

ANALYSIS OF THE CHARACTERISTICS AND CONTENT OF TWITCH LIVE- STREAMING

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By

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Abstract

Video streaming Websites are popular. YouTube is the most popular community-driven video streaming Website, and thus has been the subject of many studies. Similarly, Twitch.tv is the most popular community driven live-streaming Website, broadcasting gaming content live to millions of people. However despite their similarities, less is known about Twitch.tv's streaming and content characteristics. This project gathers data on Twitch.tv through three primary tools: A Web crawler, which gathers Twitch.tv stream metadata, a survey, which gathers YouTube and Twitch user demographics, preferences, and opinions, and a third-party Website, which gathers Twitch.tv stream technical data. Analysis of the results shows the following: Game popularity changes unpredictably over time, as age increases, the number of people that use Twitch decreases, and there are only two commonly used resolutions between most popular and least popular channels. The results should aid in the development of future live-streaming platforms.

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Chapter 1 Introduction

Communication, collaboration, calculation, and content creation have all been important aspects of society, and the Internet has allowed sharing among people all across the world. Recently, it has become easy to create content. With an Internet connection, people can upload a picture to Facebook, write an article and post it to a blog, or even share their experiences via video.

Video content on the Internet has become hugely popular, where broadcasters 'stream' video from Internet servers. In the case of a video or music, streaming means that data is being played as it is continuing to download. The user does not have to wait for the file to finish downloading before playing. Popular streaming sites such as Netflix and YouTube alone account for approximately 52% of all downstream Internet traffic in North America [15]. As streaming services grow, people have been shifting away from cable in favor of video content on the Internet [16]. Before the growth of streaming user generated content, a wide audience was only available to TV networks and filmmakers. Now people can garner millions of views for uploading a personal video. YouTube, which is owned by Google, is special in that people have been able to forge their own content and put it on the Internet for others. There is more content made available on YouTube each month than major American networks have created in years, with over 100 hours of video uploaded every minute [1].

YouTube has been around since 2005, and as such has been well researched. However, a new service called *live-streaming* has arisen. Live-streaming is where users view video broadcasts as they are being recorded. The process of live-streaming can be broken up into three parts. First, a broadcaster uses the broadcasting client of their choice to encode and stream video data in real-time to a server. Next, the

server processes that video data. Lastly, the processed stream of video data is sent out to connected clients, where their browsers decode and play the video. This new service differs from the previous services offered by sites such as YouTube in that live-streaming allows users to stream a video a broadcaster is recording, as opposed to having to wait until the video recording is completed and sent to the server in its entirety.

Many Websites have offered live-streaming services, but one in particular dominates the others. Twitch started with a live-stream Website called Justin.tv in October 2007[9]. Within two years, Justin.tv had 15 million viewers a month [19]. Broadcasters were streaming a wide variety of content, but since streaming gaming based content was very popular, in 2011 an offshoot of Justin.tv was created, called Twitch.tv [19]. Twitch stands apart from Justin.tv, and others, in that it only allows live-streaming of gaming related content. This restriction is dictated by Twitch's Rules of Conduct¹. If a user violates this rule, they could be faced with a suspension of their channel. According to a 2014 study, Twitch.tv accounts for 43.6% of all live-streaming traffic, followed by World Wrestling Entertainment which accounts for 17.7% [12]. Twitch, in terms of Website hits, has since far surpassed its parent, Justin.tv, which was taken down in 2014 [5].

Twitch is analogous to YouTube in that both allow the sharing of user generated video content, albeit in different forms: video streaming for YouTube and live-streaming for Twitch. Unfortunately, there is little recent data available regarding Twitch content. Valuable data would include information such as the most common resolutions of active streams, the average bit rate at which broadcasters upload

¹ <http://www.twitch.tv/user/legal?page=rules-of-conduct>

their streams, key demographics of the Twitch user base, and the average length of stored videos. This data could provide value for future Websites looking to offer a live-streaming service. Aside from gaming and television, other live-streaming subjects have not yet been explored, such as education, news, or general entertainment. For example, there is not yet a site for both up-and-coming and established comedians dedicated to live-streaming to their online following. Information on Twitch content may allow companies to understand what they can expect in terms of network traffic and hardware requirements, especially storage space, and also to understand what users expect from a competent service, and what features should be implemented.

Our study seeks to address that lack of data by analyzing the content of Twitch and gathering the opinions of its user base by means of a Web crawler, survey and third party stream analyzer. The Web crawler was implemented using the Twitch API to gather video metadata. The survey gathered information about user satisfaction and user interactivity with the Twitch service on any platform and browser, as well as other video streaming/sharing Websites and services. The third party stream analyzer used video links gathered by the crawler to obtain data on video bitrates, resolution, frame rate and other technical video data.

In analyzing the data, we found that the popularity of non-eSport games change sporadically and more people regularly use YouTube over Twitch regardless of age. The majority of Videos on Demand, VoDs, are under 10 minutes in length, and have less than nine total views. Most channels have consistent audio settings, using the Advanced Audio Coding encoding protocol, and broadcast at a frequency of 44,100Hz. The remainder of our analyses and conclusions are detailed in Chapters 4 and 5.

The rest of the report is organized as follows. Chapter 2 discusses related works. Chapter 3 details our methodology to gather the above data. Chapter 4 presents our collected data and the resulting analysis. Chapter 5 concludes, discussing the results of our study and mentioning possible subjects for further exploration.

Chapter 2 Related Works

This chapter discusses 2 studies which we found relevant to our project. The first looked at the differences between traditional Websites and Web 2.0 Websites. The second sought to gather data concerning YouTube videos.

Web 2.0 sites have been increasing in prevalence over the past decade. Previously, a site would have a small group of administrators who would add content, and the site's users would merely consume that content. Web 2.0 allows users to play the role of both content provider and consumer. Gil et. al. [7] studied this growing phenomenon, focusing on the popular video sharing site YouTube. They had found that Web 2.0 service providers have different hardware requirements than traditional providers. Specifically, storage requirements will not increase linearly: as more users add content, the rate of data stored increases. It is also important to have sufficient processing power and memory to process large files such as videos.

YouTube was formed in 2005 and represented a new way to share content with the world. In 2007, Cheng et al. [3] recognized this and realized that there was not much research done on YouTube. The group decided they wanted to learn more about the site to better understand it so that future projects could be done to sustain the development of these video sharing sites, and/or to assist in the network traffic engineering process and design. To better understand YouTube, Cheng et al. used a web crawler that interfaced with the YouTube API for 3 months to gather video metadata such as: ID, Uploader, Related Videos, Added Date, Category, Video Length, Number of Views, video constant bitrate, and file size. They concluded that YouTube has many unique features such as length distribution, access

pattern, and the growth trend. This research is similar to our research project in that we too are examining a popular site that exhibits a relatively new form of media: live-streaming. Our goals are also to better understand live-streaming characteristics for live-streaming sites and related hardware and network issues.

Chapter 3 Methodology

Gathering content and user interactivity information about Twitch is a vital first step to the understanding current live streaming platforms, which in turn facilitates the future development of live streaming services. In order to acquire this data, we have used three tools: a Web crawler, a survey, and a technical stream analyzer. The data gathered by the crawler allows us to determine how the popularity of a channel changes over time, the server load at any given time, the current streaming gaming trends and how they evolve over time, as well as the popularity and length of stored video on demand content. The survey results allow us to determine user satisfaction of both stream performance and the Twitch community. Finally, the technical stream analyzer provided active stream data, which allows us to compare the technical aspects between popular and non-popular streams, such as resolution, bit rate and frames per second. In addition, it allows us to determine common mistakes broadcasters make when setting up a stream.

Section 3.1 Web Crawler

In order to gather video metadata, such as length, game name and views about active streams, we employed a Web crawler that periodically examined Twitch videos. Section 3.1.1 discusses the tools we used to create the Web crawler, Section 3.1.2 specifies the video metadata we were able to collect, and Section 3.1.3 outlines the deployment process of the crawler.

Section 3.1.1 Scrapy and Twitch API

To collect the video metadata described in Section 3.1.2, we utilized a third party tool called “Scrapy” [11]. Scrapy is an open source Web crawler built in Python. We chose this tool due to its versatility, ability to work with RESTful API’s, and its extensive documentation. We were able to modify this tool to crawl the Twitch Website using Twitch API calls.

The Twitch API is a RESTful API, which means that the client making calls to the API does not need to know about the type of information the server hosts. The server provides information about the resources it hosts. This API consists of calls that are static URLs with slightly different strings depending on the information the client wants to receive. In our case, the different strings represented the channel name about which we wished to receive data.

Section 3.1.2 Data Output

We procured the following data per active channel, where an active channel is one that is currently streaming:

Total: The total number of currently active streams on Twitch.

Unique to each active stream:

Delay: The broadcaster specified delay between the video being uploaded and the end viewer seeing the stream. This delay is in addition to the standard Twitch delay of approximately 15 seconds.

Creation Time: The date and time the channel was created.

Updated Time: The most recent date and time that any channel information has been updated. This normally corresponds to the beginning time of the channel’s last stream.

Viewers: The current number of people watching the stream.

Unique to VoDs:

Length: The duration of the video in seconds.

Views: The total number of views the video has accumulated since its creation.

Common to both VoDs and streams:

Game: The broadcaster specified field indicating the game being played.

Section 3.1.3 Procedure

The crawler was implemented so that every active stream was analyzed, as well as each active channel's top 100 VoDs, sorted by number of views. First, an API call was made to get the active stream data outlined in Section 3.1.2 for the top 100 active streams, sorted by number of current viewers. Subsequently, for each stream found, a separate API call was made to get the unique to VoD data specified in Section 3.1.2 for the top 100 VoDs of each stream's channel. The output of each crawl went to a file, named after the time of its crawl, in JSON format. Each JSON object was either the stream information, VoD information, or the total number of current active streams.

We ran the crawler every hour, from January 1st, to January 23rd, 2015. To run the crawler every hour, we created a batch file that stored the time of day in a variable and ran our crawler using the time of day as the redirected output file to which the crawler wrote. We then used the Windows scheduler to execute this batch file every hour.

Section 3.2 Survey

In order to gather the opinions and preferences of the Twitch user base, we created a survey. This survey was developed utilizing an online Website called Qualtrics [14]. Section 3.2.1 discusses this online tool. Section 3.2.2 discusses the overall structure of the survey and our design. Section 3.2.3 discusses the survey approval process and subsequent deployment methods.

Section 3.2.1 Qualtrics

Qualtrics is an online platform which allows and facilitates the creation and distribution of surveys. This platform is made available to WPI students free of charge. We decided to use Qualtrics to gather user statistics because it offered a robust selection of tools to craft strong question answer-pairs.

One of the most helpful aspects of Qualtrics was its display logic system that allowed for the creation of display blocks. A display block consists of a set of question-answer pairs and a conditional statement determining whether or not those questions appear to the respondent. The primary condition we used was if a specific answer or set of answers were chosen, the conditional would be true, and thus the set of questions within the display block would be presented. For example, one of the first questions in our survey was “Do you regularly use any video-on-demand websites, such as YouTube?” If the respondents answered yes, they would be taken to a display block with YouTube based questions. If the respondents answered no, they would be taken to a different display block.

Section 3.2.2 Design

The survey was separated into three sections based on question content. The three sections were demographics, YouTube, and Twitch. We used display block logic to separate the YouTube and Twitch sections, which ensured that only respondents familiar with the given section's content would see it. For example, a respondent who has never visited Twitch would not be presented with the Twitch section. This reduces blank or invalid data, in addition to saving the respondent's time. To encourage the completion of the survey, we aimed for an average survey completion time of less than five minutes [4].

The demographics section contains questions on age, gender, continent, country, and state. In addition, we added a question regarding the Internet download speed of the respondent's primary place of residence, in order to analyze whether opinions on videos varied with Internet connectivity.

What's the download speed at your home? If unsure, visit [this website](#).

- Less than 5 Mbps
- 5-10Mbps
- 10-20 Mbps
- Greater than 20 Mbps
- Unknown

Figure 3.1: Demographics download speed question

Figure 3.1 displays the download speed question. We based the answer choices on the recommended download speeds according to Netflix for streaming video. The first answer relates to Internet speeds below the recommended 5

Mbps for streaming HD quality video (720p and up), but can handle SD quality video. The second answer is the range of speeds over which an HD stream streams smoothly. The third answer is the range over which a 1080p video stream streams smoothly. At speeds indicated by the fourth answer, 4k streaming becomes feasible. The last answer is if a respondent does not know and does not

endeavor to learn their Internet download speed. The hyperlink given in the question led to a Website called Speedtest². This Website allows a person to learn or confirm their download speed.

The YouTube and Twitch sections both follow a similar structure, with most of the questions in the two sections parallelized. Questions in common between the two include hours watched per week, devices on which the videos were viewed, viewing experience satisfaction, community interactivity, preferred content, and two open-ended questions: favorite and least favorite aspect of the Website in question. Figure 3.2 displays an example of the parallelism between display blocks. The questions ask the user how long they watch YouTube and Twitch on a given week. The left image is the YouTube question, and the right concerns Twitch.

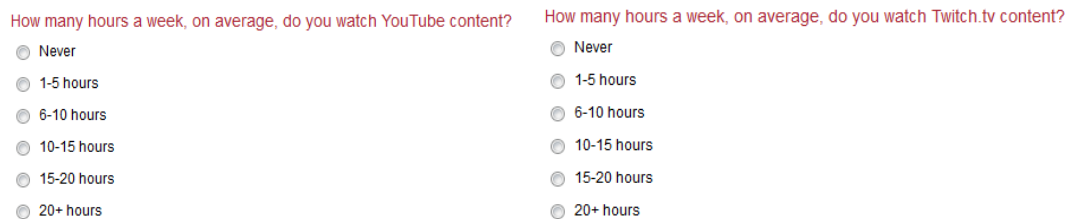


Figure 3.2 The parallelized question about the regular use of YouTube and Twitch

Each block includes its own unique set of questions. On YouTube, every video includes a resolution selector. The YouTube block contains a unique inquiry regarding preferred viewing resolution. On the contrary, Twitch does not offer resolution options for the majority of its streams. The Twitch block instead contains a question regarding whether the respondent prefers live streams versus stored VoDs.

² <http://www.speedtest.net/>

Section 3.2.3 Procedure

With the survey questions in place, we gathered feedback to determine the quality of our survey. We assessed quality based on the amount of time the respondent took to take the survey, the overall ease of understanding the questions and answers, and the ease of answering the questions based on the logical progression of question content and answer type. To test our surveys' quality, we ran a pilot study. This pilot study consisted of three people to whom we sent our survey. When they completed the survey, we noted the time they took, from start to finish, and requested feedback on their understanding or lack thereof for each question. We found that the time each person took to complete the survey was less than five minutes, which was our initial goal. The respondents in our pilot study understood what was being asked of them, and found the questions both clear and concise.

By WPI policy, all experiments involving human subjects, including surveys need be approved by an internal Institutional Review Board (IRB). This review process entailed sending a copy of our survey to the IRB as well as specifying our intended target audience. Due to the non-controversial subject matter and no information identifying individuals, we were exempt from further review. This approval process took less than a week. Upon approval, we finalized the structure of the survey.

The next step in the survey process was distribution. We sought a minimum of thirty responses so that the resulting data would contain a sufficient sample for pattern recognition and statistical analysis. We sent our survey to the Computer Science and Interactive Media and Game Development majors, as well as the current graduate students enrolled at WPI. This was the preferred audience with an age range being between 18 and 28, because we assumed these groups were more likely to have used the

Twitch platform at some time. To supplement these responses, we distributed the survey link on our Facebook pages to introduce additional diversity in the demographic. We received roughly 150 total responses.

We opened the survey on Tuesday December 2nd because it was the second day back to school after Thanksgiving break. We assumed this day would yield the maximum number of results, as we felt the survey would be ignored over a break or weekend. We closed the survey on December 14th because this was the third consecutive day in which the total number of new responses was zero.

To further encourage participation, we provided an incentive for taking our survey- a \$25 dollar Amazon eGift card. Every person who completed our survey was redirected to a separate survey where they could optionally input their email address. Each email was assigned a unique number to assist in the choosing of a winner. We used an online random number generator and chose the email corresponding to that random number. We emailed the winner, with the redeemable Amazon gift card code. Due to the lack of connection between the two surveys, each respondent's email was not connected to their response in any way.

Section 3.3 Stream Analyzer

In order to gather technical information about an active stream, we used a third party tool, “R1CH’s Twitch Analyzer”, <https://r-1.ch/analyzer/> developed by Richard Stanway. The analyzer takes the channel name of an active stream as input and outputs technical video data. We chose this tool due to its ease of use and because we were not able to record any such technical data using the Web crawler.

Section 3.3.1 Data Gathered

We gathered the following technical data:

Bitrate [kbps]: The average number of bits per second at which the streamer uploads their video to the Twitch server.

Bitrate Deviation [kbps]: The standard deviation of bits per second at which a streamer uploads their video to the Twitch server.

Key Frame Interval [sec]: The minimum time before a new key frame is created. The key frame is the full image, and the subsequent frames are bits representing changes from the previous frame.

Frames Per Second [FPS]: The frequency at which frames are drawn, determined by bitrate and resolution. The higher the frequency, the smoother the video playback.

Frame Rate Deviation [FPS]: The standard deviation of the frames per second.

Sufficient Bitrate: Boolean value representing whether or not the broadcaster has a high enough bitrate to display the given resolution at the specified frame rate.

Resolution [Pixels]: The horizontal and vertical lengths of the video measured in pixels.

Audio Levels: Whether the volume of the given stream is too high, too low, or just right. This is determined by measuring the peak audio level in decibels.

Audio Encoder: The encoding type of audio that is uploaded to the Twitch server.

Audio Frequency [Hz]: The sample rate of the audio.

H264 Profile: Which capabilities to include in the encoding and decoding process. The lower the profile the more backwards compatible the video is to older software.

X264 Preset: The speed at which the video is encoded. The higher the preset, the higher the bitrate needed to sustain the quality of the video. The lower the preset, and the longer the video will take to encode, but the required bitrate is reduced.

Uptime [Sec]: How long the stream has been active.

To verify that this data, returned by the analyzer tool, was accurate, we ran a series of tests. The first of which was running our own stream with differing values for the parameters above each time. Then, for each case, we ran the Analyzer on our stream and found that the output matched our parameter values for every case. We used the Twitch player to view statistics about the video being played and found that the data output by the Player matched that of the Analyzer. Finally, we opened a stream in VLC media player and matched the statistics of the playing video to the output of the Analyzer. The output of VLC confirmed the bitrate, resolution, frame rate, audio settings, and audio encoding as stated by the Twitch Analyzer.

Section 3.3.2 Procedure

This section details the procedure we followed in utilizing the Analyzer to gather technical data mentioned in Section 3.3.1.

The Analyzer takes a channel name as input, so we used the output of the crawler to get these names. We analyzed the ten most popular and ten least popular streams per a given hour to compare and contrast their technical characteristics. The output of the crawler is organized in descending order by

stream view count. Therefore the ten most popular streams correlated to the first ten streams output by the crawler, and the least popular streams the bottom ten. We analyzed unique streams, as to not repeat any channels. Thus, the top 10 didn't always correlate directly to streams 1-10.

One of the key requirements of the Analyzer is that the stream to be analyzed needs to have been online for at least two minutes. This was met by utilizing the most recent output of the crawler because the output only contains data for the currently active streams.

The Analyzer allowed up to nine streams to be analyzed within an hour per IP address. As a result of this, both authors each analyzed nine streams twice a day, once in the late afternoon, and once in the late evening. Specifically, we chose 4:00PM and 11:00PM as the two times to analyze streams because these times roughly correspond to the periods of high and low overall viewer activity on the Twitch Website according to Figure 3.3. Figure 3.3 displays the number of total viewers on Twitch, indicated by the upper top curve. The small middle curve above the time axis indicates the total number of active at the given time.

We began analyzing streams on January 3rd and concluded on January 20th. On average, this culminated with 34 analyzed streams a day. This actual number of analyzed streams was not the expected 36 a day due to the Analyzer's inability to reach every chosen stream, but still counted towards the total nine an hour limit.

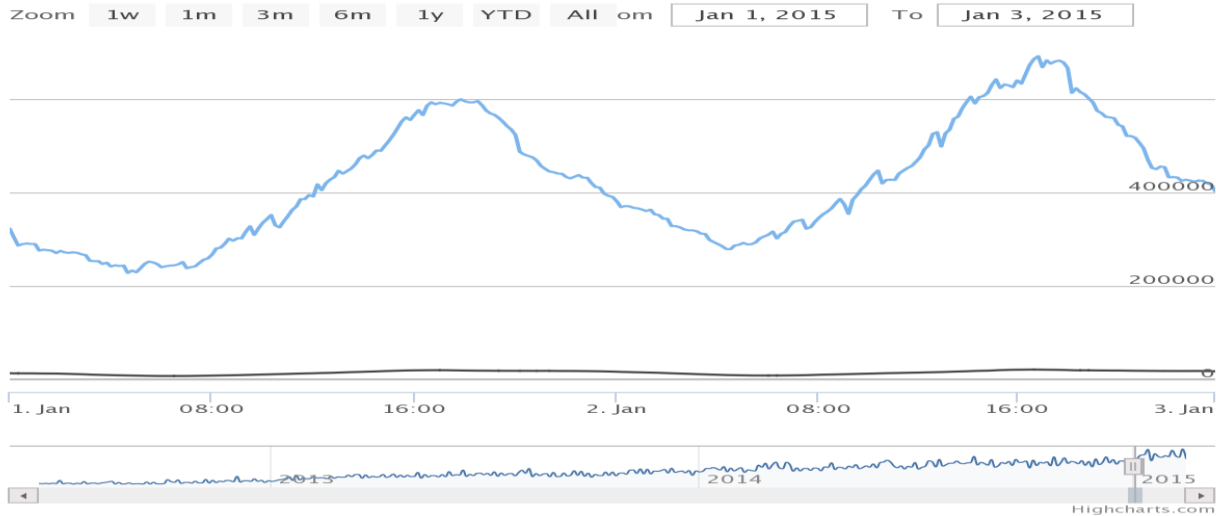


Figure 3.3 The number of active viewers and broadcasters, represented by the top and middle curves respectively. Source <http://stats.twitchapps.com/>.

For each of the analyzed streams, we were redirected to a page containing the data mentioned in Section 3.3.1. During the data collection process, we took a screen capture of this page and stored it in a folder hierarchy denoting the date and time of the image. We also made sure to include the date and time stamp given by the Windows 7 toolbar in each image. We ended up with a total of 503 images. We proceeded to manually extract the data from each image into a Google Spreadsheet. We translated the data in such a way that each image was placed into a single row, and each column specified the type of data. Figure 3.4 demonstrates the organization of our Analyzer data as stated above.

Channel1	Bitrate1	Bitrate Deviation1	Key Frame Interval1	FPS1	...
Channel2	Bitrate2	Bitrate Deviation2	Key Frame Interval2	FPS2	...

Figure 3.4: The organization of all of the Analyzer output

Chapter 4 Analysis

This chapter examines the data we gathered. Section 4.1 discusses the audio settings set by Twitch broadcasters. Section 4.2 displays the video settings used by Twitch broadcasters. Section 4.3 presents our findings regarding stream and VoD metadata and game popularity. Section 4.4 discusses the user satisfaction and demographics of Twitch and YouTube.

Section 4.1 Audio

Audio configuration for a stream impacts its audio quality. This section presents our findings regarding the audio of all analyzed Twitch streams.

Over all analyzed channels, 96.94% used the audio encoding Advanced Audio Coding, aac, while the remaining channels used mp3. The percentage of the most popular channels using aac encoding is even higher with 99.59%. We also found that the every channel analyzed uses an audio frequency of 44,100Hz.

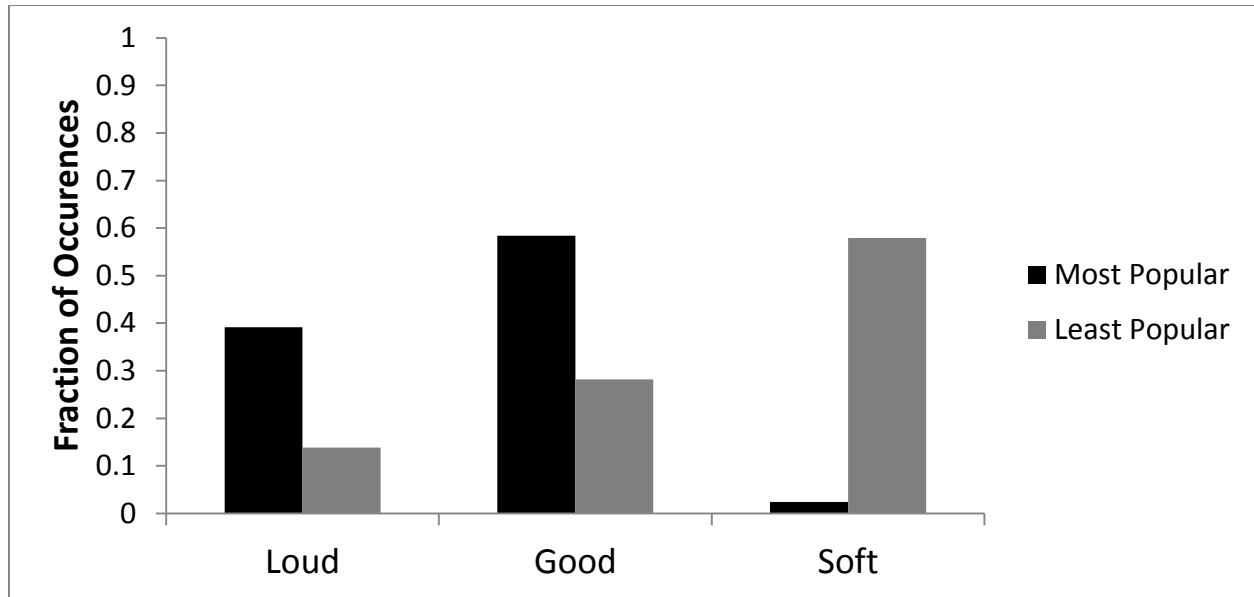


Figure 4.1: Fraction of channels with Loud, Good, or Soft volumes determines by decibels. The black bars represent the most popular channels, and the grey bars represent the least popular channels.

Figure 4.1 displays the fraction of analyzed channels with each audio level: Loud, Good, and Soft. These levels are determined by the peak audio level found during the analysis and measured against base levels in decibels. The most popular channels have mostly “Good” and “Loud” audio levels, whereas the least popular channels have mostly “Soft” audio levels. This implies that proper audio configurations consist of “Good” or “Loud” audio levels, an encoding of aac, and 44,100Hz frequency.

Section 4.2 Video

This section displays and discusses the data gathered from the Twitch Analyzer regarding video technical data.

Section 4.2.1 Resolution

The broadcaster set resolution is one of the key factors in determining video quality. Resolution is the number of pixels that can be displayed in each dimension. The higher the resolution, the sharper the video appears to a viewer. In contrast, the lower the resolution, the blurrier the video appears to a viewer. A cost of broadcasting at a high resolution is a higher bandwidth requirement [12]. Another cost of streaming at a high resolution is an increased strain on the hardware of the broadcaster's system, as well as the server to which the stream is being uploaded.

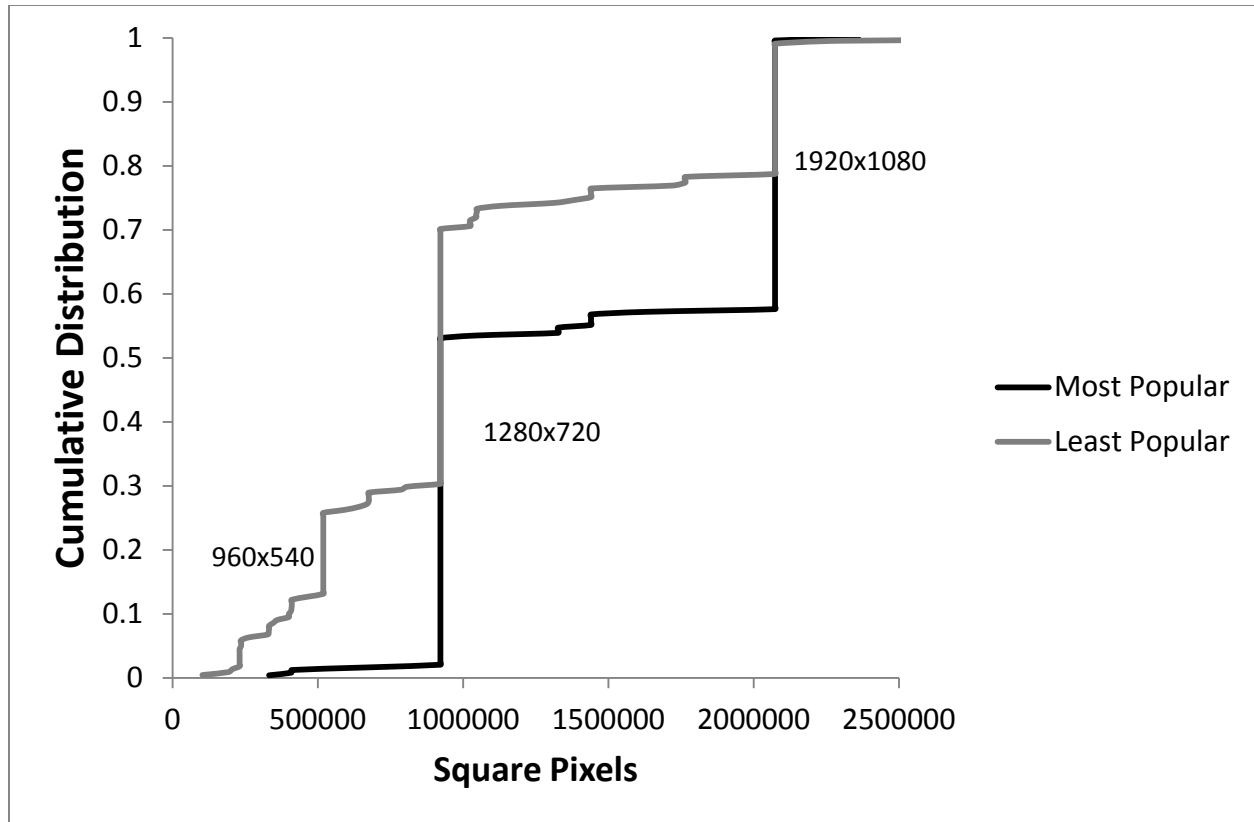


Figure 4.1 CDF of resolutions for all analyzed channels.

Figure 4.2 is a cumulative distribution function of the broadcaster set resolution of all analyzed streams. The x-axis displays the number of square pixels, representing all possible resolutions. For example, the high definition resolution for 1920x1080 is equivalent to 2,073,600 square pixels. The y-axis displays the cumulative fraction of streams. As denoted by the three major vertical lines, there are three resolutions which are most frequently broadcasted: 960x540, 1280x720, and 1920x1080. Out of these three, 1280x720 is the most common for both least popular, with 40%, and most popular streams, with 50%. In addition, only the least popular streams commonly broadcast with a resolution of 960x540. The least popular streams also broadcast at a much wider range of resolutions than the most popular streams.

Section 4.2.2 Bitrate

Bitrate is the number of bits per second at which the broadcaster uploads their stream to the server. A properly set bitrate is important to the performance of the stream. If the bitrate is set improperly, the stream will appear choppy. Frame rate and resolution are the two factors in determining the minimum bitrate. Twitch recommends that broadcasters set their bitrate to 1800-2500kbps to ensure optimal performance when the resolution is set to 1280x720. However, it is also necessary to not set bitrate too high, as doing so may cause a viewer to have trouble downloading and viewing a stream.

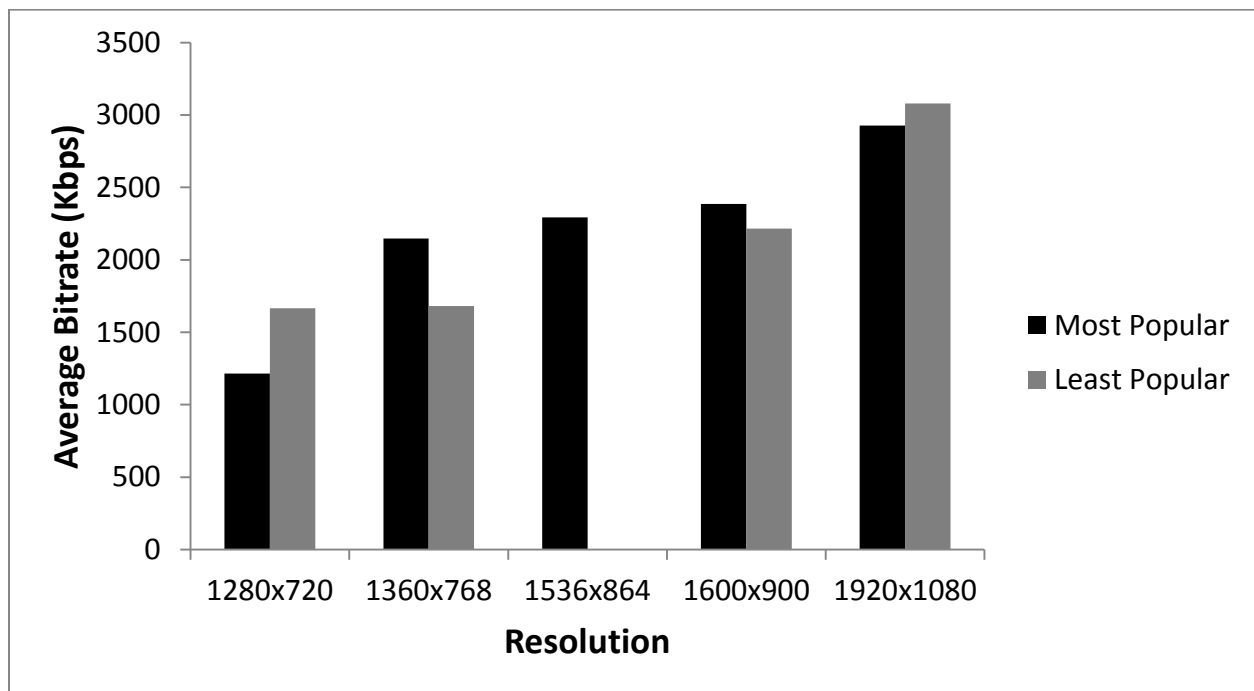


Figure 4.3: Average bitrates for each common resolution found for most and least popular channels.

We gathered data to determine a correlation between the broadcaster set resolution and the bitrate at which those resolutions are broadcasted. Figure 4.3 displays this data. The x-axis represents the resolutions commonly used between both the most popular and least popular streams. The y-axis

represents the average bitrate at which the stream is being broadcasted. For both the most popular and least popular streams, as the resolution increases, the bitrate does as well. The average bitrate for each resolution never exceeds 3,400, and never goes below 1,000kbps.

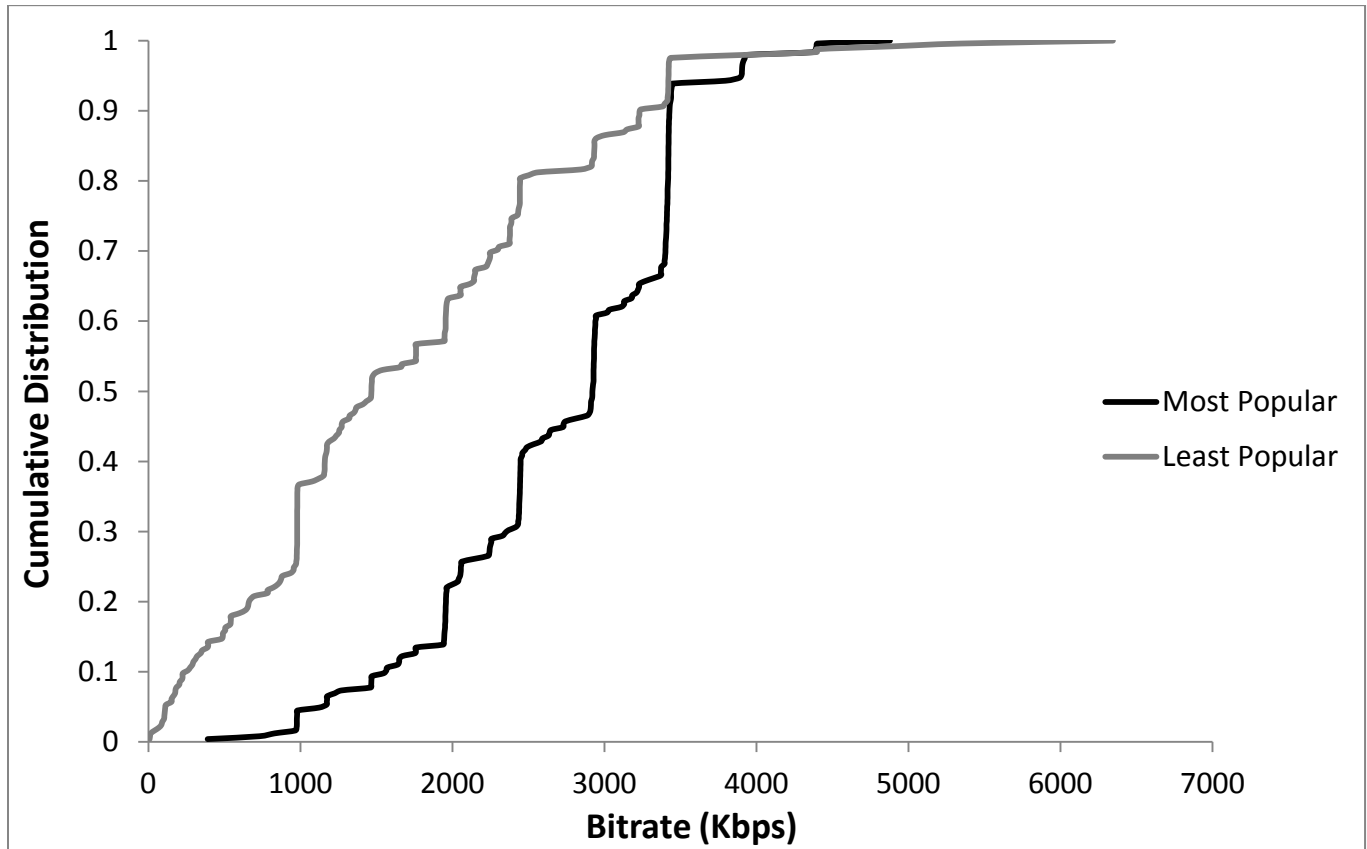


Figure 4.4: CDF of bitrates for most and least popular channels.

Figure 4.4 displays a CDF of bitrates for all analyzed streams over the course of our methodology. The x-axis represents the bitrate at which a stream is broadcasted and the y-axis is the cumulative fraction of streams. The black line represents the most popular streams, while the grey line represents the least popular streams. Both sets of channels use a wide range of bitrates, ranging between 8 and around 6,000kbps. The most popular channels used higher bitrates than that of the least popular channels. As

denoted by the large vertical step, the most popular channels' most common bitrate is 3,200kbps. The least popular channels' most common bitrate is around 800kbps.

Section 4.2.3 Frame Rate

Frame Rate is the number of frames per second at which the broadcasters upload their streams to the server. A properly set framerate is important for how the viewer will see the stream. If the framerate is set too low, the stream will appear choppy, with. If a framerate is set to 1, the viewer will see one static image a second. Most movies and film are recorded and subsequently streamed at 24 frames per second [6]. The higher the framerate, the more the machine's hardware needs to work. Therefore, a balance needs to be found between what looks most realistic and smooth to viewers, but does not require too expensive hardware.

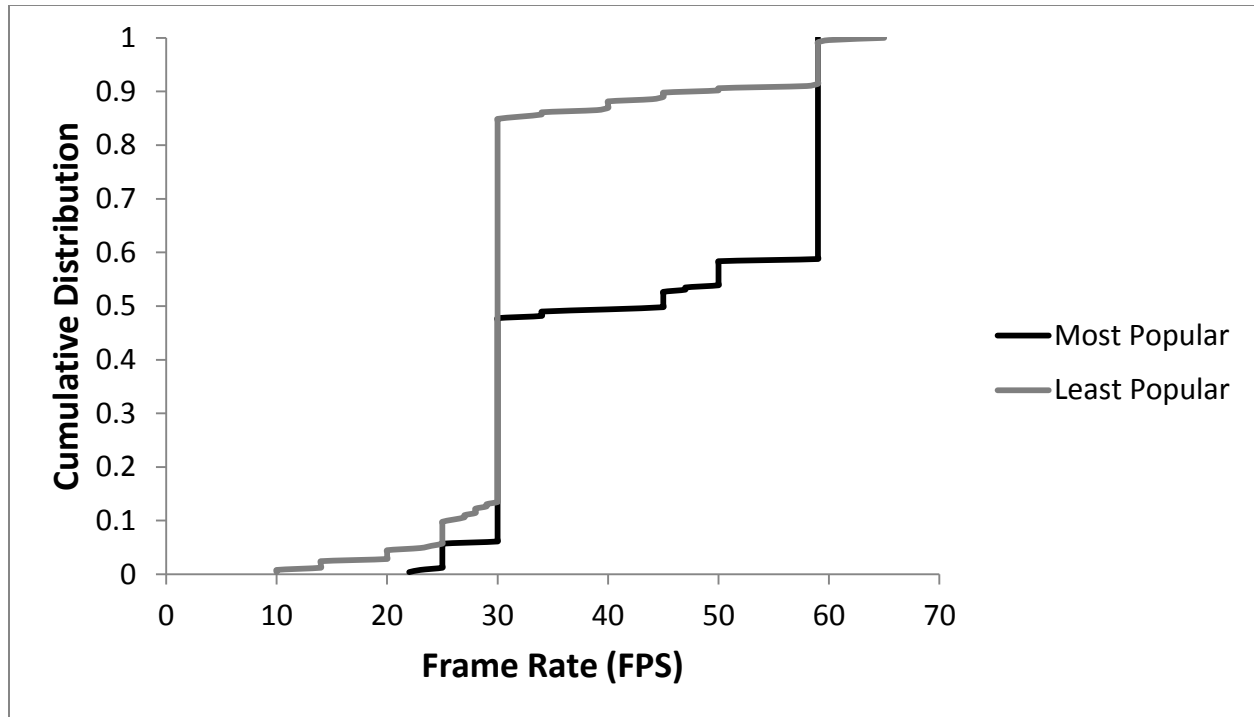


Figure 4.5: CDF of frame rate for most and least popular channels.

Figure 4.5 displays a CDF of the frame rate for all analyzed streams. The black line represents the most popular channels, and the grey line represents the least popular channels. The x-axis shows the number of frames, and the y-axis is the cumulative fraction of streams. There is not a wide range of frame rates that either set of channels utilize. A majority of all analyzed channels used 30 or 60 frames per second. Half of the most popular channels analyzed streamed at 30 frames per second, while the other half streamed at 60 frames per second. A majority of the least popular channels streamed at 30 frames per second.

Section 4.2.4 Key Frame Interval

Key frame interval is the maximum amount of time before a new key frame is created and broadcasted. A key frame is the data containing an image, and each frame sent between key frames is

just the changes of the current image from the previous. Twitch recommends a key frame interval of 2 seconds. Setting a key frame interval too low has an overhead cost of creating many key frames, which consists of more data than just some changes. If an image only slightly changes, creating a new key frame is more expensive than simply creating a frame representing those changes. Similarly, setting a key frame interval too high is also not good for performance. When a key frame interval is set too high, a new image is not created until this time is reached. If an image changes dramatically, the cost of creating a frame to represent every change between images is more expensive than simply creating a new key frame.

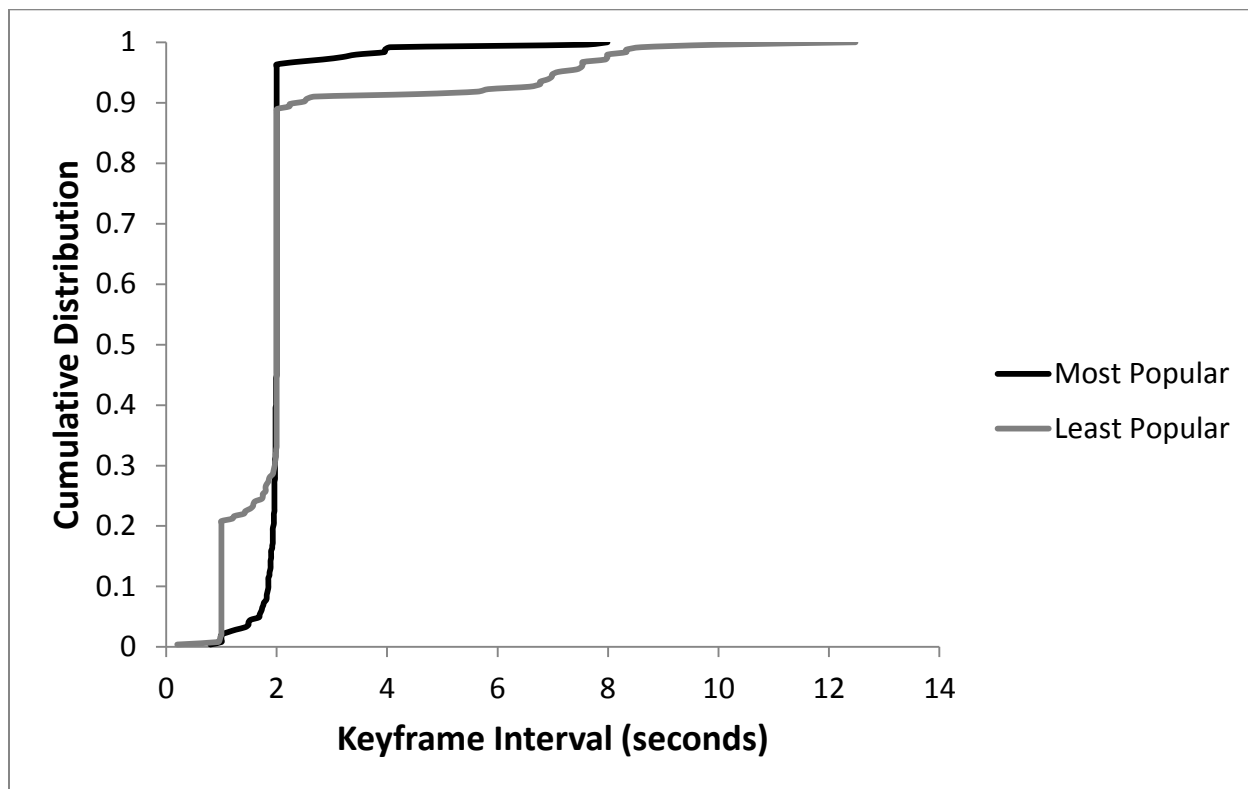


Figure 4.6: CDF of key frame interval for most and least popular channels.

The percentage of key frame intervals that each analyzed stream broadcasts at is represented in the CDF in Figure 4.6. The x-axis represents the key frame interval in seconds, and the y-axis represents the

cumulative distribution of key frame intervals. The black line represents the most popular channels, and the grey line represents the least popular channels. Both sets of channels generally broadcast with a key frame interval of 2 seconds. The least popular channels have a slightly wider range of key frame intervals than that of the most popular channels, but roughly 60% set the interval at 2 seconds. About 95% of the most popular channels have a key frame interval of 2 seconds.

Section 4.2.5 H.264 Profile

When a video is encoded using the H.264 encoding format, as Twitch streams are, a profile type must be specified by the broadcaster. These primary profiles are: Baseline, Main, and High. Each of these profiles comes with a set of capabilities and restrictions that the encoder enforces. The Baseline profile is primarily used for mobile videos, the Main profile is used for standard definition videos, and the High profile is used mainly for high definition videos. Certain devices and hardware can only decode certain profiles. The Baseline profile is the most compatible with a range of devices, and the High profile is the most constricting [17].

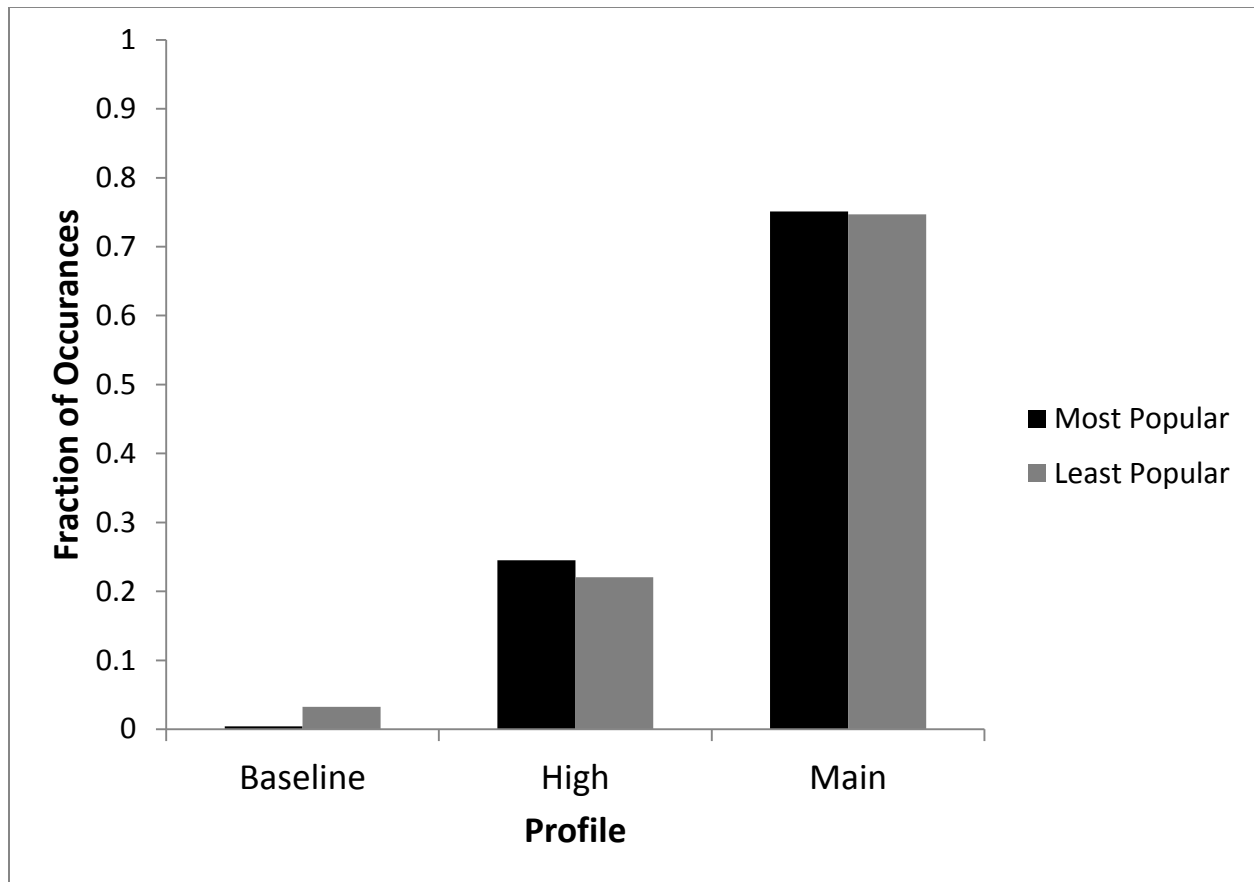


Figure 4.7: H264 Profile settings for most and least popular channels.

Figure 4.7 displays the fraction of analyzed streams that use each of the following H.264 Profiles: Baseline, High, and Main. The black bars represent the most popular channels, and the gray bars represent the least popular channels. A majority of analyzed streams, over 70%, use the “Main” profile, while fewer than 5% use the “Baseline” profile, and fewer than 25% use the “High” profile. The percentage of channels broadcasting with either one of the profiles is independent of popularity.

Section 4.2.6 x264 Preset

The encoding process for Twitch streams is done using the x264 encoder. Prior to initializing a stream, a broadcaster must set a preset for the x264 encoder. These presets range from veryslow to ultrafast.

The faster the preset, the faster the video is encoded, but the larger the file size of the stream. The slower the preset, the longer it takes to encode the video, but the file size of the stream is also reduced [8].

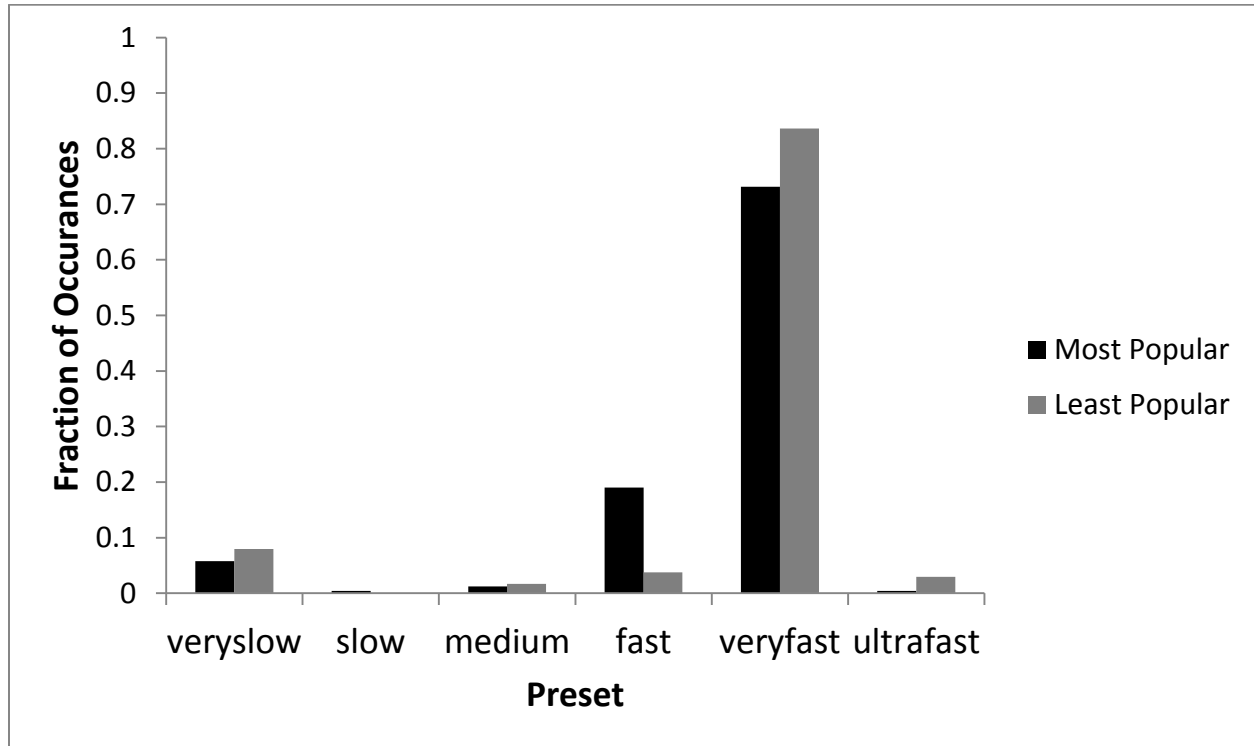


Figure 4.8: x264 Preset settings for most and least popular channels.

The fraction of channels broadcasting with each x264 preset is displayed in Figure 4.8. The x-axis displays the different possible presets, and the y-axis displays the fraction of analyzed streams using the given preset. The black bars represent the most popular channels, while the gray bars represent the least possible channels. The most commonly used preset is the veryfast preset, with over 70% of most popular channels, and over 80% of least popular channels broadcasting with this preset. The preset used by a broadcaster was independent of popularity, and the rarest used preset was the slow preset.

Section 4.3 Content

This section displays and discusses interesting data gathered by the crawler.

Section 4.3.1 Stream Count

The crawler ran every hour for a given day. For each hour, the crawler recorded how many broadcasters were currently streaming on Twitch in total.

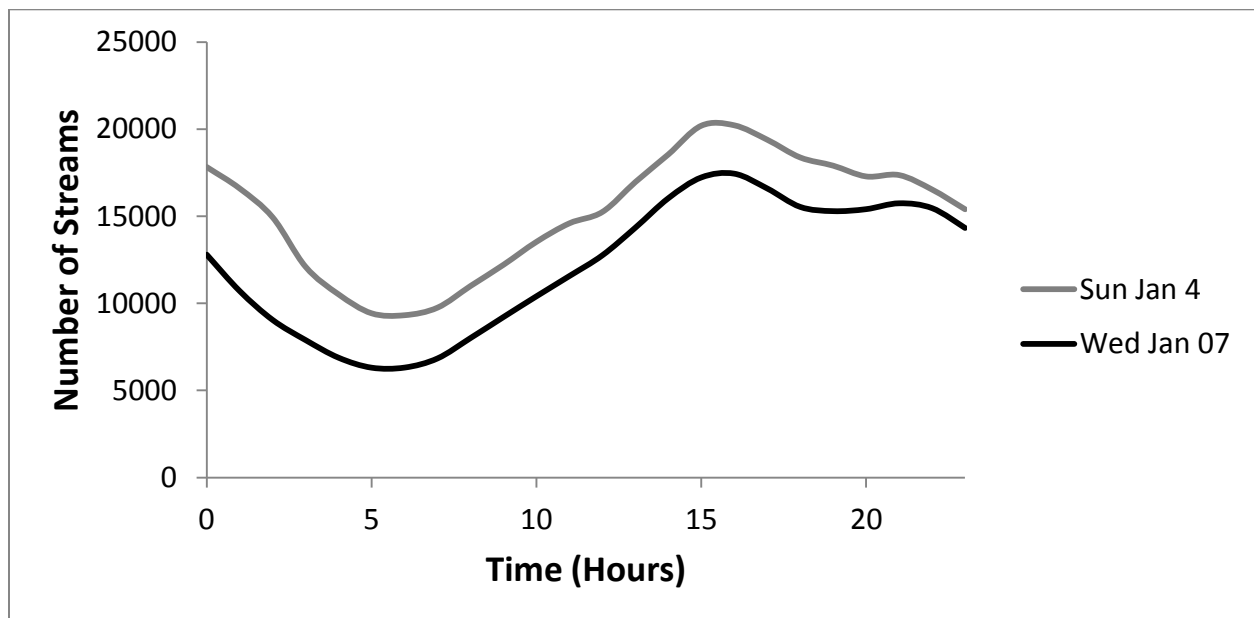


Figure 4.9 Number of streams over the course of a day.

Figure 4.9 displays the number of Twitch streams over the course of two different 24-hour periods, Sunday January 4th and Wednesday January 7th. All times are in Eastern Standard Time. Both days follow roughly a sinusoidal curve. From this, we can find the times of maximum and minimum stream activity on Twitch. The absolute minimum stream activity occurred between 05:00 and 06:00. The absolute maximum stream activity occurred between 15:00 and 16:00. There is a second local maxima for both days at around 21:00.

Also we can see that while both the Sunday and Wednesday curves have mostly the same sinusoidal shape, Sunday is a busier day likely due to weekend conditions where most people get the day off. The absolute maximum stream count for Wednesday is around 17,200 streams, where the absolute maximum stream count for Sunday is around 20,200 streams. Overall, we find that Sunday on average has approximately 3,000 more live streams than Wednesday.

Section 4.3.2 VoD Length and Views

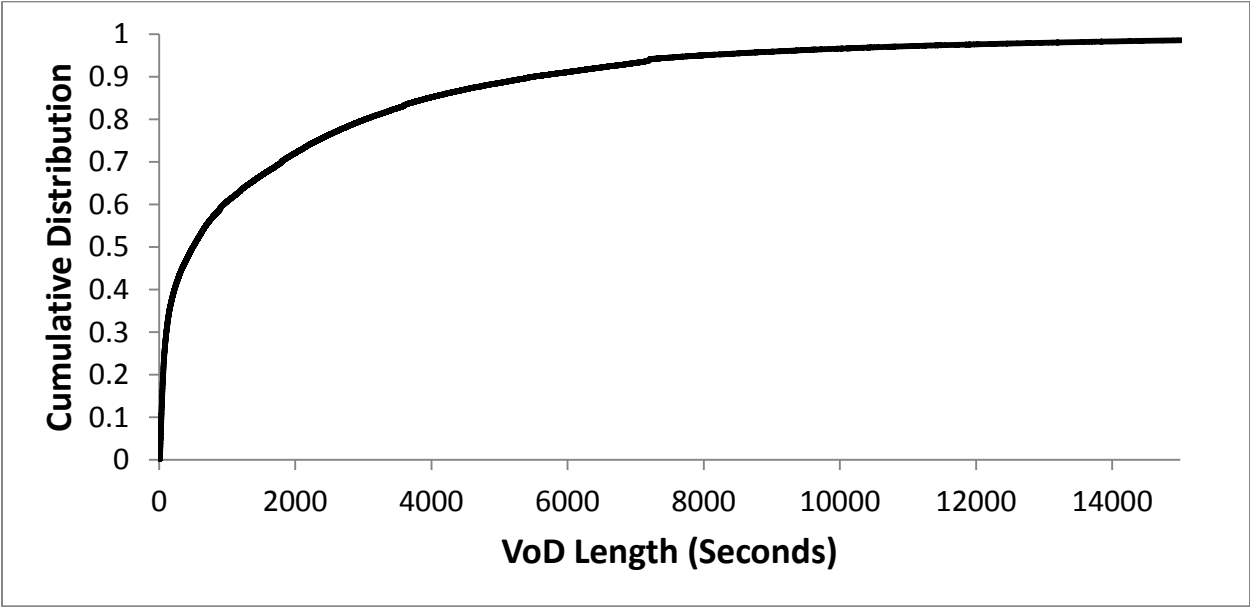


Figure 4.10: CDF of lengths of the set of VoDs given over the course of a day.

Figure 4.10 displays a cumulative distribution function for the length of analyzed VoDs. The x-axis represents the length of each VoD in seconds. The y-axis represents the cumulative distribution of VoDs. The lengths of VoDs on Twitch are mostly short, with a few edge cases where videos are longer than 14,000 seconds. Most of the VoDs, over 90%, are shorter than 6,000 seconds, which is 10 minutes.

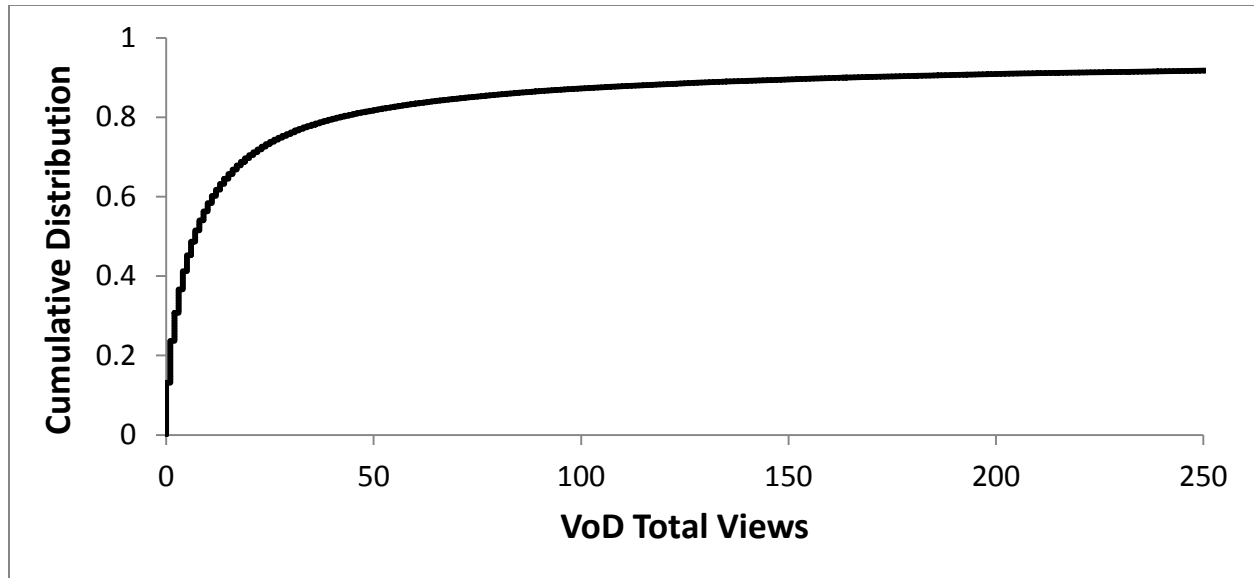


Figure 4.11: CDF of views of the set of VoDs given over the course of a day.

Figure 4.11 depicts the cumulative distribution function of the total view counts of a day's worth of VoDs, 102,805 VoDs in total. The x-axis represents the total views of each VoD. The y-axis represents the cumulative distribution of VoDs. Importantly, approximately 81% of these VoDs, or 83,272 VoDs, have less than or equal to 50 total views. Further, approximately 50% of these VoDs, or 51,402 VoDs, have less than or equal to eight total views. Only about 10%, or around 10,280 VoDs, have greater than 150 total views.

Section 4.3.3 Game Popularity

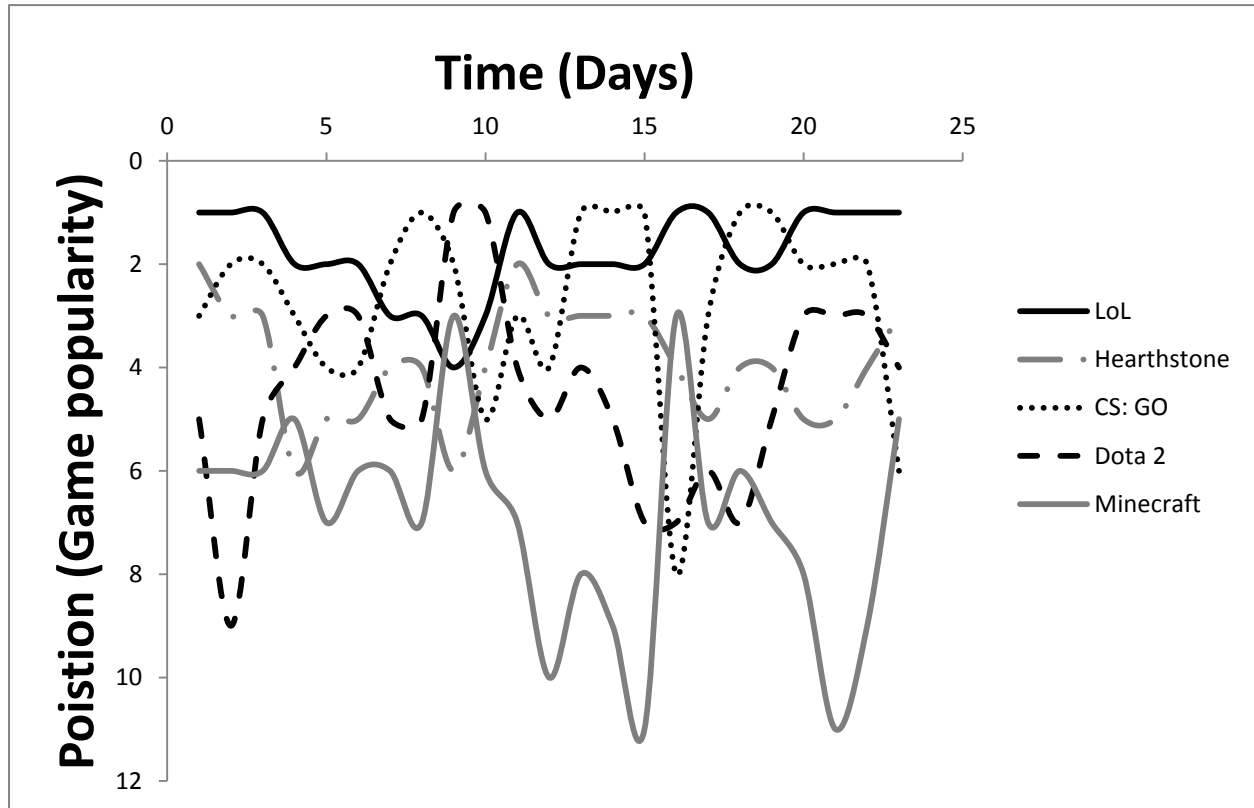


Figure 4.12: The popularity of five games, in terms of the overall number of viewers. A lower y-position represents a lower overall view count for that game.

Figure 4.12 displays our results of tracking the popularity of 5 games over the course of twenty three days. The x-axis represents the time, in days that we looked at the games. The y-axis represents the popularity of a game, with 1 being the most popular game on Twitch, and lower numbers correlating to a decrease in popularity. This popularity was determined by the number of viewers streaming a game, taken from all broadcasters broadcasting the game. So if 5 people were broadcasting the game Minecraft, each with 500 viewers, the popularity of Minecraft would be determined using the viewer value of 2,500. If another game had a viewer value of 2,000, that game would have a lower popularity value than Minecraft. We tracked 4 eSport games, League of Legends, Hearthstone, Counter Strike:

Global Offensive, and Dota 2. We also kept track of a non eSport game, popular nonetheless, Minecraft. According to Figure 4.12, the 4 eSport games never fell below 9th in popularity, while Minecraft dropped as far as 12th. Out of the 4 eSport games, Dota 2 was the only game that moved in popularity by more than 4 places. Minecraft on the other hand, fluctuated between 10 popularity places over the course of our study.

Section 4.4 Demographics and Opinions

This section displays and discusses the data gathered from the survey. We look at how a user's age, gender, and download speed correspond to whether or not they use Twitch or YouTube, and if so their preferences for each Website.

As detailed in Chapter 3, the survey asked a series of demographics questions. This allowed us to separate and analyze the results of the survey based on the respondents' genders, ages, and download speeds, which was instrumental in our analysis. This is helpful in aiding the understanding of both Twitch's and YouTube's users.

Section 4.4.1 Gender Dependency

In our survey, the respondents were asked to specify their gender. We hoped that these results would provide insight as to who uses Twitch and YouTube. We hypothesized that more males than females would be familiar with Twitch, since Twitch hosts only gaming content and because of our experience in online gaming which we find is a male-dominated field.

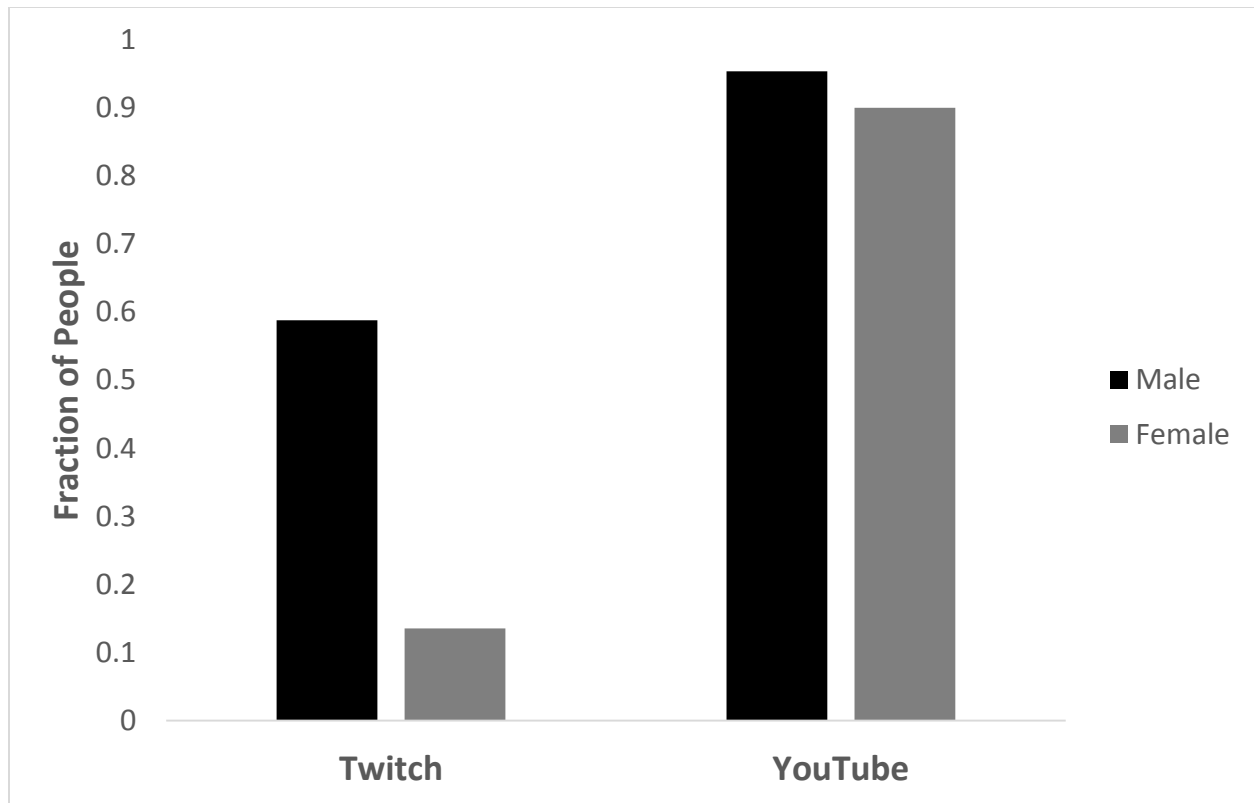


Figure 4.13: Fraction of respondents who have used Twitch and YouTube based on gender.

Figure 4.13 displays the fraction of people of each gender who have used Twitch and YouTube. From this graph, over 90% of both genders have used YouTube, where only about 60% of males and about 13% of females have used Twitch. YouTube as expected is widely known and used, where Twitch is less popular.

In addition, there is a gender dependency found in whether a user has used Twitch, wherein the percentage of males who have used Twitch is almost 5 times larger than the percentage of females who have used Twitch. This dependency does not exist for YouTube.

Section 4.4.2 Age Dependency

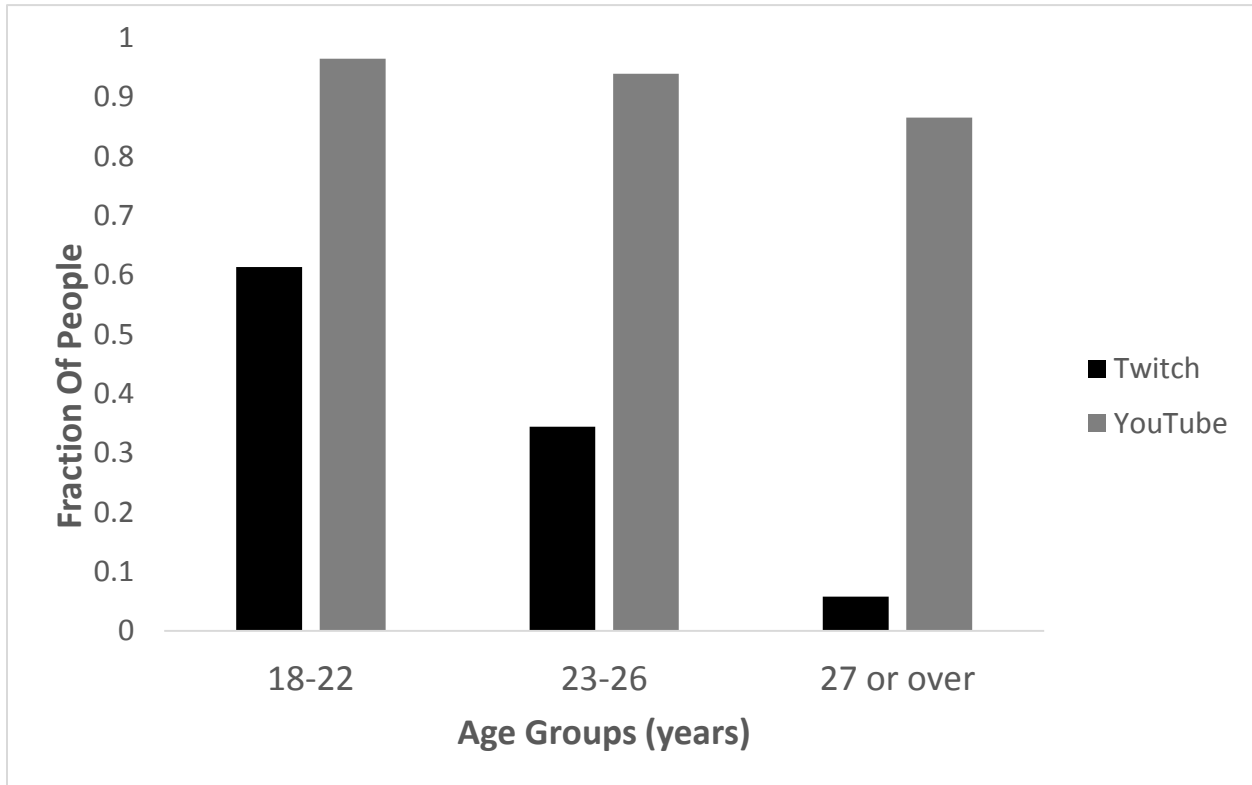


Figure 4.14: Fraction of people who have used Twitch.tv or YouTube.

Another dependency is found in Figure 4.14, which displays the fraction of people who use Twitch and YouTube based on their ages. The ages are separated into three discrete groups as seen on the x-axis. These are based on the survey question which asked for the respondent's age, as the question used the same categories for its answer bins. The first age group is typical of a college undergraduate. The second age group is typical of a graduate student. The last group is everyone older than 26, typically working people regardless of education.

What is found is an age dependency that exists for Twitch, but not for YouTube. From the graph, we see that most people have used YouTube, regardless of age. On the contrary, for Twitch, at most 60%

of people aged 18-22 have used Twitch, but less than 10% of people aged 27 and over have used Twitch.

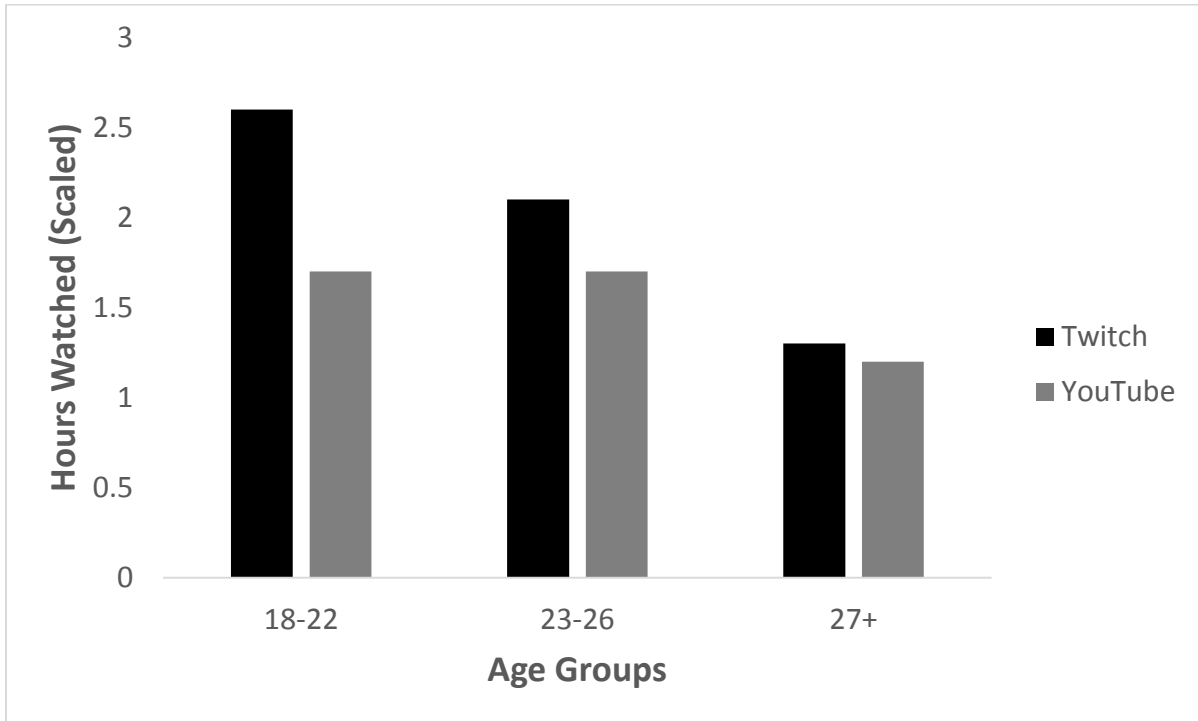


Figure 4.15: Scaled number of hours that each age group watches Twitch.tv and YouTube videos. 0 refers to never, 1 refers to 1-5 hours, 2 refers to 6-10 hours, 3 refers to 11-15 hours, 4 refers to 16-20 hours, and 5 refers to 20+ hours.

Figure 4.15 displays how the age of a user affects how many hours of content they watch each week on both Twitch and YouTube. The y-axis, quantified in the caption above for Figure 4.15, is a scaled quantity describing the average number of hours a user watches each week. The ages of our survey respondents are categorized by the age groups seen on the x-axis. These categories are based on the survey question which asked for the respondent's age.

We find that age corresponds to the number of hours a user watches Twitch per week, and less for YouTube. A steady decrease in hours of Twitch watched is displayed from the first age group to the third. However for YouTube, the first two age groups display a similar number of hours watched, with a decrease only observed for the third group.

Section 4.4.3 Download Speed Dependency

In the survey, the respondent was asked to provide the internet download speed of their home. We hypothesized that the lower a user’s download speed, the more frustrated they would be watching a video online, as a lower download speed usually results in many pauses while watching in order to buffer the video.

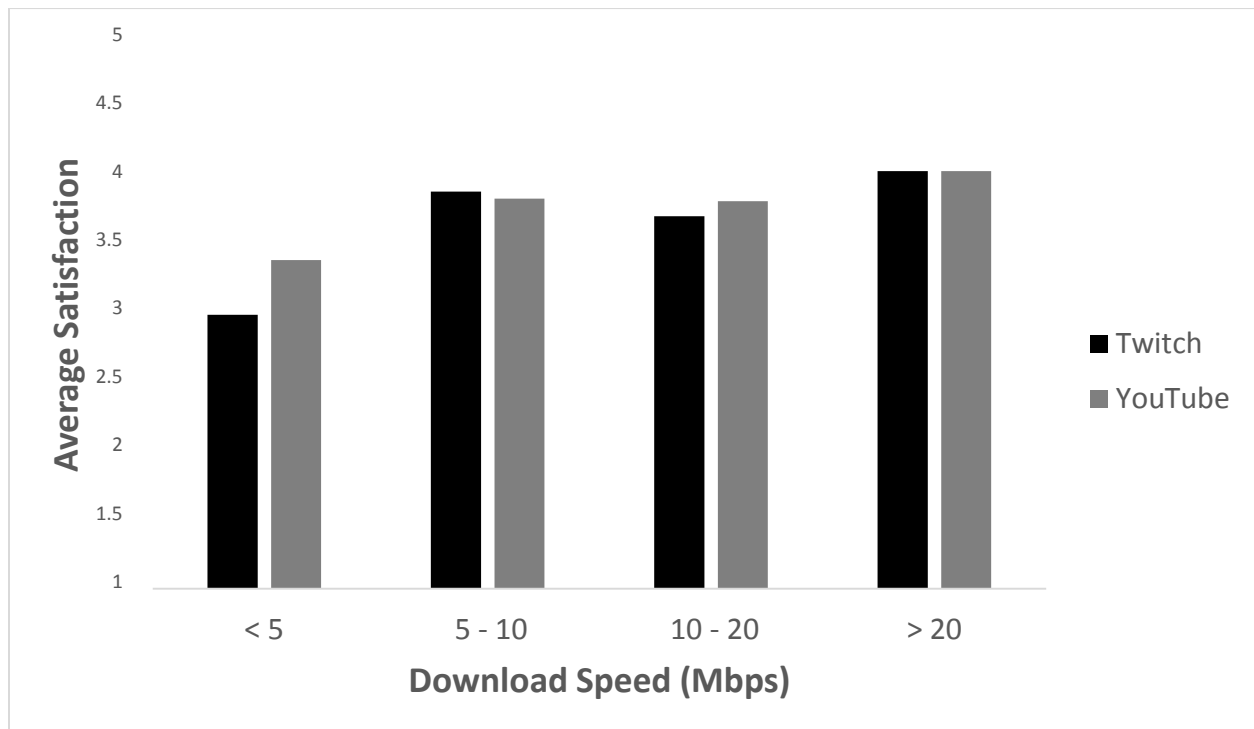


Figure 4.16: Average respondent satisfaction for Twitch and YouTube. 5 represents very satisfied and 1 represents not satisfied at all.

Figure 4.16 displays the relationship between the average satisfaction of users and their download speed. The x-axis represents download speeds in Mbps. The y-axis represents the satisfaction levels a respondent could pick in our survey in regards to how happy they are with both Twitch and YouTube. A satisfaction of one represents the minimum level of satisfaction, or lack thereof, where a satisfaction five represents the maximum level of satisfaction.

We find that only the minimum download speed group, those with a download speed less than 5 megabytes per second (Mbps), are of average satisfaction. The other three download speed groups are of roughly above-average satisfaction. This may be because most peoples' download speeds are at sufficient levels for video streaming with low or no interruption.

Section 4.4.4 Preferred Lengths

On Twitch, broadcasters can stream for hours at a time, allowing viewers to tune in at any time.

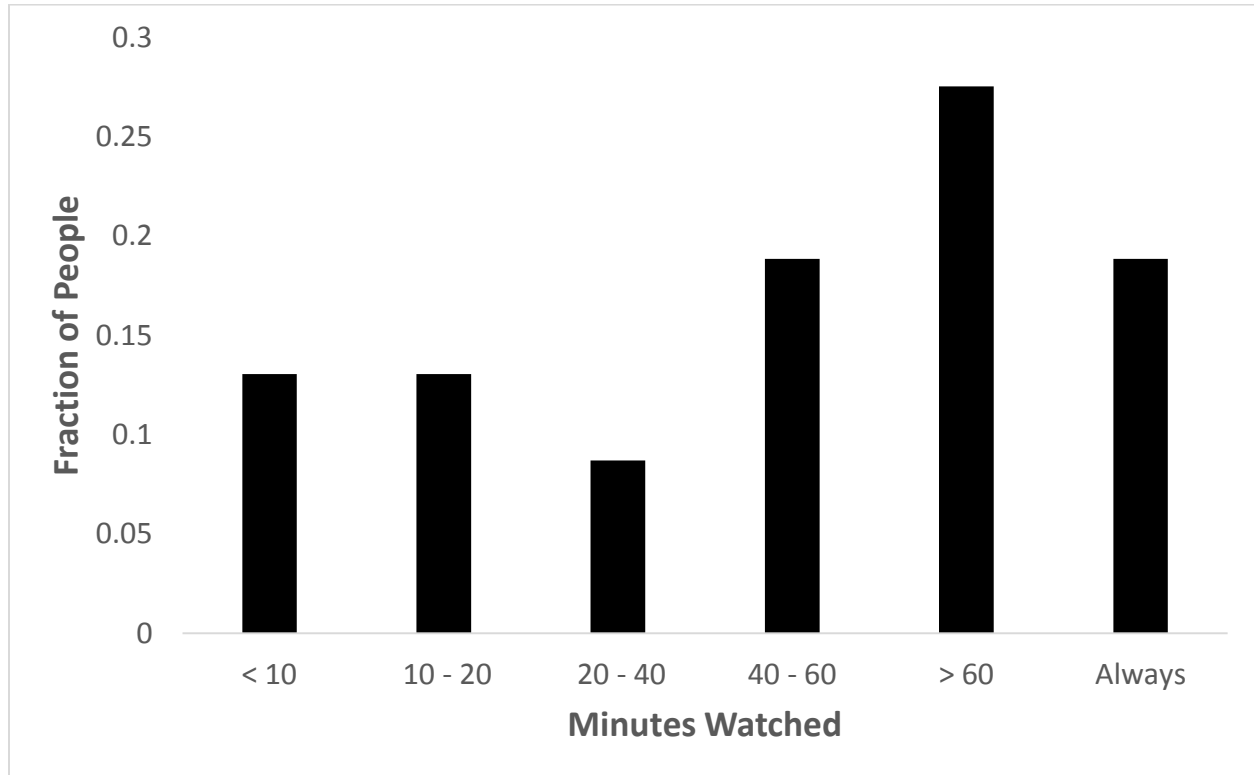


Figure 4.17: Amount of time respondents watch a single stream.

Figure 4.17 depicts the lengths of time for which a Twitch user prefers to watch a single stream. The x-axis represents the lengths of time, grouped as they were in the relevant survey question.

Of note is that the lengths of times for which a user prefers to watch a stream varies greatly, with on one end of the spectrum many users viewing a stream only briefly for less than 10 minutes, and on the other users who leave a stream on constantly, as many people do with television.

This wide distribution of viewing preferences for Twitch is contrasted with those for YouTube, which is detailed in the following paragraphs.

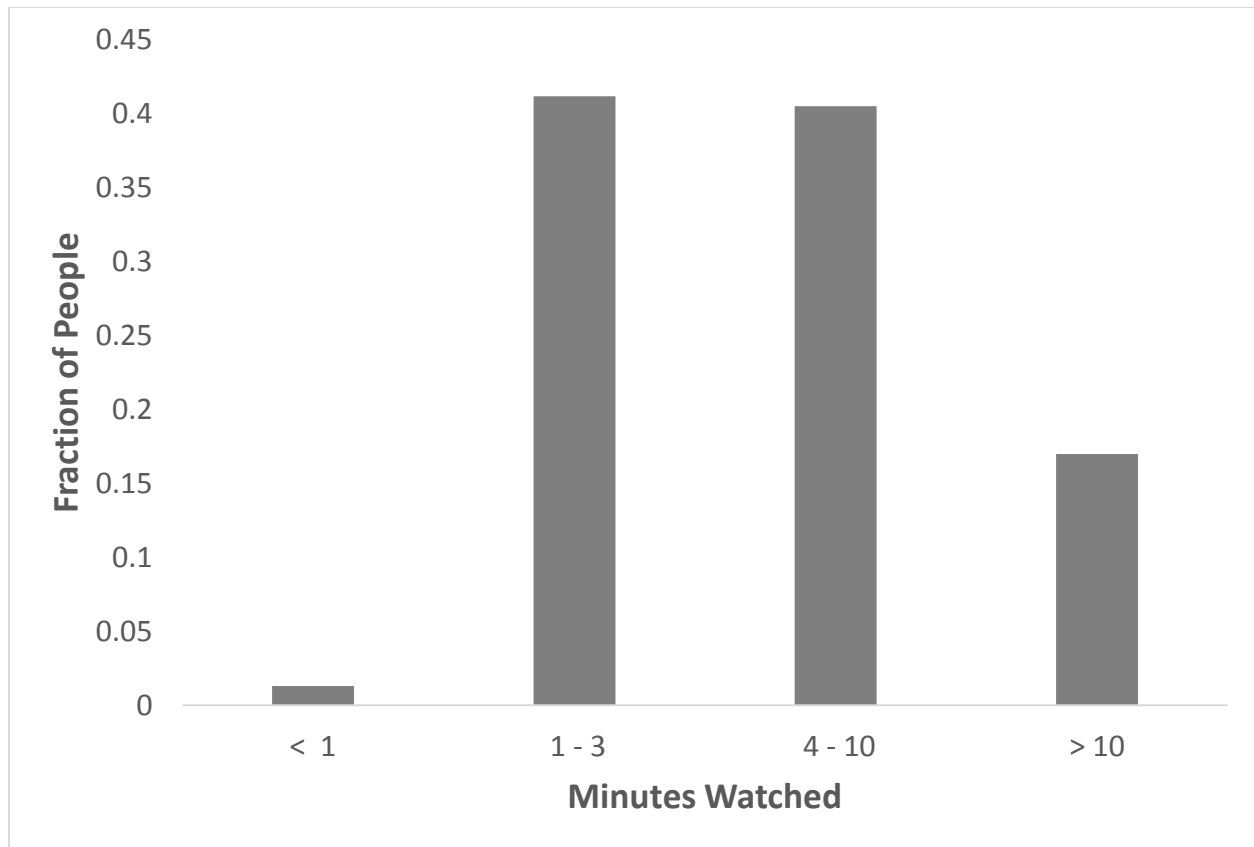


Figure 4.18: Preferred YouTube video length.

Figure 4.18 depicts the lengths of time for which a YouTube user prefers to watch a single stream. The x-axis represents the lengths of time, grouped as they were in the relevant survey question.

In contrast with the Twitch preferred watching lengths detailed in the preceding paragraphs, in which we find that for Twitch about 75% people enjoy watching a stream for at least 20-30 minutes. For YouTube around 80% of people prefer to watch videos which are less than 10 minutes long.

Section 4.4.5 Twitch Broadcasts versus VoDs

Twitch's primary function is the delivery of broadcaster's streams to their audience. In addition, once a broadcaster concludes a stream, they have the option of saving segments of that broadcast as highlights, which can be viewed by anyone at any time in a similar manner to YouTube videos.

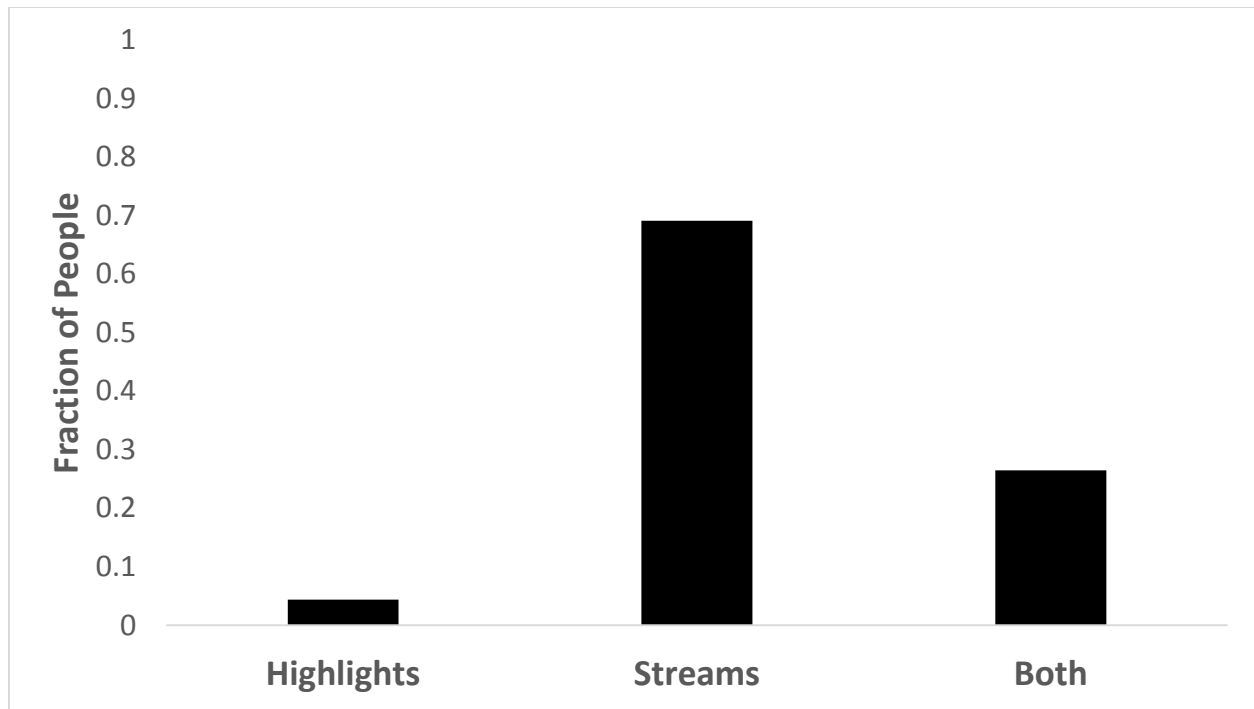


Figure 4.19: Fraction of respondents who watch Twitch.tv Highlights, Streams, or Both.

Figure 4.19 displays the fraction of users who use Twitch to watch either VoD highlights, live streams, or both.

From this, we find that 35% of users watch highlights, whereas almost all users watch live streams.

Very few users watch only highlights on Twitch.

Section 4.4.6 Devices Used on Twitch and YouTube

Twitch and YouTube both allow users to view video streams using any device which support the video format H.264. In our survey we asked respondents which devices they prefer to watch video streams on both Twitch and YouTube with. The results were graphed in Figure 4.20.

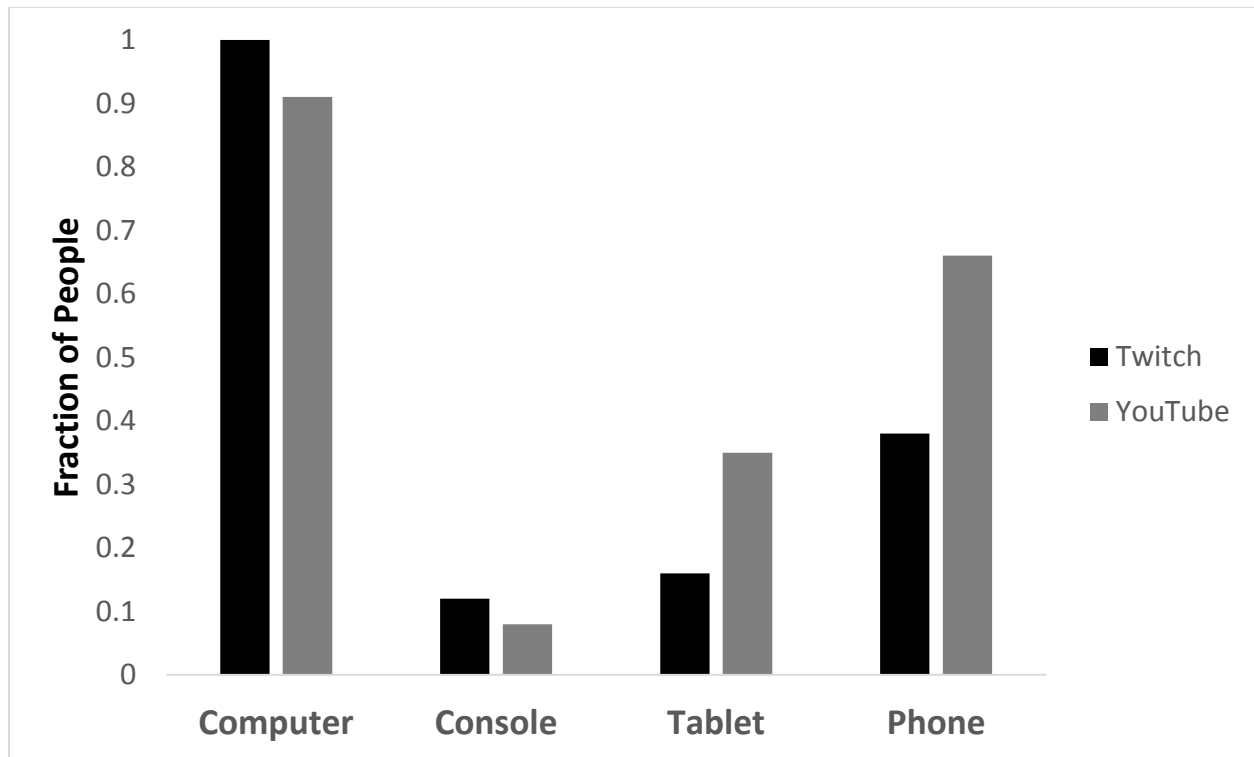


Figure 4.20: Devices on which users prefer to watch YouTube and Twitch.tv videos. Respondents were able to select multiple devices.

Figure 4.20 depicts the fraction of people who prefer to use each device listed on the x-axis with both Twitch and YouTube.

We find here that everybody who uses Twitch uses it on their computer, with lesser numbers using their consoles, tablets, and phones. For those who use YouTube, we find interesting that not everybody uses a computer to watch YouTube videos. Also, almost double the percentage of people use their tablets and phones to watch YouTube videos than to watch Twitch streams.

Chapter 5 Conclusions

Our project sought to gather data about live-streaming service Twitch to provide insights on its content and characteristics. These may be found useful for future live-streaming Website developers. To accomplish this, we used three primary tools: A Web crawler, which gathers Twitch.tv stream metadata, a survey, which gathers YouTube and Twitch user demographics, preferences, and opinions, and a third-party Website which gathers Twitch.tv stream technical data. This chapter describes the conclusions we have made from the analyses detailed in chapter 4.

Audio encoding of Twitch streams is homogenous. Encoding in AAC with a frequency of 44.1 KHz is standard. However, many broadcasters have not properly set their stream's volume levels, resulting in audio that is either too loud or soft. The most popular channels are often loud. The less popular channels tend to be quiet.

Both popular and unpopular streams most commonly use 3 resolutions: 960x540, 1280x720, and 1920x1080. This commonality suggests that other resolutions need not be fully supported within the domain of a live streaming-service. Reducing the number of resolutions to support can reduce both the transcoding time and the requirement for more powerful hardware.

Each resolution corresponds to an upload bitrate. Restrict the resolutions to the above 3, we can also set a bitrate for the broadcaster to ensure the most optimal viewing experience. For example, the bitrate we would associate with the 1920x1080 resolution would be just below 3,000kbps. Knowing these bitrate to resolution pairs, we can automatically set a bitrate for a user, further simplifying the broadcasting experience.

The broadcaster set frame rate and keyframe interval are important for a streams' quality. Since only frame rates of 30 and 60 are used and the keyframe interval of 2 seconds is most commonly used, a future live-streaming service should optimize for these options.

Video encoding is resource intensive for hosting a live-streaming site. Our results show that the most commonly used H.264 profile is Main, and the most commonly used x264 preset is veryfast. Instead of allowing the user to choose from the broad spectrum of options, broadcasters could be forced to use the Main profile and veryfast preset.

Most people are broadcasting between around 16:00 to 17:00, the usual time a working person in the Eastern or Central US time zones would finish working. There is a second maxima at approximately 21:00, which may indicate the time which a person from the Pacific time zone finishes work. Lastly, the least number of people are broadcasting between 05:00 and 06:00, times when most people in the U.S. are either asleep or at work.

The majority of VoDs are obscure, with less than 9 views. A majority of VoDs are less than 10 minutes in length. There are a few that are hours long, but also have a small viewer count. Since these VoDs consume space, perhaps it would be better to outsource VoD storage to a Website such as YouTube.

The popularity of eSport games could possibly be predicted since they are always popular. We found that the eSport games analyzed never fell below 9th in popularity. A future live-streaming website also focusing in gaming may want to consider dedicating their platform to the already popular eSport phenomenon. For live-streaming sites wanting to focus on other topics, this data implies that the popularity of certain topics is unknowable. The advertisement and marketing side of future platforms need look into the popularity of their given topics.

Gender corresponds to the likelihood of using Twitch. Males are approximately five times more likely to use Twitch than females. Female gamers may make up an equal or even greater percentage of total gamers [2], but our data supports that traditional gaming, i.e. non-mobile and non-browser games, is still primarily enjoyed by males. Note that this gender dependency does not exist for YouTube, in which females are almost just as likely to use YouTube as males.

Younger people are more likely to use Twitch than older people, in that older people are at most 55% less likely to use Twitch than younger people. This does not hold true for YouTube, where older people are about 10% less likely to use YouTube than younger people. We also found that the younger a person is, the more hours they watch on average for both Twitch and YouTube.

Download speed does not have a large effect on how satisfied a user is with both Twitch and YouTube. On average, users with download speeds above 5 Mbps reported above average satisfaction levels. Only those with download speeds less than 5 Mbps were less satisfied. This may be because the average download speed in the US is approximately 33 Mbps, which is more than sufficient to stream online HD video [17].

While more people watch YouTube overall, individual users on average would watch Twitch longer than YouTube. Also, Twitch users are more inclined to watch a single stream for a long period of time, in many cases for periods greater than an hour. On YouTube, a user may instead watch many videos which are less than 10 minutes long.

This finding may draw from the difference in nature between Twitch and YouTube, which is the difference between live-streaming and video-on-demand. On Twitch, a stream lasts as long as the broadcaster wants, with many streams lasting in excess of eight hours. Most Twitch users prefer

watching these live streams. YouTube videos tend to be shorter, with an average video length of 4.4 minutes [10].

Everybody surveyed who used Twitch used a computer to view streams, and approximately 90% of those we surveyed who used YouTube used a computer to view videos.

In addition, we found that mobile devices such as phones and tablets are less popular for use with Twitch than with YouTube.

Lastly, we found that consoles are an unpopular choice for viewing Twitch and YouTube content.

Perhaps they may not be made a priority beyond ensuring functionality.

Section 5.1 Future Work

There are several potential areas for future exploration.

- Create an in-house analyzer tool in the vein of the Twitch analyzer we used in our methodology. This would allow for a larger amount of data to be gathered, in addition to ensuring the accuracy of the tool.
- Create a wider, better designed survey. For example, several questions were forgotten such as asking the respondent which browser they used, and their operating system. Also, the questions towards Twitch broadcasters were not thorough, and thus were not very useful in our analysis. In addition, we distributed our survey to a very limited population: Friends, and WPI students. A larger, more diverse sample would have been ideal to further validate our findings. An online platform called Mechanical Turk would have allowed us to distribute our survey to such a sample.
- Design a live-streaming Website using this paper to facilitate some design choices.
- Interview Twitch staff to gather additional insight unobtainable through other means, as well as correlating their insights with our data.

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Appendix

Survey

Live-Streaming Usage Survey

Q55 No identifying information will be recorded. All responses are appreciated.

Q1 How old are you?

- 17 or under (1)
- 18-22 (2)
- 23-26 (3)
- 27 or over (4)

Q2 Gender

- Male (1)
- Female (2)
- Abstain (3)

Q3 Which continent do you live on?

- Africa (1)
- Asia (2)
- Australia (3)
- Europe (5)
- North America (7)
- South America (6)

Answer If Which continent do you live on? North America Is Selected

Q4 Which country or state do you live in?

- Canada (1)
- Mexico (2)
- Arkansas (3)
- Arizona (4)
- Alabama (5)
- Alaska (6)
- California (7)
- Colorado (8)
- Connecticut (9)
- Delaware (10)
- Georgia (11)
- Hawaii (12)
- Idaho (13)
- Illinois (14)
- Indiana (15)
- Iowa (16)
- Kansas (17)
- Kentucky (18)
- Louisiana (19)
- Maine (20)
- Maryland (21)
- Massachusetts (22)
- Michigan (23)
- Minnesota (24)
- Mississippi (25)
- Missouri (26)
- Montana (27)
- Nebraska (28)
- Nevada (29)
- New Hampshire (30)
- New Jersey (31)
- New Mexico (32)
- New York (33)
- North Carolina (34)
- North Dakota (35)
- Ohio (36)
- Oklahoma (37)
- Oregon (38)
- Pennsylvania (39)

- Rhode Island (40)
- South Carolina (41)
- South Dakota (42)
- Tennessee (43)
- Texas (44)
- Utah (45)
- Vermont (46)
- Virginia (47)
- Washington (48)
- West Virginia (49)
- Wisconsin (50)
- Wyoming (51)

Q5 What's the download speed at your home? If unsure, visit this website.

- Less than 5 Mbps (1)
- 5-10Mbps (2)
- 10-20 Mbps (3)
- Greater than 20 Mbps (4)
- Unknown (5)

Q6 Do you regularly use any video-on-demand websites, such as YouTube,?

- Yes (1)
- No (2)

Q7 How many hours a week, on average, do you watch YouTube content?

- Never (1)
- 1-5 hours (2)
- 6-10 hours (3)
- 10-15 hours (4)
- 15-20 hours (5)
- 20+ hours (6)

Q8 Which best describes your viewing experience for YouTube videos?

- Very Bad (1)
- Poor (2)
- Neither Good nor Bad (3)
- Good (4)
- Very Good (5)

Q9 On which devices do you use YouTube?

- Computer (1)
- Console (2)
- Tablet (3)
- Phone (4)

Q10 At which resolution do you normally view YouTube videos?

- 1080p (1)
- 720p (2)
- 480p (3)
- 360p (4)
- 240p (5)
- 144p (6)
- Auto (7)
- Unknown (8)

Q11 What content do you typically watch on YouTube?

- Music (1)
- Movies/TV Shows (2)
- News (3)
- Gaming (4)
- Sports (5)
- Educational (6)
- Popular on YouTube (7)
- Entertainment (8)
- Other (Please State): (9) _____

Q12 On average, how long do you prefer YouTube videos to be?

- Less than 1 Minute (1)
- 1-3 Minutes (2)
- 4-9 Minutes (3)
- More than 10 Minutes (4)

Q13 Have you posted videos to YouTube?

- Yes (1)
- No (2)

Q14 How would you describe YouTube comments?

- Entertaining (1)
- Helpful (2)
- Annoying (3)
- I don't look at YouTube comments (4)
- Other (5) _____

Q15 Do you ever leave YouTube comments?

- Yes (1)
- No (2)

Q16 What do you like the most about YouTube?

Q17 What do you like the least about YouTube?

Q18 Have you ever used the live-streaming website Twitch.tv?

- Yes (1)
- No (2)

Q19 How long do you usually watch a single stream?

- (1)
- 10-20 Minutes (2)
- 20-40 Minutes (3)
- 40-60 Minutes (4)
- >60 Minutes (5)
- I always have a stream up (6)

Q20 On which devices have you used Twitch?

- Computer (1)
- Console (2)
- Tablet (3)
- Phone (4)

Q21 What games do you typically watch on Twitch?

- League Of Legends (1)
- World Of Warcraft (2)
- Heartstone (3)
- Dota 2 (4)
- Counter Strike (5)
- Other (Please State): (6) _____

Q22 How many hours a week, on average, do you watch Twitch.tv content?

- Never (1)
- 1-5 hours (2)
- 6-10 hours (3)
- 10-15 hours (4)
- 15-20 hours (5)
- 20+ hours (6)

Q23 Do you prefer to watch highlights or live streams?

- Highlights (1)
- Streams (2)
- Both (3)

Q24 Which best describes your viewing experience for live streams?

- Very Bad (1)
- Poor (2)
- Neither Good nor Bad (3)
- Good (4)
- Very Good (5)

Q25 How do you feel about the chat on popular streams?

- Entertaining (1)
- Helpful (2)
- Annoying (3)
- I don't pay attention to the chat (4)
- Other (5) _____

Q26 Do you participate in the chat?

- Yes (1)
- No (2)

Q27 Have you streamed video to Twitch before?

- Yes (1)
- No (2)

Q28 What do you like the most about Twitch?

Q29 What do you like the least about Twitch?

Q30 What's the upload speed at your home? If unsure, visit this website.

- Less than 3 Mbps (1)
- 4-6 Mbps (2)
- 7-9 Mbps (3)
- 10-12 Mbps (4)
- 13-15 Mbps (5)
- Greater than 16 Mbps (6)
- Unknown (7)

Q31 At what bit rate do you stream? (0 for unknown)

Q32 At what resolution do you stream? (0 for unknown)

Q33 At what FPS (frames per second) do you stream? (0 for unknown)