiment was first conducted on a site with mainly engineering/technology students, then on a campus with non-engineering students.

7.1.4 Avoiding bias

For the public test the participants did not know in advance it was a stream they were playing. For the online test the players did not get any more details than needed. This was in order to avoid bias ahead of testing.

7.1.5 Game selection

All the games must have a fair amount of real-time requirements that is necessary to really test the cloud performance of the platforms. It is important that the games are not typical hardcore or casual, but something that fits "everyone" in order to avoid player bias towards certain games or genres.

Former studies have tried to define different types of games, i.e. fast-paced, medium-paced and slow-paced depending on the genre and level of interactivity [10]. For instance a fast-moving and graphically intense genre as the FPS (first-person shooter) is more hurt by performance issues such as delay and packet loss than a slow-paced adventure game. The more speed and precision needed, the harder QoS requirements.

7.2 Test setup

7.2.1 Emulation tools

Several tools can be used for emulating the cloud gaming experience without the boundaries set by the commercial companies. Three software options have been thoroughly tested for setting up a cloud gaming testbed.

StreamMyGame

Released in 2007 for Windows and Linux, StreamMyGame is a software-only solution where players can stream games from another computer. Server software have to be installed on the same computer where the games are installed. Player software is installed on the light device. Games can be used over both local connections and broadband Internet connections.
The software has not been updated since 2008 and together with its cumbersome interface, lack of support and connection problems it was an easy decision skipping the software. It has also been surpassed by the other services in terms of latency and performance coming out unfavorable in tests compared to for instance OnLive [5]

GamingAnywhere

Released in 2013 GamingAnywhere is the first open source system of cloud gaming. This allows researchers to experiment their ideas on a real testbed, service providers to build their services on top of it and end users to set up game servers using their home workstations. It is implemented as a library where each module can be freely changed and modified for custom-made services and research.
It is an interesting system, but comes with some compatibility issues making some games impossible to run in a fully playable state. It is also a work-in-progress application with little documentation and support. While connection was easy to obtain, picture problems often arouse. In the end GamingAnywhere was dropped in favor of Steam.

Steam In-home Streaming

Steam in-home Streaming is a commercial available setup. It is (at least as of 2015) not intended to be used for cloud gaming, but as a streaming software for local area networks (LAN). The stream comes featured with valuable performance information, such as delay, lost packets and missing frames. This info is fully accessible during gameplay. As a commercial service it is also more relevant for the thesis. It is possible it one day will turn out to be a full-fledged cloud gaming service comparable to OnLive.

7.2.2 Setting up a cloud gaming system

The system in use consists of mainly four entities:

- Valve's Steam In-Home Streaming software on both server and client.

- Amazon Web Service's EC2 cloud computing service for setting up a virtual gaming machine.
- OpenVPN (Virtual Private Network), a sort of "hack" to trick Steam into thinking both machines are on the same LAN.
- ZOTAC ZBOX PI320 pico micro-PC acting as a microconsole.

Client

Zotac ZBOX PI320 pico is chosen as the client machine. It is mainly mimicking a microconsole as pioneered by OnLive. This tiny, fanless micro-PC are indirectly running games which otherwise would have required a huge desktop computer consuming over 500 watts. It is a Windows 8 machine, but it could have been a Linux or Mac as Steam is cross-compatible in this manner.

The client was intended to act as an eye-catcher for curious bystanders in the public test seeing high-end games running on such a small device.

Figure 7.1: Zotac ZBOX PI320 pico

After testing, it was known that Valve will launch a very similar device, the Steam Link, in November 2015.

Server

The AWS EC2 server closest to the test location featuring the nescesarry GPU instances was in Dublin, Ireland. The average ping time between the Dublin, Ireland server and the Trondheim, Norway location is 59 ms. This latency alone is too much for competitive games, but may be adequate for the mid-tier latency dependent games used in this test.

The rented virtual machine (or "instance" as Amazon calls it) is equipped with a 8-core Intel Xeon with 15 GB RAM and a Nvidia GRID K520 server GPU running Windows Server 2012 R2. VNC Viewer is used for connecting to the machine.

Getting the instance to work as a high-end gaming machine was a cumbersome affair, but after manually changing graphic and sound drivers and disabling firewall, the server was finally working as intended.

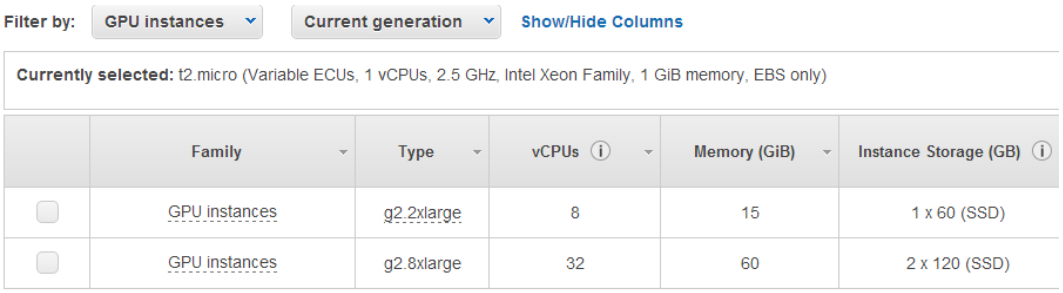

Figure 7.2: Choosing a new instance (virtual machine) in AWS EC2.

Virtual Private Network

Open-source VPN software OpenVPN helps to expand a private network across a public network, such as the Internet. It enables the client and server to send and receive data across shared or public networks as if they were directly connected to the private network. Peers authenticate with each other using a pre-shared secret key, certificates or username/password.

Streaming Software

When OpenVPN is up and running and correctly configured the Steam software running on both machines automatically detects each other and are ready for streaming. As seen in Figure 7.3, Steam features several options for optimizing the experience. Users can for instance choose between "Fast", "Balanced" and "Beautiful". This is about how much bandwidth the stream will use. Fast is limited to 5 Mbps, Balanced is 10 Mbps while 15 Mbps is the limit for the Beautiful setting. A lower bandwidth means lower latency and might also improve stability. After loads of testing, the balanced option seemed to be best suited. Fast is clearly worse graphically being slightly blurry while Beautiful seems to escalate the latency making it hard to justify the extra eyecandy. Also on Beautiful the games would freeze a couple of times. This never happened on the Balanced setting.

Configuration

We ensure that all four subsystems, that is the server, the client, the game itself and the streaming software, all are using same resolution. This saves some precious milliseconds as the need to upscale and downscale is gone. The fairly average resolution of 1280x720 is chosen.

Setup instructions:

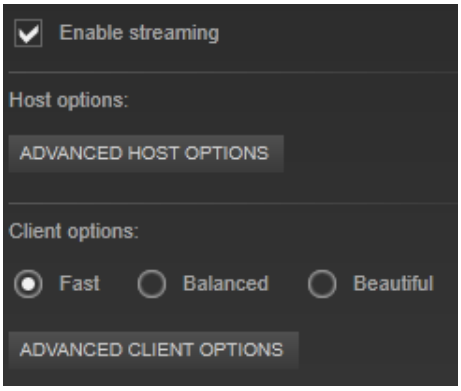

Figure 7.3: Streaming options inside the Steam client

- 1. Start server (AWS)
- 2. Start VNC Viewer
- 3. Sign into Windows using password.
- 4. Start OpenVPN on server
- 5. Start Steam on server
- 6. Manually change IP config in client

Play instructions:

- 7. Start OpenVPN client
- 8. Start Steam client
- 9. Stream the game

Pretesting

A 25 Mbit fixed internet connection has been used for these tests.

Pretesting starts off by trying the graphically impressive Far Cry 3 (Ubisoft, 2012) at ultra high settings, requiring far above the native specs of the machine. At "Balanced" it uses 10-11 Mbit in average, the average framerate was a respectable 48 fps. The visuals are significantly better than anything on OnLive, but comes with a slight stuttering at times.

Grand Theft Auto V (Rockstar, 2013), the game ultimately chosen for the public test, had initially more performance problems. After some time the framerate fell way below 20 fps for some reason. The in-game settings were put down from high to normal, many effects were turned off and draw distance was limited to 50%. The average went up to 48 fps with these settings using around 8 Mbps. Steaming statistics shows packet

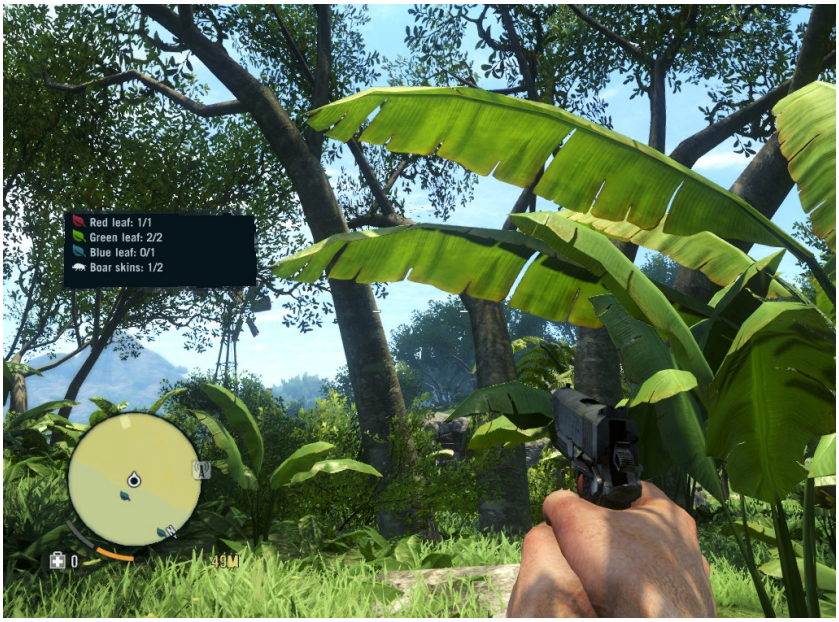

Figure 7.4: Far Cry 3. In-game screenshot from the custom Steam/EC2 setup.

loss: 0.2% and frame loss: 3%. Steam notified about a 77.4 % "slow network" and 19.1% "slow game" in average during gameplay.

The game ran OK, but with some clear stuttering at times. This is likely what is called microstuttering, irregular delays between frames which causes moving video to stutter. This is probably due to the system needing to drop frames not available in time. A 3% frameloss shows that in average the game drops 1.4 frames per second.

The EC2 virtual machine should have been able to run the game better, but this could be because of the machine are using loads of resources to run the encoding and transferring of the stream. Also the display drivers available in the server machine were quite outdated, meaning they were not well optimized for the game.

Figure 7.5: Far Cry 3. In-game screenshot with Steam performance information.

Measuring latency

Steam has valuable performance information including in-depth information about latency. The average input time (corresponding to L2 i Section 4.4) is 30 ms. This is the time between an input is registered on the local device till it is registered on the server.

A frame in GTA V takes on average 51 ms from capture till display (corresponding to L4 and L5), this consists of:

- Capture: 5 ms
- Encode: 8 ms
- Network: 35 ms
- Decode: 3 ms

The games' response time can be measured by capturing video. Screen capture software starts recording at the moment the space key is pressed. The same key also performs a command in the game. We find the response time by measuring how many frames there are in the recorded video before an on-screen change occurs. Screen capture is done at 60 fps. By simple mathematics we have that 60 fps = 1 second/60 = 1000 ms/60 = 16.666 ms. Each frame is shown in approximately 16.7 ms. This means that each video frame before on-screen action adds 16.7 ms of delay. The game has on average 8 such frames or approximately 133 ms in total response time.

From this we can estimate the rest of the steps:

- L1 Local Input: 3 ms
- L2 Network Input: 30 ms
- L3 Game: 45 ms

- L4 System (capture and encode): 13 ms
- L5 Network Output: 35 ms
- L6 Local Output (decode and display): 7 ms
- TOTAL: 133 ms

Figure 7.6: Grand Theft Auto V. In-game screenshot from the custom Steam/EC2 setup

Figure 7.7: Grand Theft Auto V. In-game screenshot with Steam performance information.

7.3 Test execution

A total of 65 people where participants in the experiment, either online or public.

7.4 OnLive - Online test

The online test and questionnaire was available for two weeks in late April 2015. The test got 31 respondents during this period.

People were recruited from the Norwegian discussion forums Diskusjon.no (mainly a computer and gaming forum), Freak.no (IT-related), Kvinneguiden.no (catering to women) and VG Debatt (general discussion being Norway's largest forum).

The participants were asked to download and test the OnLive application. A questionnaire then followed with multiple choice questions and testers being able to write more freely in the "further comments" section.

The experiment was done with little control over the test. The amount of time being used or how they spent their time in OnLive was not being controlled. Also the hardware and infrastructure such as Internet speed was impossible to enforce or control. OnLive requires 5 Mbps, but this is usually far below the lowest tiers currently offered by broadband providers in Norway with the average by the end of 2014 being 28.3 Mbps [24].

7.4.1 Games

The following games were available for free for testers:

- Batman: Arkham City (Rocksteady, 2011)
- Saints Row: The Third (Volition, 2011)
- Just Cause 2 (Avalanche, 2010)
- Borderlands (Gearbox, 2009)

7.5 Custom Cloud Streaming - Public test

The public test was done at NTNU's campuses Gløshaugen and Dragvoll during the pre-exam period in May 2015. 34 participants (20 at Gløshaugen, 14 at Dragvoll) were part of the experience. People at both campuses had about the same age and level of education.

While the online test focused much on the OnLive service, this test was solely focused on the game performance with the latency and other technical underlyings making up a good quality in-game experience. People were testing the game for approximately 10 minutes each, then a short questionnaire was answered. Also some additional follow-up questions were asked for selected individuals.

7.5.1 Grand Theft Auto V

GTA5 is an open-world third-person action game similar to most of the games available in the OnLive test. Grand Theft Auto V was mainly chosen because of its huge popularity. The game has sold 52 million copies as of April 2015. It fits perfectly between the casual and hardcore gamer categories by being not too hard and complex, but not too simple either. GTA is also a game where you can play for 5 minutes and get a meaningful and entertaining experience.

In terms of latency the game was neither too demanding (such as a competitive FPS) or too easy (such as a turn-based game) for testing this part of the system.

7.5.2 Testbed

The public test system consists of the client, a 24" LCD screen and an Xbox 360 wireless gamepad. Although sound was not directly a part of the questionnaire, it is still important for the overall experience, so a 2.1 PC speaker system was brought in as well.

A fixed Internet line was used because of stability as wireless networks are known to cause lag spikes and may provide fairly unpredictable results.

Figure 7.8: The test system at Gløshaugen campus, NTNU.

7.5.3 Observation

Participants looked in general to be very immersed in the game. Most people played the game without questioning the setup. A few people, especially at Gløshaugen, noticed or questioned if the game was being streamed. Many expressed astonishment after being told that the game was indeed a stream. A few bystanders preferred not to play, but openly discussed the game and the technology.

A few users were willing to partake in a more in-depth enquiry, an informal interview, about their positioning towards this type of gaming after playing.

Figure 7.9: Grand Theft Auto V. In-game screenshot from the custom Steam/EC2 setup.

Figure 7.10: Dragvoll campus, NTNU.

Chapter 8

Results

This chapter shows the results of the questionnaires and interviews.

It is important to differentiate between the two tests. The OnLive test is very much about testing the system itself with usability as the main criteria. The campus test is more about audiovisual impression and latency acceptance. The online test was also more complex and time-consuming compared to the public test, which makes the gamer enthusiast more prolific in the former. The tests should therefore be viewed as entirely independent of each other.

As mentioned in Section 7.1.2 the hardcore and casual gamer category have here been established by the amount of hours they spend on games. A clear majority of participants in both tests are male.

A person spending **10 hours or more** on games weekly is considered a hardcore gamer.

8.1 Questionnaire - Online test

	Total	Male	Female
N participants	31	24	7
% participants	100 %	77 %	23 %

Participants and gender distribution in online test.

As seen in Figure 8.1 the wide majority of people participating online are in their teens or young adults.

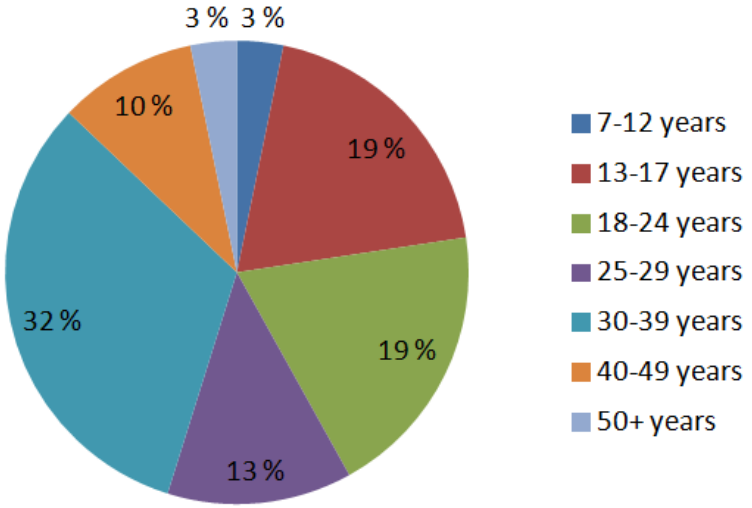

Figure 8.1: Age distribution in the online test.

OQ1: *"How many hours do you spend on games weekly?"*
Most people were spending 10 hours or more. As Figure 8.2 shows many were on the border of being classified as hardcore.

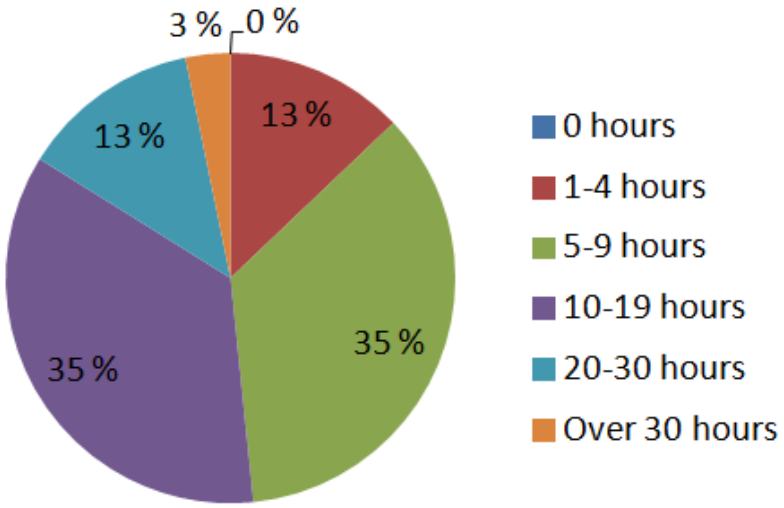

Figure 8.2: OQ1: "How many hours do you spend on games weekly?"

OQ2: "*How where you connected to the Internet?*"
Only 9 out of the 31 were using the preferred cable connection. There were negligible differences in QoE parameters between those who had a wired and a wireless connection. Most of the cable users were hardcore gamers.

OQ3: *"How do you think the game experience was compared to "regular" games where you have to download the game in advance?"*
Hardcore gamers clearly compares the OnLive experience worse than the casuals as shown in Figure 8.3. A significant amount of casual testers rate it "Better" or "Much better", probably due to the accessibility advantages such as no need to download in advance.

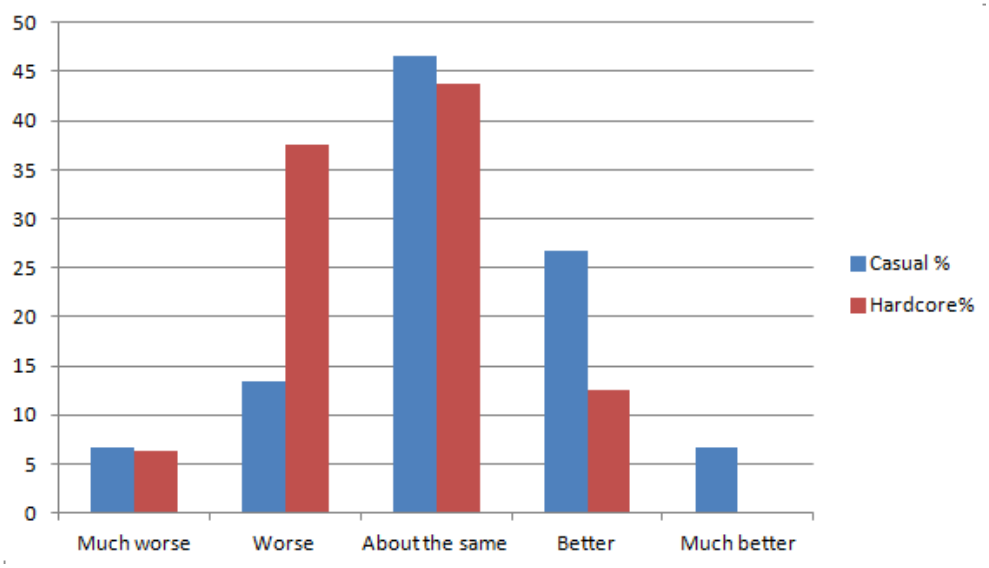

Figure 8.3: OQ3: "How do you think the game experience was compared to "regular" games where you have to download the game in advance?"

OQ4: *"How was the experience getting started with the game? (installation, setup, loading) before entering the gameplay?"*
It looks like both groups are seeing the advantages cloud gaming have in this department as Figure 8.4 shows. Both casuals and hardcore have a very high rating for the pre-play experience.

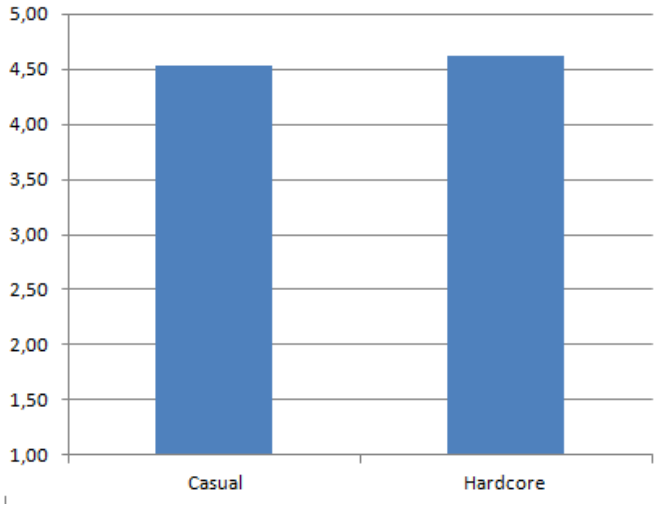

Figure 8.4: OQ4: "How was the experience getting started with the game? (installation, setup, loading) before entering the gameplay?"

OQ5: "*How did you experience the graphics/visuals?*"
OQ6: "*How was the flow in the game/games?*"

Using the word "flow" instead of for instance "framerate" was done on purpose, so people not using this kind of vocabulary can answer. As Figure 8.5 shows, hardcore gamers rates the fidelity slightly worse than casuals.

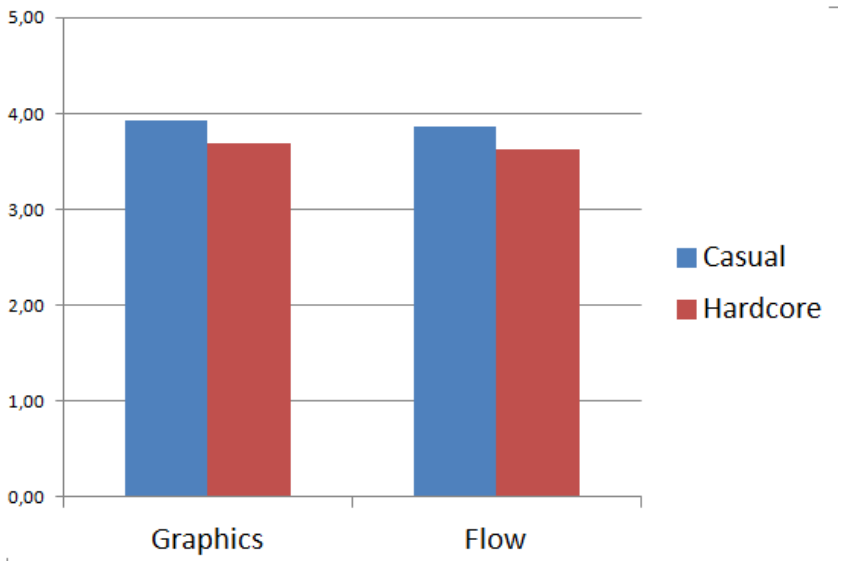

Figure 8.5: OQ5: "How did you experience the graphics/visuals?", OQ6: "How was the flow in the game/games?"

OQ7: "*Were there any problems with the stream (hiccups, bad picture quality, interruptions etc.)*"
Hardcore gamers are noticing more technical problems than their casual counterparts, shown in Figure 8.6. This can imply hardcore gamers have a lower threshold for what they consider a problem or a fault.

OQ8: "*Could you have paid for such a system, for instance 200 kr. a month, if all games were available?*"
This is an interesting question because intuitively hardcore gamers should be more interested in paying a subscription for a gaming service. Hardcore gamers are much more likely to spend money on gaming in general. Surprisingly the amount of people saying "Yes" to the question were over 40 % for each group. Figure 8.7 shows there is still a big amount of casuals (40%) who answered downright "No".

Gamer enthusiasts are more on the fence about cloud gaming with almost half answering "Maybe".

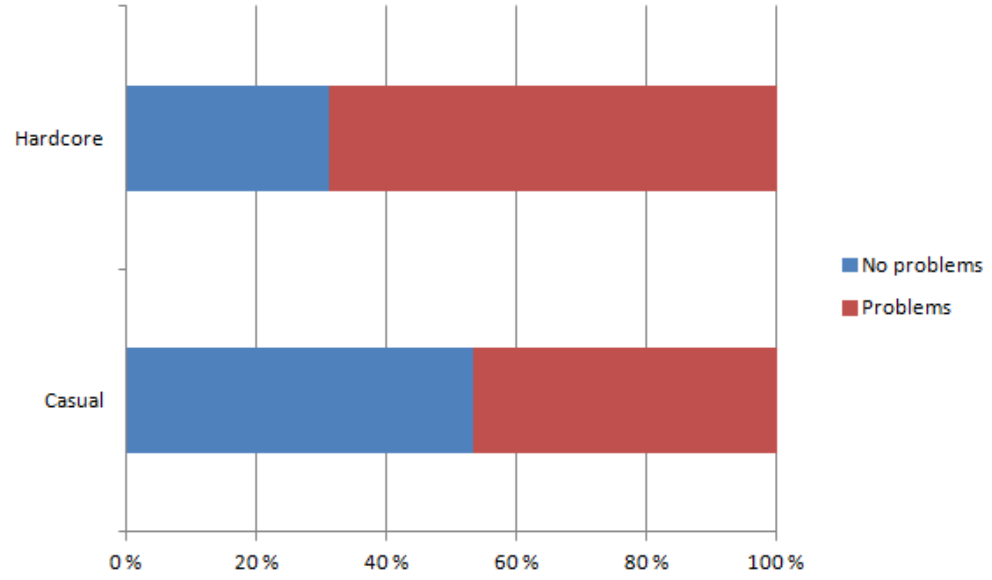

Figure 8.6: OQ7: "Were there any problems with the stream"

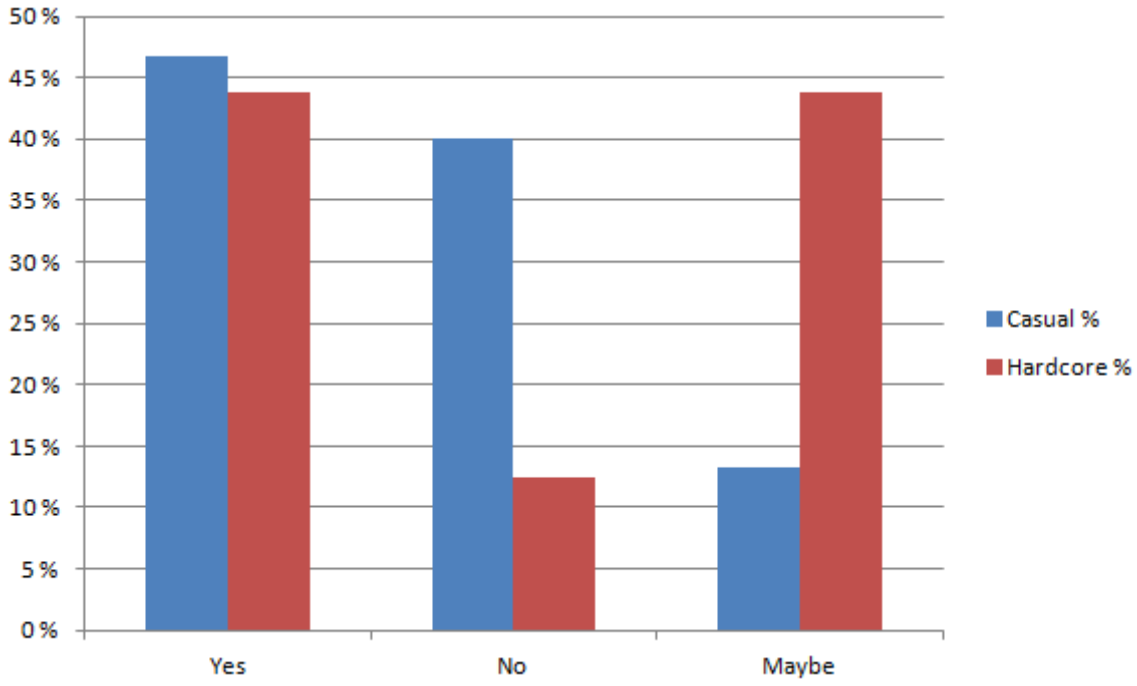

Figure 8.7: OQ8: "Could you have paid for such a system, for instance 200 kr. a month, if all games were available?"

8.1.1 System Usability Test

Aspect	**SUS Reply**	**Converted**
1. I think that I would like to use this system frequently	3,55	6,38
2. I found the system unnecessarily complex	1,72	8,19
3. I thought the system was easy to use	4,62	9,05
4. I think that I would need the support of a technical person to be able to use this system	1,41	8,97
5. I found the various functions in this system were well integrated	4,04	7,59
6. I thought there was too much inconsistency in this system	2,14	7,14
7. I would imagine that most people would learn to use this system very quickly	3,69	6,72
8. I found the system very cumbersome to use	1,45	8,88
9. I felt very confident using the system	3,97	7,41
10. I needed to learn a lot of things before I could get going with this system	1,48	8,79
Total SUS Score		**79,13**

OnLive quality using SUS among participants

A total of 29 people answered this part. A total SUS score of 79 which is considered a good score, meaning the system has high user-friendliness. There were no clear difference between the groups in this area.

8.2 Questionnaire - Public test

This is basically a shorter version of the original questionnaire where the usability and service related questions have been removed.

	Total	Male	Female
N participants	34	27	7
% participants	100 %	79 %	21 %

Participants and gender distribution in public test.

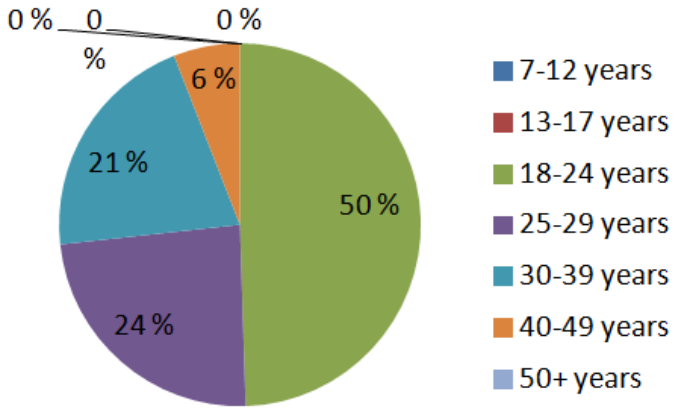

Figure 8.8: Age distribution in the public test.

Unsurprisingly in a student environment, most people were young adults with around 3 out of 4 being below 30 years of age as seen in Figure 8.8.

PQ1: *"How many hours do you spend on games weekly?"*
The number of more moderate/casual players are more prevalent here than in the online test as shown in Figure 8.9. This is due to the nature of the test, the more spontaneous approach bringing in different people, also those little interested in games.

PQ3: "*"How do you think the game experience was compared to "regular" games where you have to download the game in advance?"*
We see in Figure 8.10 that the difference was much clearer compared to the online test. This is probably due to the fact that this test was only about the game itself. The cloud gaming advantages such as the no need to download and setup a game is nowhere to be seen. Again hardcore gamers are paying more attention to the technical aspect of the games, which is why they rate the comparison so much lower than casuals.

PQ5: "*How did you experience the graphics/visuals?*"
PQ6: "*How was the flow in the game/games?*"
The hardcore gamers rate the fidelity clearly worse than the casuals. The difference was

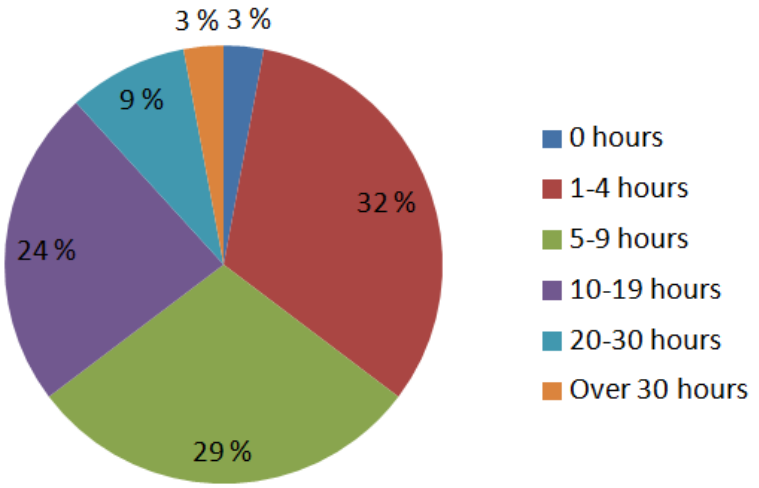

Figure 8.9: PQ1: "How many hours do you spend on games weekly?"

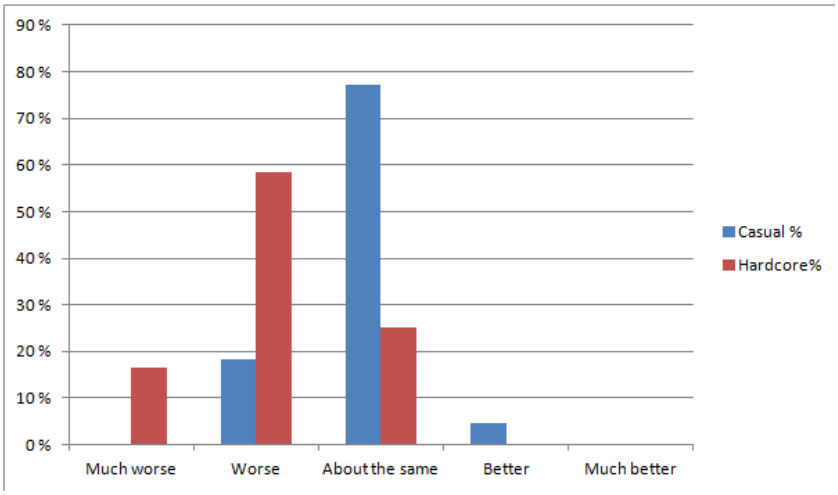

Figure 8.10: PQ3: "How do you think the game experience was compared to "regular" games...?"

much more clear compared to the online test. It is possible the hardcore gamers were put off by the relatively low graphics settings used in GTA V. Also the microstuttering in the game was probably being noticed more by the hardcore than the casuals.

PQ7: "*Were there any problems with the stream? (hiccups, bad picture quality, interruptions etc.)*"
We see in Figure 8.12 a night and day difference between hardcore and casual. It must

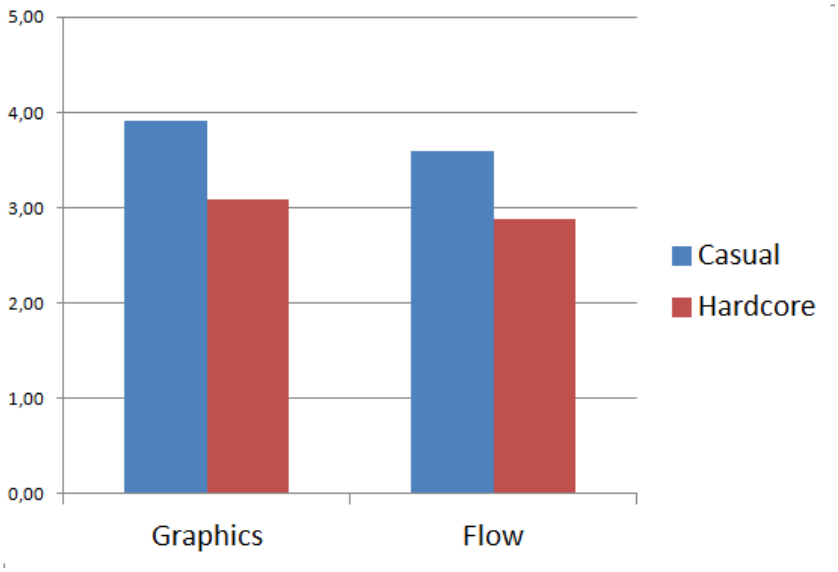

Figure 8.11: PQ5: "How did you experience the graphics/visuals?", PQ6: "How was the flow in the game/games?"

be said that many of the public testers came in groups and discussed the game with each other. This may have affected their position.

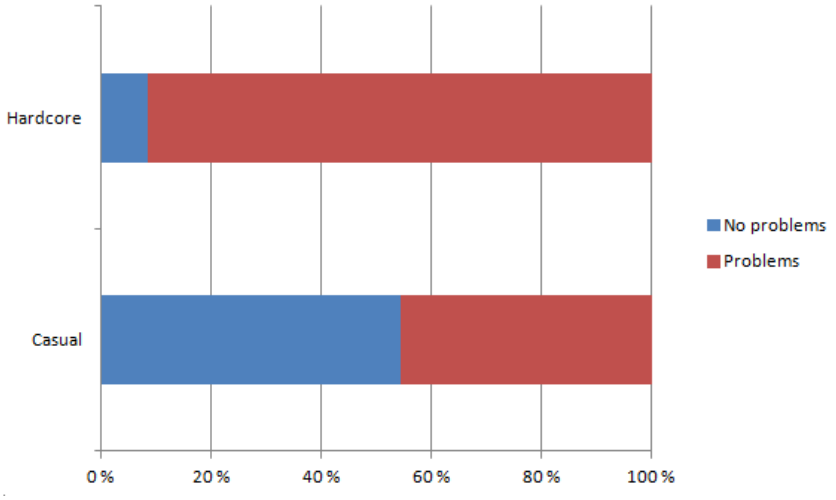

Figure 8.12: PQ7: "Were there any problems with the stream"

8.3 Validity

8.3.1 Correlation

The groups "hardcore" and "casual" have rather arbitrary been established by game time. Using SPSS we see how strong a correlation is on an individual basis. Using question OQ3, the scatter plot (Figure 8.12) shows a clear linear trend. Pearson correlation is p=-0,452. This means there is a fairly strong negative correlation between the amount of hours spent on games and how well the testers rank the OnLive experience.

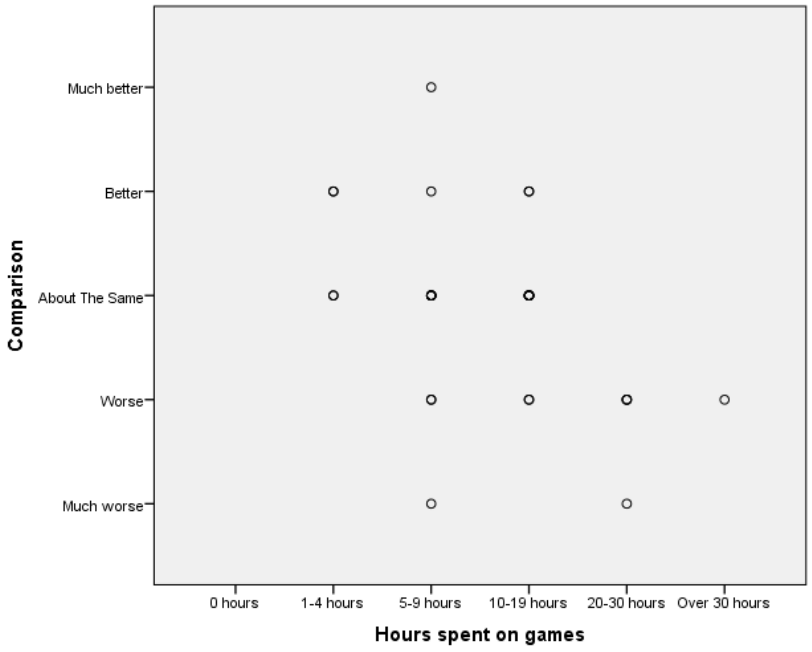

Figure 8.13: Scatter plot of the game experience compared to "regular" games in the online test

8.4 Further comments and interviews

The questionnaire had an optional "further comments" section to garner textual feedback. About a third of the respondents filled in something in this section.

Some expressed that the lag was too big, but argumented you can get used to it. The lack of interesting new games in OnLive was seen as a the main problem for many in the online test.

Some had worries about the QoS of such a system, as one put it:

> "I have very little faith in them delivering the right quality and game experience despite how broad broadbands will be in the future"

This was a concern among many gamers. They saw it as a cool tech demo, but not something that will replace traditional game delivery.

Four people were interviewed in an informal manner. Two participants from the online test were interviewed via a discussion forum and two from the public test at the test site. This happened after their questionnaire was filled out. 3 out of 4 came out as hardcore gamers.

The hardcore gamers were impressed, but noncommittal to cloud gaming, one questioning the capacity of such a service:

> "What if 100,000 or even a million players are logged in at the same time?"

Two of the hardcore gamers was worried what this could mean for ownership claiming gamers like to own and collect games. One suggested cloud gaming could be an interesting try-before-you-buy system praising its accessibility, but implying it would act be more as a complement to regular gaming than replacing it.

The casual gamer had no worries about the technical underlyings. Instead she said the price would be the key question claiming it should not be more expensive than a Spotify or Netflix subscription (currently around 100 Norwegian kroner).

Chapter 9

Evaluation

This chapter answers the research questions and gives a project reflection.

9.1 Research questions answered

RQ1 - How does the hardcore gamer and the casual gamer react to cloud gaming services in terms of quality of experience?
The online experiment shows that both hardcore and casual gamers are in general quite positive to what OnLive has on offer.
Despite many hardcore gamers coming off as positively surprised by how well it works, they are overall more negative to the experience. Especially on how it compares to the traditional game delivery they are used to. In terms of flow and visuals we see the biggest differences. The hardcore is likely to have a higher standard for visuals and performance, so they are more likely to see the problematic properties of game streaming such as high latency and stuttering. Both type of gamers were particularly impressed by the instant loading of games with no installation and setup required.

RQ2 - What is "good enough"? Does the quality threshold for being acceptable differ among the gamer groups?
The tests show that while casuals seemed fairly satisfied with the framerate and latency issues presented, the hardcore gamers were clearly more negative as they rate this a very important part of the experience.
In the test with the most quality issues, the public one, we see that almost all hardcore gamers are experiencing problems with the stream. The latency of around 133 ms is simply too much to handle the high performance expected from dedicated gamers. The casual gamers on the other hand were mixed in their reaction to latency and stability of the stream. While former studies have shown that different types of games can have widely different latency thresholds, this looks also to be true for different types of players.

RQ3 - How does each group compare streaming to the local/traditional alternative?
There were big differences between the groups in the tests. Over 60% of the hardcore gamers thought it was worse than the local experience. It looks like they demand more and are more picky on the technical hindrances such as the latency issue.
It is also important to note that dedicated gamers have already invested highly in the local alternative and may see cloud gaming as a threat to their investment. While both groups see the advantages compared to the local alternative, the casuals signals they may choose convenience over fidelity as have been seen in the movies and music industry.

The textual feedback may imply that casuals simply see the service as a black box. In contrast, the hardcore are worried about the underlying technology and how it may be inferior to conventional game delivery.

RQ4 - What type of gamer is most likely to embrace cloud gaming?
It looks like the casual gamer are most likely to embrace the cloud technology without the need for a dedicated machine and having to struggle with setup procedures.

Hardcore gamers are more noncommittal, having perhaps a more realistic stand, where they question the technical underlyings and the feasability of such game delivery. With technology improving and new services appearing the non-competitive side of dedicated gamers may change their mind in the future.

Hardcore gamers have also expressed a skepticism towards the non-ownership of games, while this was not brought up by anyone under the casual definition.

RQ5 - What types of streaming services works best for the respective groups?
In order to cater to the casuals, services should not aim to be a PC gaming competitor the way OnLive did. Instead companies should get the games onto everyday platforms such as the web browser, the TV and 4G mobile phone. The kids and family demographic can find a service where you can play games on devices you already own very attractive with the right price. A subscription or a free-to-play model is likely the best way to go in terms of pricing models.

9.2 Project reflection

In the nature of up-and-coming technology things change fast, which has forced changes in the project strategy. The project was originally going to be a face-off between the two PC competitors OnLive and Gaikai. Gaikai became PlayStation exclusive over night and the PC version was soon removed. The new service, PlayStation Now, was as of early 2015 still not released in Europe. OnLive was therefore the only commercial cloud gaming service available in Norway.

OnLive's sudden departure in mid-semester was therefore a big blow to the thesis. Anyhow, the project got decent results from OnLive in the weeks before it shut down and the thesis took a very interesting turn with the idea of using Steam In-home Streaming for cloud gaming.

Part IV

Summary

Chapter 10

Conclusion

This chapter sums up the report with an overall conclusion and future perspectives.

10.1 Summary

While it may take some years, cloud gaming is very likely to become significant for the gaming industry in the upcoming decade. OnLive has showed the technical potential, but not being successful in their approach with catering to hardcore PC players. PlayStation Now on a mainstream console such as PlayStation 4 and in TVs are probably more viable. The more casual console audience is more inclined to cloud gaming if the test findings are to believed.

The tests reveal that this group are more positive to cloud gaming than the hardcore, especially when compared to the traditional alternative. Mainly technical limitations deny the dedicated gamers from the high-end gaming they are used to. They seem also more skeptical about the feasibility and what cloud gaming implies for ownership.

It will be important for upcoming services to be marketed more towards the casual and mid-core. Interesting platforms in the upcoming years will be TV (either set-top-box or built-in), web browser (which means games can be played on all sorts of connected devices) and mobile phones. These are platforms non-dedicated players have anyway. It provides a clear entrance for trying and playing games for people who may not see the point of owning gaming devices.

Seeing how the consumers of music and movie are fast approaching away from physical media and downloads, it is only a matter of time before cloud gaming hits the mainstream. The right content, the right platform and the right pricing is important to get this done. PlayStation Now and Nvidia Shield will be an interesting start of this approach.

10.2 Further work

Given the popularity of smartphones, it would have been interesting setting up a 4G test that might imply whether mobile phones are the future for cloud gaming. A 4G mobile

phone is something most young people in the Western world has in their hands every day, a market waiting for to be tapped. The upcoming 5G aims for latencies down to around 1 ms in best-case scenarios. If it is able to achieve anywhere close to that, there is no reason mobile phones will not be able to run high-end games.

It would also be interesting to see how cloud gaming issues such as latency affects core gameplay with both groups. For instance how the win-lose percentage is affected for both hardcore and casual players.

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OnLive Questionnaire (originally in Norwegian)

OnLive is a streaming service for computer games where you can play a wide array of games instantly without downloading. Similar to how Netflix works for movies and Spotify for music. Instead of running the game locally, the system streams a video of the game from a server. Thus the system requirements are very low. You only need a PC capable of playing video and at least 5 Mbit/s broadband.

This anonymous questionnaire seeks to find out how such a service will be accepted by different types of players.

To get started, open onlive.com on a PC or Mac and press "Download Client". Follow the installation procedure. Open the program and choose "Create Free Account" to create a new user. You can now play several games for 30 minutes each.

All data concerning you on OnLive will be deleted on April 30th, 2015. All data in the questionnaire will be treated confidentially and follow NTNU's policy on data gathering.

Gaming habits

1. **Gender**
   Markér bare én oval.

   - ◯ Male
   - ◯ Female

2. **Age**
   Markér bare én oval.

   - ◯ 7-12
   - ◯ 13-17
   - ◯ 18-24
   - ◯ 25-29
   - ◯ 30-39
   - ◯ 40-49
   - ◯ 50+

3. **How many hours do you spend on games weekly?**
   Markér bare én oval.

   - 0 timer
   - 1-4 timer
   - 5-9 timer
   - 10-19 timer
   - 20-30 timer
   - Over 30 timer

4. **What type of platform do you play the most?**
   Markér bare én oval.

   - PC
   - Console
   - Handheld
   - Mobile/tablet

5. **What do you prefer?**
   Markér bare én oval.

   - Singleplayer games
   - Online multiplayer
   - Party games (with friends)

6. **What genre do you play the most?**
   Markér bare én oval.

   - FPS/Action
   - Strategy
   - RPG/Adventure
   - Puzzle
   - Racing
   - Fighting
   - Sports
   - Simulation
   - Platform
   - Andre: .....

7. **About how much money do you spend on games (including hardware, accessories, subscriptions etc.) throughout a year?**
   Markér bare én oval.

   - ◯ 0-99 kr
   - ◯ 100-499 kr.
   - ◯ 500-1999 kr.
   - ◯ 2000-4999 kr.
   - ◯ 5000-9999 kr.
   - ◯ 10000 kr. or more

Quality of Experience

To be answered after the use of OnLive

8. **How where you connected to the Internet?**
   Markér bare én oval.

   - ◯ Wireless (WiFi)
   - ◯ Wired

9. **Please write some details about the PC and internet speed being used**

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10. **How do you think the game experience was compared to "regular" games where you have to download the game in advance?**
    Markér bare én oval.

    - ◯ Much worse
    - ◯ Worse
    - ◯ About the same
    - ◯ Better
    - ◯ Much better

11. **How was the experience getting started with the game? (installation, setup, loading) before entering the gameplay?**
    Markér bare én oval.

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

12. **How did you experience the graphics/visuals?**
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	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

13. **How was the flow in the game/games?**
Markér bare én oval.

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

14. **Was there any problems with the stream (hiccups, bad picture quality, interruptions etc.)**
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- ◯ Yes, in high degree
- ◯ Yes, in some degree
- ◯ No, no problems

15. **Did you experience latency/lag during play?**
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- ◯ Yes, in high degree
- ◯ Yes, in some degree
- ◯ No, nothing

16. **Overall. How did you experience the service?**
Markér bare én oval.

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

17. **Could you have paid for such a system, for instance 200 kr. a month, if all games were available?**
Markér bare én oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

Usability

18. **1. I think that I would like to use this system frequently**
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	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

19. **2. I found the system unnecessarily complex**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

20. **3. I thought the system was easy to use**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

21. **4. I think that I would need the support of a technical person to be able to use this system**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

22. **5. I found the various functions in this system were well integrated**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

23. **6. I thought there was too much inconsistency in this system**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

24. **7. I would imagine that most people would learn to use this system very quickly**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

25. **8. I found the system very cumbersome to use**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

26. **9. I felt very confident using the system**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

27. **10. I needed to learn a lot of things before I could get going with this system**
Markér bare én oval.

	1	2	3	4	5	
Disagree completely	◯	◯	◯	◯	◯	Agree completely

Finally

28. **Further comments about the system**
What was good, what can be improved etc.

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